DEVELOPMENT AND SYSTEMATICS OF EARLY LIFE HISTORY STAGES IN SOME FISHES OF PORTO NOVO COAST, INDIA

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DECLARATION

Certified that this thesis is a record of original research work done by the candidate during the period of his study under me from 1977 to 1979 at the Centre of Advanced Study in Marine Biology, Annamalai University, Porto Novo, for the Degree of Doctor of Philosophy; and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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1 GENERAL INTRODUCTION

1. 1 IMPORTANCE OF THE STUDY

Interest on a study of development and systematics of early life history stages of marine fishes may be said to have originated as early as in 1865, when the eminent Norwegian planktologist G.O. Sars discovered that eggs of European cod, haddock, etc are planktonic and not benthic (vide: Russell, 1976; Ahlstrom and Moser, 1979). Subsequently, considerable attention was paid to this subject in England, Italy, Germany and United States of America (Ahlstrom and Moser, 1979). And, with progress of research in fisheries biology of commercially important species, it was realized that absolute knowledge on development and systematics of early life history stages of marine fishes is required to assess their distribution and abundance in space and time (Ahlstrom, 1954; 1966). Such a study is an essential prerequisite in order to undertake spawning surveys of target species, aimed at estimation of biomass of the adult stock, monitoring changes in exploitable stocks and yields, explaining causes for fluctuations in strength of year-classes, forecasting trends of production, etc (Ahlstrom and Moser, 1976). For instance, in the case of European plaice a correlation has been found between abundance of early life history stages in plankton and subsequent recruitment to the fishery and in the herring between spawning stock and egg production (Russell, 1976). In Pacific sardine it was found out that the rate of survival from newly spawned eggs to the end of planktonic phase of life during 1950 and 1951 was about one in one thousand (Ahlstrom, 1954). Only if and when proper identities of eggs, larvae, etc are established will it be possible to determine the above events and to point out as to whether the brood resulting from a parental stock has good or poor chances of survival. Hence, as pointed out by Smith (1974) and others, the above studies in marine biology and fisheries research constitute the most important objective in quantitative plankton samplings.

Apart from the above, studies on marine fish eggs and larvae are important in identification of new stocks of commercial potentialities (Ahlstrom, 1968 a) and in evaluation of fish resources (Ahlstrom and Moser, 1976). Also, in order to correlate distribution and abundance of early life history stages of target species in the environment in relation to prevailing parameters there (Ahlstrom, 1954; 1966), the studies are important.

In Coastal Aquaculture operations as well as in "sea ranching", one of the basic requirements is to collect young stages of fishes from natural seed resources areas for stocking in grow-out structures such as net cages, pens, coastal ponds, etc as well as for releasing them into the sea. For these purposes it is imperative that the characteristic features of early life history stages of target species are known adequately, by resorting to a study of their development and systematics. Character variability of young stages in aspects such as pigmentation, morphometric features, etc occurring in different areas should be understood properly, so that possible confusion in their collection and stocking could be avoided. Distinguishing features of different developing stages should be studied and documented, in order to segregate the most desired stage if available sparsely, for bestowing special attention such as feeding with growth-promoting food organisms, protecting from large-scale mortality due to adverse hydrological and climatic conditions, etc. Knowledge on development and systematics of larval series would facilitate observations on effect of certain ecological and physiological conditions on the particular stage and their impact on growth and production. Also, character differences between developmental stages occurring in natural state and those obtained by artificial means such as induced breeding should be known and documented in order to find out, if any, the role of such differences in subsequent development.

Accurate identification and documentation of fish eggs and larvae are important in fish taxonomy (Ahlstrom and Moser, 1976; 1979) such as for clarification of taxonomic features based on ontogenetic differences. The study is important for delineating spawning grounds, breeding seasons, breeding migrations, parental care and other similar behaviour of the species involved, aspects which are vital in rational exploitation and conservation of economically important resources in space and time. In order to make an assessment of quality and quantity of ichthyoplankton as a component of plankton biomass, to determine general productivity in the region, to assess fish resources and their potentialities in various areas and to gather information on the whole spectrum of fishes in the area, a study of early life history stages is important.

As a biological indicator, eggs and larvae brought by certain water masses have to be identified and documented in sufficient detail. And, for use as a general study material, as an experimental organism in bioassays, in aspects of toxicology, embryology, etc, a study on development and systematics of early life history stages is important.

In view of these reasons, it has become imperative to study early life history stages of marine fishes with accuracy and document them in different geographical areas. The International Symposia on Early Life History of Fish, first held in 1973 (Blaxter, Ed., 1974) and then in 1979 (ICES, 1979) have focussed attention on the importance of this branch of fisheries science. And, such publications on early life history stages as of Uchida, Imai, et al (1958) and Mito (1966) from Japan, of Russell (1976) from Britain and of Jones, P.W., Martin and Hardy Jr (1978), Hardy Jr (1978 a; b), Johnson (1978), Fritzche (1978) and Martin and Drewry (1978) in the form of a series of atlases from mid-Atlantic Bight are substantial contributions in this direction and need emulation in other parts of the world as well.

For an account of historical background of the study on development and systematics of early life history stages of marine fishes in different parts of the world, present status of this discipline and potential future directions, Ahlstrom and Moser (1979) may be referred to.

1. 2 IMPORTANCE OF THE STUDY IN INDIA

India, a tropical peninsular country and situated between about Lat 3^{0} and 38^{0} N and between Long 68^{0} and 90^{0} E, has an extensive coastline of more than 6,500 km long, south of Tropic of Cancer. The coastline is dotted with many estuaries, creeks, backwaters, bays, lagoons, etc, offering good scope for Coastal Aquaculture. About 1,800 species of marine and estuarine fishes are known to occur in India, as against about 12,000 reported throughout the world by Nelson (1976). Most of these fishes are found along both the east and west coast of the peninsula, in Bay of Bengal and Arabian Sea respectively. A perusal of literature (vide: section 1. 3) shows that among the above number not more than 160 species have received attention so far for a study of development and systematics of their early life history stages, forming hardly 10%. So much so, ichthyoplankton surveys undertaken by agencies such as UNDP/FAO (1974; 1976 b) are not able to state precisely to which species most of the early life history stages which they have surveyed and/or collected belong. Hence, it is quite important and urgent that development and systematics of early life history stages of as many species as possible are known adequately. And, any substantial attempt in this direction should be considered as vital for contributing to our knowledge in this difficult field.

A perusal of literature further shows that among the few centres where some work on fish eggs and larvae was carried out in the past along about 6,500 km coast, it has not yet been possible to identify and document early life history stages of a substantial number of species in each centre, including many commercially important ones. For instance, in Porto Novo itself along south-east coast, among about 600 species of fishes reported to occur (Natarajan, R. and Ramaiyan, unpublished), developmental stages of not even 10 % of the species are identified and documented. And, even among the species which have received attention, all vital developmental stages are not yet reported adequately and variations if any of characters in stages occurring in one locality from another are not brought out clearly. This is important because geographical differences are said to play some role in certain characters of early life history stages. In view of such an inadequate state of our knowledge, an attempt at a study of their systematics and development in representative centres constitutes an important step in widening our knowledge.

India being a tropical country, speciation in her waters has been taking place much more rapidly than in temperate regions (Panikkar, N.K., 1952) and it is found that in many cases groups of species constitute combined fisheries. Although adults of most of these are morphologically and/or meristically distinct enough, their early life history stages are found to resemble one another very closely due to the fact that in ontogeny similarities do exist among species of the same genus and/or allied genera. An illustrative example of this kind is found among Clupeiformes (Bensam, 1979). And, unlike in temperate countries, practical hurdles have been experienced by workers in successfully carrying out collections of spawners, effecting artificial fertilization and rearing eggs and larvae under laboratory conditions, in most cases. In view of the above reason, fairly positive identification of eggs and larvae of various species has not progressed so well when compared to more comprehensive studies made elsewhere. And, although studies on development of marine fish eggs and larvae have been undertaken by quite a few workers in the past (vide: section 1. 3. 3), the present state of our knowledge on this subject is far from satisfactory, while considering the multiplicity of species present. Hence, any additional contribution on development and systematics of early life history stages of marine fishes would certainly be important.

It may also be added that early life history stages of quite a few culturable fishes along coastal areas of India remain either unknown or only imperfectly known at present, inspite of the recent thrust and importance given for proper identification and collection of young stages for commercial stocking in Coastal Aquaculture. In order to remove such uncertainty in identification and collection of young stages of target species, it is important and urgent that development and systematics of these stages of culturable fishes also are known in sufficient detail.

As mentioned earlier, the principal benefit from a study of this nature is that the results can be used in undertaking spawning surveys and forecasting to the fishing industry the trend of production from important resources. In United States of America, California Cooperative Oceanic Fisheries Investigations (CalCOFI) programmes on these aspects have yielded valuable information on these aspects to the fishing industry there (Ahlstrom, 1968 a; Ahlstrom and Moser, 1976). Such an approach is needed in management of marine fisheries resources in India also.

1. 3 REVIEW OF PREVIOUS WORK IN INDIA

The first comprehensive attempt at a study of development and systematics of early life history stages from Indian Ocean region was by Delsman (1922 - 1938) from Java coast. The above work remains as a standard one of reference even today. Following this, many publications have emanated from India, adding to our knowledge on eggs, larvae, postlarvae, etc of many species of marine and estuarine fishes. In the following review, publications dealing with early life history stages from east coast of India (Bay of Bengal) and west coast (Arabian Sea) are dealt with separately. For the sake of easier understanding of the localities from where reports were made, publications from northern sector and southern sector in respect of each coast are treated separately. The boundary separating northern and southern sectors is determined approximately at Lat 15° N. In east coast, the States of West Bengal, Orissa and most part of Andhra Pradesh north of Nellore are included in northern sector; and part of Andhra Pradesh south of Nellore and Tamilnadu comprise the southern sector. In west coast, the States of Gujarat, Maharashtra and Union Territory of Goa are grouped in northern sector;

and the States of Karnataka and Kerala in southern sector. Abstracts of papers mentioning mere occurrence of eggs, larvae, etc, without descriptions or figures are not included for the purpose of the present review. For a more detailed list of references on early life history stages of fishes from Indian region till 1968, the annotated bibliography by Jones and Bensam (1968) may be referred to.

1. 3. 1 East Coast (Bay of Bengal)

(A) Northern Sector (North - East Coast)

Perhaps, the first ever publication from India on marine fish eggs and larvae is that of Bhattacharya (1916) on embryonic and larval stages of *Gobius ostericola*, *Petroscirtes bhattacharyae* and *Hemirhamphus limbatus* from Chilka Lake. Nair, K.K. (1939; 1940) described a few postlarval stages of *Hilsa ilisha* and *Engraulis telera* respectively from Bengal. Pillay and Sarojini (1950) dealt with larval development of *Gobiopterus chuno* from West Bengal. Jones, S. and Menon (1950 - 1953) studied the eggs, larvae and/or postlarvae of *Setipinna phasa* (1950 a; 1951 c), *Hilsa ilisha* (1950 b; 1951 a), *Brachiurus pan*, Cynoglossus lingua and C.cynoglossus (1951 b), Coilia dussumieri (1952), Tylosurus strongylurus, Polynemus paradiseus, Ichthyocampus carce, Paragobiopsis ostericola and Callionymus fluviatilis (1953) from north-east coast. Sarojini and Malhotra (1952) reported on postlarvae and juveniles of Eleutheronema tetradactylum from West Bengal and environs. Jones,S. and Pantulu (1952 - 1958) studied metamorphosing stages of Muraenesox talabon and some leptocephali from Bengal and Orissa (1952), leptocephali of Congrellus anago and Pisoodonophis hijala (1955) and larvae and juveniles of Zenarchopterus buffoni, Bregmoceros macclelandi, Callionymus melanopterus, Arnoglossus tapeinosoma, Samaris macrolepis, Solea ovata, Heteromycterias oculus, Triacanthus brevirostris and Parapegasus natans (1958) from Bengal and Orissa coasts. Sarojini (1957) gave an account of early larval stages of Mugil parsia from Bengal; and later (1958) dealt with identification of the fry of five species of mullets from West Bengal, viz, Mugil corsula, M.parsia, M.tade, M.cephalus and M.cunnesius.

Ganapati and Raju (1961 a; b; 1963) described three types of spawn masses eggs and early development of some unidentified muraenid and ophichthyid eels from Waltair. Nair,R.V. and Dharmamba (1961) dealt with early development of an ophichthyid egg, also from the same locality. Chandra (1964) gave an account of distribution and abundance of the larvae of a few fishes in Hooghly Estuary. Rao,N.G.S.(1967) dealt with distribution of larvae and juveniles of some fishes in Mahanadhi Estuary. Similar account on occurrence and distribution of pelagic fish eggs and larvae in Chilka Lake is given by Kowtal (1967). The above author (1970) described eggs and larvae of Nematalosa nasus from Chilka Lake. Rao,V.V.(1971) described early development of Omobranchus japonicus and Cruanthus smithi from Godavari Estuary. Kowtal (1972) gave an account of eggs and larvae of Eleutheronema tetradactylum from Chilka Lake. From the same locality, Natarajan,A.V. and Patnaik (1973) studied embryonic and larval development of Liza macrolepis. Ghosh (1973) dealt with larvae and juveniles of Lates calcarifer from Hooghly - Matlah estuarine system. Chaudhuri, Bhowmick, et al(1978) described eggs and larvae of Mugil cephalus obtained by artificial fertilization from north-east coast. Kowtal (1979) published a note on oozing ovum, developing and early larval stages of Pseudosciaena coibar from Chilka Lake. Mukhopadhyay and Verghese (1979) reported on a postlarva of Lates calcarifer from Hooghly Estuary.

(B) Southern Sector (South - East Coast)

In south-east coast of India, Nayudu (1922) reported on embryonic stages of Cypselurus from Negapatam (Nagapatnam). Whitehouse (1923) gave size ranges of the youngones of Teuthis java, Gobius criniger, Lutjanus quinquelinearis, Lethrinus cinereus and Equlla edentula from Tuticorin. Aiyar (1935) described development of the goby Acentrogobius neilli from Madras. Devanesan (1937) described eggs and embryonic stages of Hemirhamphus georgii from south-east coast. Jones,S. (1937) dealt with development of Etroplus suratensis, E.maculatus, Acentrogobius viridipunctatus, Boleophthalmus boddaerti, Petroscirtes bhattacharyae, Aplocheilus melastigma and Panchax parvus, from Madras. Job and Jones,S.(1938) reported on the eggs and larvae of Tylosurus strongylurus and a few postlarvae of Hemirhamphus gaimardi, also from the same area. Devanesan and Chacko (1944) gave an account of eggs and larvae of Dussumieria hasseltii from south-east region. Nair,R.V.(1946; 1947; 1948) dealt with leptocephali of Uroconger lepturus, Muraenesox cinereus, Muraena macrura and Congrellus anago from Madras and Gulf of Mannar. Nair,R.V. and Bhimachar (1950) described three types of eel eggs and two types of eel larvae from the latter locality. Chacko (1950) reported on occurrence of the eggs of sixteen species from around Krusadai Island with notes on their characteristic features. Alikunhi and Rao, S.N. (1951) gave an account of the metamorphoses of Elops saurus and Megalops cyprinoides from Madras. John (1951) described the eggs, larvae and/or juveniles of thirteen species of fishes belonging to ten families, from Madras. Bapat and Prasad (1952) dealt with postlarvae and juveniles of Caranx kalla from Palk Bay. Nair, R.V. (1952 b; c) reported on some unidentified eggs and larvae of clupeids, carangids, etc and on postlarvae of Elops saurus, Tylosurus strongylurus, Hemirhamphus gaimardi, Trichiurus haumela, Ambassis miops, Therapon jarbua, Lactarius lactarius, Leiognathus ruconius, Gerres lucidus and Scatophagus argus respectively, all from Madras. Rao, K.V. and Basheeruddin (1953) noted the occurrence of youngones of Rastrelliger kanagurta at Madras. Bapat (1955) assigned certain eggs to Kowala coval, Dorosoma chacunda, Sardinella fimbriata, Caranx leptolepis, etc from Mandapam area, with notes on characteristics of eggs and larvae and their distribution. Vijayaraghavan (1955) reported on the eggs, larvae and juveniles identified as of Scomberomorus guttatus; and described (1957) eggs and larvae of Engraulis grayi, Anchoviella tri, Decapterus russelli, Saurida tumbil, Hemirhamphus far, Cynoglossus bilineatus, and Triacanthus brevirostris, from Madras. Kuthalingam (1957 - 1961) studied eggs, larvae and/or juveniles assigned to Cynoglossus lingua (1957), Megalaspis cordyla and Caranx mate (1959 a) Saurida tumbil (1959 b), Triacanthus brevirostris (1959 c), Solea elongata (1960 a), Sardinella longiceps (1960 b), Polynemus indicus (1961 a), Dussumieria acuta (1961 b) and Mugil cephalus (1961 c), all from Madras. Rangarajan and Jacob (1960) dealt with development of Symbranchus bengalensis from Porto Novo. Basheeruddin and Nayar (1962) made a preliminary report on occurrence of juveniles of forty marine fishes of Madras City and tabulated their size range, major size group and food; without descriptions or figures of juveniles. Mahadevan and Chacko (1962) gave notes on eggs and larvae of Dussumieria hasselti from south-east. Rao,K.S.P.B. (1963) described eggs and early development of Caranx sp from Porto Novo. Subrahmanyam (1964; 1968) assigned certain eggs and their larvae to Caranx hippos (1964), C.carangus and Selar kalla (1968), all at Madras. Sudarsan (1968 a; b) reported on the eggs and larvae of Syngnathoides biaculeatus and Hemirhamphus quoyi respectively from Mandapam. Rao,A.V.P.(1970) gave an account of the larvae of Syngnathus cyanopsilus from Pulicat Lake. James (1971) noted early development of Micrognathus brevirostris at Mandapam, recorded newly. Ramaiyan and Rao,T.V.S. (1972) dealt with an interesting postlarval bothid fish from Porto Novo. Rao,K.S.(1973) reported on the eggs and larvae of *Hilsa kelee* from Madras. Bensam (1973) described a few postlarvae and juveniles of *Sardinella dayi* from Tuticorin. Rao,K.S. and Girijavallabhan (1973) dealt with eggs and larvae of an engraulid and two carangids from Madras; subsequently Girijavallabhan and Gnanamuttu (1975) observed a postlarva of *Rastrelliger*, from the same locality. Vijayaraghavan (1973 a; b; 1974) gave an account of the eggs and larvae of *Hirundichthys (Hirundichthys) coromandelensis*, *Acentrogobius ornatus* and *Cypselurus spilopterus* respectively from Porto Novo. From the same locality, Venkataramanujam (1975 a) described the eggs, larvae, postlarvae and/or juveniles of about forty species of marine and estuarine fishes belonging to thirtysix Families and including early life history and/or larval development of *Ambassis commersoni* (also Venkataramanujam, 1975 b), *Saurida gracilis*, *Pseudorhombus javanicus*, *Parastromateus niger*, *Gnathanodon speciosus*, *Carangoides malabaricus*, *Chorinemus tol*, *Trachinotus blochii*, *Parapocryptes rictuosus*, *Grammoplites scaber*, *Arthron hispidus* and *Pseudobalistes fuscus*. Venkataramanujam (1975 a) and Venkataramanujam and Ramamoorthi (1976) have also dealt with seasonal distribution and abundance of fish eggs and larvae of Porto Novo waters. Ramanathan (1977) and Ramanathan and Natarajan,R.(1979) studied eggs, larvae, etc of Psettodes erumei, Pseudorhombus arsius, Bothus myriaster, Brachypleura novae-zealandiae, Synaptura albomaculata, S.commersoniana, Cynoglossus macrolepidotus and C.monopus, from Porto Novo. From the same locality Natarajan,R. and Bensam (1978) reported on eggs and early larvae of Rastrelliger kanagurta.

Apart from the above, observations on development and distribution of early life history stages of marine fishes in Bay of Bengal, based on research cruises, etc were undertaken as follows. Balasubrahmanyan (1968) dealt with larva of Idiacanthus fasciola; Balasubrahmanyan, Rao,K.S.P.B. and Subbaraju (1969 a; b) described larval and juvenile stages of Hirundichthys coromandelensis and Exocoetus volitans; Raju and Ganapati (1970) observed distribution of fish eggs and larvae in the Bay; Balasubrahmanyan (1971) reported on Gempylid larvae; the same author subsequently (1976) on larval billfishes; Balasubrahmanyan and Natarajan,R. (1978) on larvae of Holocentrus sp; Peter (1979) dealt with influence of environmental changes on distribution and abundance of ichthyoplankton in the Bay.

1. 3. 2 West Coast (Arabian Sea)

(c) Southern Sector (South - West Coast)

The first report from west coast of India on marine fish eggs and larvae is that of Panikkar, N.P. (1920) on those of *Etroplus suratensis* and *E. maculatus*, from erstwhile Malabar. Devanesan and John (1940; 1941) reported on eggs assigned to *Rastrelliger kanagurta* and *Kowala thoracata* from the same area. Devanesan and Chidambaram (1941) studied two kinds of eggs and their larvae identified as of *Dorosoma chacunda* and *Caranx crumenophthalmus* from Calicut. Gopinath (1942) dealt with occurrence and seasonal abundance of the postlarvae of fifteen species of fishes belonging to twelve families as well as feeding habits of a few of them along Trivandrum coast. Devanesan (1943) described eggs and embryonic stages of *Sardinella longiceps* from Malabar area. Gopinath (1946) gave notes on larval and postlarval stages of about twentythree fishes from Trivandrum. Nair, R.V. (1952 a) reported on eggs and larvae of *Kowala coval* from Calicut. From the same locality, Seshappa and Bhimachar (1955) studied the larvae and metamorphosis of *Cynoglossus semifasciatus*. Also, from the same region, Chacko and Mathew (1955; 1956) dealt with eggs and early larvae of

Decapterus russelli, Caranx crumenophthalmus, C.djeddaba, C.kalla (1955) and Sardinella albella (1956). Nair,G.S. (1957 a; b; 1961) gave descriptions of the eggs and larvae of Ambassis gymnocephalus, Mugil cephalus and Stigmatogobius javanicus respectively from south-west region. Balakrishnan,V.(1957) made a brief note on the eggs and larvae assigned to Rastrelliger kanagurta , from Vizhingam. Padmanabhan (1957; 1961; 1963) has dealt with development of Antennarius marmoratus, Stolenostomus cyanopterus and Cypselurus comatus respectively, from Trivandrum region. Nair,R.V.(1960 a) reported on early life history of Sardinella longiceps from Calicut. Balakrishnan,K.P.(1961; 1963; 1971) described larvae of Cynoglossus semifasciatus, Arnoglossus tapeinosoma, Bothus ocellatus, Laeops guntheri, Solea ovata, Cynoglossus monopus and Bregmoceros, all from south-west region. Bensam (1968 a; b; 1969; 1970; 1971 a; b) studied eggs and larvae of an unidentified muraenid eel, Opisthopterus tardoore, Cynoglossus semifasciatus, Sardinella jussieu (S.gibbosa), Kowala coval and Anodontostoma chacunda, all from Cannanore. Balakrishnan,V. and Rao,K.V.N.(1971) reported on a few postlarvae and juveniles of Rastrelliger kanagurta. Balakrishnan,K.P. and Devi (1974) reported on larvae of Solea heinii, Cynoglossus *puncticeps*, *C.brevis*, *C.cynoglossus* and *C.lida* from Cochin area.

(D) *Northern Sector* (North - West Coast)

From north-west coast of India, Bal and Pradhan (1945; 1946; 1947; 1951) observed occurrence and seasonal abundance of eggs, larvae and/or juveniles of more than forty fishes, belonging to about twentythree Families, at Bombay. Kulkarni (1950) described eggs and larvae of *Hilsa ilisha*, from north-west region. Nair,R.V. and Mohamed (1961) described some metamorphosing stages of the eels *Muraenesox talabanoides*, *M.talabon*, *Uroconger lepturus* and a few unidentified leptocephali from Bombay. From the same locality, Masurekar (1967) described eggs and developmental stages of *Tylosurus crocodilus*. Bhatt and Bhargava (1973) dealt with the development of the same species from Goa also.

In addition to the above, based cruises off west coast of India, the following studies were undertaken. Jones,S.(1958 - 1967) reported on larvae and postlarvae of *Xiphias gladius* (1958; 1965), *Istiophorus gladius* (1959 a; b), *Gempylus serpens*(1960 a), *Katsuwonus pelamis*, *Neothunnus macropterus* (1960 b), *Euthynnus affinis* (1960 c), *Auxis thazard*, *A.*

thynnoides, Sarda orientalis (1961; 1963), Scomberomorus guttatus, S.commerson and S.lineolatus (1962), Pegasus volitans, Dactyloptena orientalis and D.macracanthus(1967); Jones,S.and Kumaran (1964 a) on larvae of Myripristis murdjan and Holocentrus; Peter (1967; 1970 a) on larvae of Rastrelliger; Devi (1969) on larvae of Pseudorhombus elevatus; Silas and George (1971) on larvae and post-larvae of the mesopelagic fish Vinciguerria nimbaria; Silas (1974) on larvae, postlarvae and juveniles of Rastrelliger kanagurta; UNDP/FAO (1976 a) on eggs, larvae and postlarvae of Sardinella longiceps; and Devi (1979) on developmental stages of Psettina brevirostris and P.iijimae. Also, Peter (1974) dealt with seasonal variations of ichthyoplankton in Arabian Sea in relation to monsoons; and UNDP/FAO (1974; 1976 b) reported on distribution and abundance of eggs, larvae, etc.

Besides, contributions of a general nature on one or the other aspect of development and systematics as well as distribution of early life history stages of marine fishes from India are those of Jones,S.(1950) on terminology of early developmental stages; Jones,S. (1951) and Jones,S. and Bensam (1968) on bibliographies; Nair,R.V.(1961) dealing with general remarks on Indian leptocephali; Jones,S. and Kumaran (1963) on distribution of larval tuna in Indian Ocean as well as (1964 b; c) early life history stages of Indian scombroid fishes and distribution of larval bill fishes in Indo-Pacific respectively; Rao,K.V.(1964) on distribution of young stages of Rastrelliger kanagurta in India; Peter (1970 b) on density of fish eggs and larvae in Indian Ocean; Bensam (1972) on identification of Clupeiform eggs and early larvae; Rao,T.S.S.(1973) on abundance of larvae in oceanic and intermediate zones of Indian Ocean; Bensam (1979) on taxonomic problems in identification of Clupeiform eggs and larvae; and of Ahlstrom and Moser (1979) on achievements made in systematics and development of early life history stages with suggestions for future, including for India.

1. 3. 3 Remarks

A perusal of literature has shown that studies on marine fish eggs and larvae in India have been carried out rather discontinously and at irregular intervals, mostly from Calcutta (also Bengal or West Bengal), Chilka Lake, Waltair, Pulicat Lake, Madras, Porto Novo, Mandapam and Tuticorin along east coast; and Trivandrum and its environs, Cochin, Calicut, Cannanore, Goa and Bombay along west coast, all mostly limited in space and time. It may also be seen, even based on a liberal assessment, that the number of species which have received some attention for a study of their eggs larvae, etc does not exceed 300, forming about one species each in Elopidae, Megalopidae, Albulidae, Moringuidae, Symbranchidae, Solenostomidae, Atherinidae, Tripauchenidae, Sillaginidae, Lactariidae, Pegasidae, Antennariidae, Ephippidae, Acanthuridae, Scatophagidae, Coryphaenidae, Gempylidae, Kurtidae, Psettodidae, Xiphiidae, Triacanthidae; two each in Dussumieridae, Dorosomidae, Plotossidae, Anguillidae, Muraenidae, Congrellidae, Ophichthidae, Belonidae, Bregmocrotidae, Fistulariidae, Sphyraenidae, Scorpaenidae, Platycephalidae, Dactylopteridae, Siganidae, Periophthalmidae; three each in Muraenesocidae, Cichlidae, Pomacentridae, Callionimidae, Trichiuridae, Stromateidae, Tetrodontidae; four each in Apogonidae, Lethrinidae, Blennidae; five each in Syngnathidae, Pleuronectidae, Mullidae, Theraponidae; six each in Polynemidae, Istiophoridae, Cynoglossidae; seven in Synodidae; eight in Centropomidae; nine in Tachysuridae, Hemirhamphidae, Exocoetidae; ten in Mugilidae, Bothidae; twelve in Gobiidae, Sciaenidae; fourteen in Leiognathidae; nineteen in Engraulidae, Carangidae; twenty in Scombridae; twentyfour in Clupeidae; etc. However, adequate attention in a comprehensive manner was received only by about 160 species present along the coasts of India, thus the number of species the eggs and larvae of which are known partially or fully, constituting not more than 10 %. This is in agreement with the remarks of Smith (1974) that early life history stages have been described only in perhaps less than ten percent of marine fishes known.

Also, in most of the species dealt with in India, the entire life history stages are not yet known; but only one or a few stages of eggs, larvae, postlarvae and juveniles are described. In some cases, identifications have not yet been made accurately and convincingly (vide: Jones, S., 1962; Nair, R.V., 1960 a; Bensam, 1973; Silas, 1974), while in others (Bal and Pradhan, 1945; 1946; 1947; 1951; Chacko, 1950; Basheeruddin and Nayar, 1962), only occurrence of eggs, larvae and/or juveniles is reported, without accompanied by adequate descriptions and/or figures of the early life history stages reported, thus making such reports and identifications unhelpful and ineffective for future workers. It is needless in this connection to stress that any first report on a hitherto unidentified early life history stage should be supported by enough description and illustrations.

One principal reason for the imperfect state of our knowledge on early life history stages of marine fishes from Indian waters is the lack of adequate information on distribution, biology and spawning of the ichthyofauna of the regions concerned. But, with rapid progress being made in recent years on these aspects, the situation is gradually changing. It may not be out of place in this connection to mention that the results of International Indian Ocean Expedition on zooplankton studies(IOBC, 1970) have shown that fish eggs and larvae are abundantly distributed in many localities in the Ocean. Also, the zone towards coastal area is reported to be quite rich for eggs and larvae of commercially important marine fishes (Rao,T.S.S., 1973). As such, there is urgent need for intensification of studies on development and systematics of early life history stages of different species, particularly with reference to commercially important ones. This is all the more important because only after having known fully well the various early life history stages that it will be practicable to formulate and implement various resources assessment and production forecasting programmes.

1. 4 SCOPE OF PRESENT WORK

In Porto Novo, situated in south-east coast of India on northern bank of Vellar Estuary (Plate I, Figure 1), more than six hundred species of marine and estuarine bony fishes, belonging to about 120 Families are known to occur (Natarajan,R. and Ramaiyan, unpublished). Only a few reports on development and systematics of early life history stages of some of these fishes have been published till mid seventies from this region (Rangarajan and Jacob, 1960; Rao,K.S.P.B., 1963; Ramaiyan and Rao,T.V.S., 1972; Vijayaraghavan, 1973 a; b; 1974). A concerted effort to study development, distribution and seasonal abundance of eggs, larvae, etc was first made by Venkataramanujam (1975 a;b), Venkataramanujam and Ramamoorthi (1976), Ramanathan (1977) and Ramanathan and Natarajan,R.(1979). But, much more work still remains to be done on these aspects in respect of many more estuarine and marine fishes of this locality. Realizing the above fact, collections of early life history stages made for a period of about two years, from August 1977 till June 1979 off Porto Novo and at the mouth of Vellar Estuary (Fig 1) have been used in the present study; and the development and systematics of twentyfive species belonging to sixteen genera and thirteen Families are dealt with in the present thesis.

Of these, fifteen species have been dealt with for the first time and the other cases relate to early life history stages which are either not yet described from Indian waters or from Porto Novo or are described because earlier accounts available are not quite adequate.

1. 5 PLAN OF THE THESIS

The thesis is presented in three sections. The first one deals with importance of the study with particular reference to India at present, a review of work undertaken in the country so far, scope of present investigations and plan of the thesis. While attempting a review of literature, it was at first thought desirable to comment upon merits/demerits of each work as well as to point out gaps, if any. But, even at the outset it was realized that such an attempt without adequate material at disposal for comparison and contrast is not justifiable. Hence, the chapter on review of literature is only in the form of a perusal, pointing out general gaps as remarks (vide: 1. 3. 3), rather than evaluation of each publication. In the second section is given a brief note of Porto Novo Coast, its major ichthyofauna, method of collection of material used, general guidelines for identification and terminology of life history stages.

The third and main section contains the results of present work on development and systematics of early life history stages of species studied. All species belonging to a particular Family are arranged under it, including a mention of important genera and species in Indian waters, commercial importance and annual production, as recounted by Silas (Ed., 1977). In order to present a comprehensive and coherent account, each species is treated separately, irrespective of the station and time of collection of the stages. However, the date and/or time of collection of each stage are recorded in the text. In dealing with each species, a note on its distribution in India, importance and publications on its fishery and biology is given. This is followed by a description of the development of early life history stages. Every effort was made to identify the material "with complete certainty" (Ahlstrom and Moser, 1976) upto specific level, based on data available and pieces of evidence at disposal. Notes on systematics including comparison with earlier work on the species are given. In the subsection 'General Remarks', salient findings as a result of the present study are highlighted and commented upon.

The main section is followed by a résumè and references cited in the text. A list of publications of the author is incorporated in the Appendix.

2 MATERIAL AND METHODS

2. 1 PORTO NOVO AND ITS ENVIRONS

Material for the present study was drawn principally from plankton samples collected off Porto Novo (Figure 1). Porto Novo is situated at Lat 11^{o} 30' N and Long 79^{o} 46' E in south-east coast of India (Fig 1, inset), bordering Bay of Bengal on its west and on the northern bank of Vellar Estuary. The latter is a true estuary, open to the sea throughout the year. Water masses in the area have a wide range of biotopes, such as neritic, estuarine, backwater, mudflat, mangrove swamp, etc. The estuary is subjected to semidiurnal tides, the amplitudes of which reaching about one metre upto a distance of about 16 km from the mouth. During North - East monsoon rains from about October till about December, the estuary is filled with freshwater; and during other times of the year the water is mostly brackish or neritic. From the estuary backwaters extend in southern direction for about 12 km and become confluent with Coleroon Estuary (not shown in the figure). About 5 km south of Vellar Estuary mouth there is another connection to the sea. Width and depth of the backwaters differ from place to place ranging from

PLATE I

Figure 1. Map of India showing location of Porto Novo in south-east coast of India(inset) as well as stations in the sea and **Vellar** Estuary, from where eggs, larvae and juveniles of marine and estuarine fishes were collected for the purpose of present study. A: Location of laboratories of the Centre of Advanced Study in Marine Biology, where the studies were carried out; B: Location of station at about 15 metres depth off Porto Novo from where routine collections of plankton were made for eggs, larvae, postlarvae, etc; C: Location of station at the mouth of Vellar Estuary from where fry net collections were made, forming minor part of the material used in the present studies.

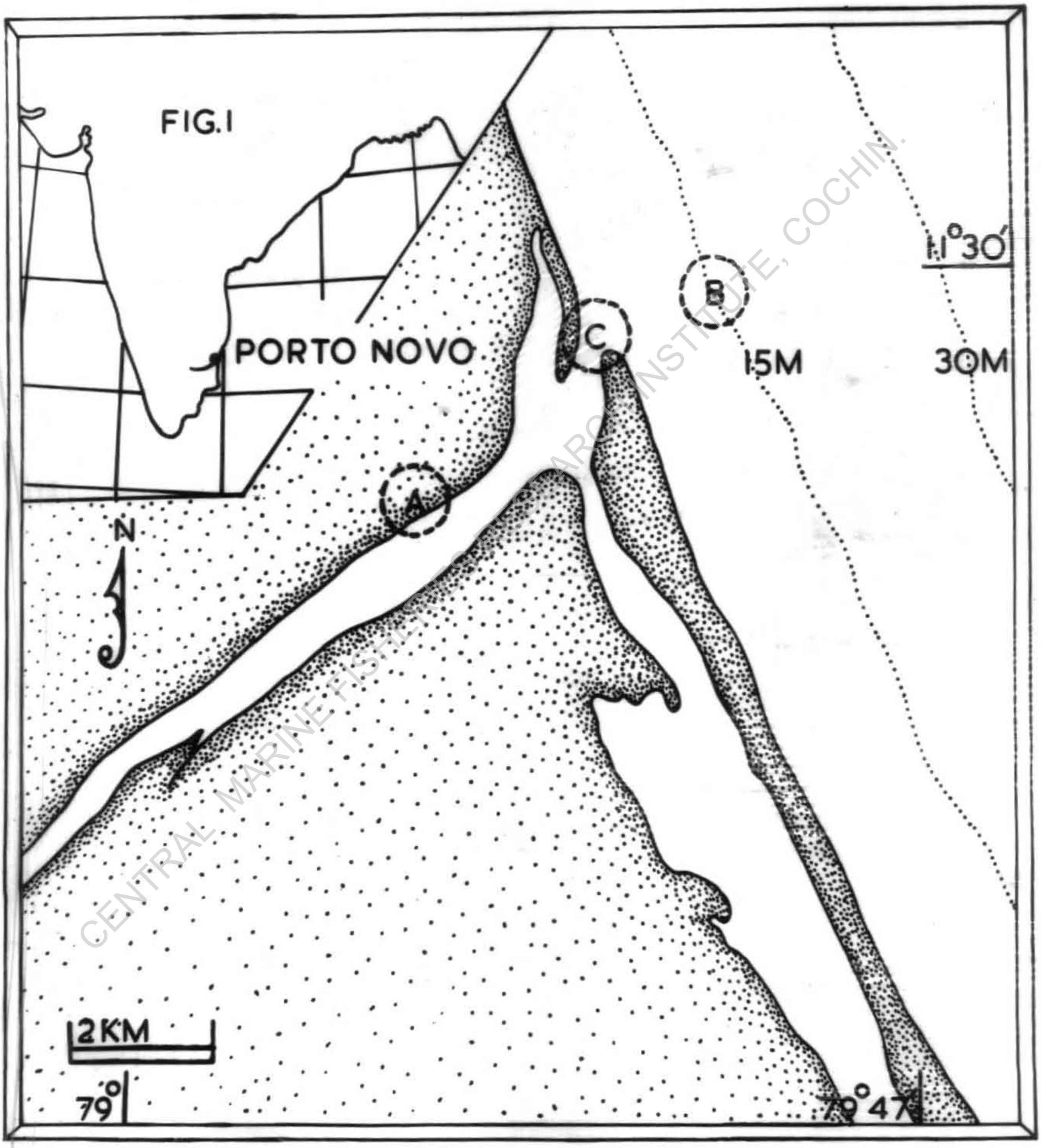


FIG.I
PORTO NOVO
N
A
B
C
15M
30M
11°30′
2 KM
79°
79°47′

about 30 m to about 450 m in width and from 1 m to 3 m in depth. Bottom is mostly clayey with isolated but extensive beds of the edible oyster Crassostrea madrasensis, the mussel Perna, clams and cockles Anadara, Donax, Meretrix, Katelysia, etc. Apart from these, a wide variety of fishes, crustaceans, etc are also present. Luxurient growth of mangrove swamps dominated by Rhizophora and Avicennia is another ecological feature of this region.

2. 2 ICHTHYOFAUNA OF PORTO NOVO

As per a recent checklist by Natarajan,R. and Ramaiyan (unpublished), coastal waters of Porto Novo harbour about 600 species of marine and estuarine fishes, belonging to about 120 families and many of them contributing to valuable fisheries almost throughout the year. During North - East monsoon period however, fishing operations are usually suspended, due to inclement weather conditions. More important of the fishes are Elasmobranchs, Clupeiformes, Mugiliformes, Pleuronectiformes and Perciformes. Among Elasmobranchs, species of Scoliodon, Carcharinus and Dasyatis are more common. Sardinella, Thryssa and Stolephorus spp constitute Clupeiformes in the locality. Mugiliformes are represented by Mugil and Liza spp and Pleuronectiformes by species of Cynoglossus, Psettodes, etc. Family Sciaenidae is composed of the genera Johnius, Pseudosciaena, Otolithes, etc, mostly in demersal catches. The catfishes consist of Tachysurus and Plotossus; the scombroid fishes of Rastrelliger and Scomberomorus; the ribbon fishes of Trichiurus and Lepturacanthus; the goatfishes of Upeneus; eels of Anguilla, Ophichthys and Muraena; carangids of Caranx, Chorinemus, etc; silverbellies of Leiognathus and Secutor; gobies of Acentrogobius, Ctenogobius, Boleophthalmus, etc; and perches of Lethrinus, Lutianus, Epinephelus, Lates, Therapon; etc; etc.

2. 3 COLLECTION OF MATERIAL

Early life history stages of eggs, larvae, postlarvae, etc of the various species utilized for the present study were obtained from daily plankton collections made in the sea at a station situated about 2 km off the mouth of Vellar Estuary (Fig 1, B), where depth is about 12 to 15 m. Plankton net used for collections was made of No 20 bolting silk having a mesh of about 0.1 mm. The net measured 1.5 m long and 0.5 m wide at the mouth. It was towed in surface waters for a duration of about 15 minutes between 06.00 and 07.00 hours and the plankton thus collected was brought to the laboratory for study. Vast majority of early life history stages used for the present thesis is from plankton collections made in the abovesaid locality; and unless otherwise mentioned in the text, all collections denote to the above only.

In addition to the above, fish fry collections were made with velon screens of about 1 mm mesh size operated in shallow areas of Vellar Estuary mouth (Fig 1, C) for larvae, postlarvae and juveniles available there. A few juvenile stages were also obtained from trawlers operating in the sea south-east of Porto Novo, at a distance of about 5 - 7 km.

2. 4 METHODS OF STUDY

Eggs from plankton collections were examined under a binocular microscope in living condition. Each type of egg was separated based on such characteristic features as diameter of eggs, presence, absence or number of oilglobules, vacuolation or segmentation of yolk and pigmentation pattern of embryo. After separation, each type of egg was transferred to a large container having filtered sea water, in order to study various stages of development. Representative stages during development were sketched by studying the live eggs in cavity slides under a monocular microscope and with the aid of a mirror type *camera lucida*. Formalin preserved samples were also utilized for this purpose; and are indicated as such in the text. Wherever possible, the process of hatching was observed under a binocular microscope by keeping eggs in embryo cups. Characteristic features of larvae and postlarvae were also recorded in live condition; while, for making *camera lucida* drawings, these were fixed in 2 % formaldehyde in order to prevent shrinkage in higher concentrations.

While rearing eggs and larvae, growth of micro organisms which cause mortality was minimised by filtering sea water, keeping them in sterilized vessels and by adding Streptopenicillin at a concentration of 25 mg/100 ml of water. For feeding the larvae, fresh phytoplankters and zooplankters were isolated from plankton. *Skeletonema*, *Coscinodiscus*, *Thalassiothrix*, etc as well as small sized copepods and nauplii were not consumed well by the larvae. It was found that most of the larvae hatched out in the laboratory died within about four to six days after hatching.

In the case of larvae and postlarvae collected directly from plankton, representative stages of each species were studied under microscope for their characters, pattern of pigmentation, myotome or vertebral counts, etc and sketched with all these details immediately on fixation in 2 % formalin. Lebour (1921) has pointed out the importance of myotome counts as reliable characters in identification of fish larvae; and hence great attention was paid to this aspect. The number of myotomes in preanal region could be counted precisely in all larvae and postlarvae. But, the number of myotomes in postanal region in early larval stages could not be ascertained fairly accurately because myosepta towards caudal end became rather indistinct and notochordal vacuolations appeared more prominent than myotome boundaries, thus obliterating the latter. However, in later stages of larvae and in postlarvae, myosepta became quite distinct, thus facilitating the determination of myotome boundaries in postanal region also. In specimens having excessive pigmentation on body and in advanced postlarval condition approaching juvenile phase, myotome boundaries and vertebrae could not be delineated adequately. Such specimens were treated in Potassium hydroxide, stained with alizarin dye and cleared in glycerin, to facilitate counting of the number of vertebrae. For comparing larval myotome number with adult vertebrae, the urostylar segment was treated as the last one, both in larvae and in adults.

Attempts at rearing larvae and postlarvae collected directly from plankton by feeding them with phytoplankters, zooplankters and/or yolk of chicken were not successful, in all cases.

Length of larvae, postlarvae and juveniles given are total length extending from tip of snout or lower jaw, whichever was longer, to tip of larval finfold or tip of caudal fin, as the case may be. Standard length from tip of snout or lower jaw till the end of caudal peduncle is also given, in some cases.

Since most figures presented in eleven Plates follow one after another in a serial manner and from one Plate to the next, the specific number of the Plate in which a particular figure is placed is not mentioned in the text. In a few instances however, due to necessity for adjustment of space a few figures are placed in Plates different from the previous ones. In these cases, the specific number of the Plate in which the figures are placed is also mentioned in the relevant place in the text, preceding the number of figure. Number of the Plate is recorded above explanation to figures given opposite to it.

2. 5 GUIDELINES FOR IDENTIFICATION

Although in recent years a few modern techniques have been sought to be employed in solving some intricate taxonomic problems in development of fishes, the procedures already in vogue remain as the basic guidelines for identification, particularly among species and in areas which are not explored adequately. These and other characters are recounted by Ahlstrom and Moser (1976) and are used with advantage in the present study. Also, Ahlstrom and Moser (1979) have rightly pointed out that our ability to solve difficult identification problems can be enhanced by improving the quality of specimens, by critically evaluating various characters, by discovering new diagnostic features, etc. While formulating guidelines for identification of early life history stages in the present study, such a principle was followed. And, the guidelines followed are recounted below:-

(1) Occurrence of early life history stages in plankton and of spawners, spent, mature and/or recovering stages in fishermen's catches, as circumstantial evidence.

(2) Similarities between ripe ovarian eggs of the species concerned and planktonic eggs in early stages of development. Size range of ripe ova and

that of planktonic eggs in some fishes remain almost the same without "swelling up" on coming into contact with sea water unlike others which do swell up in water and as development progresses, thus altering original overall egg size. However, even in the latter category, the size of ripe ova remains unchanged as "yolk" and aids in identification of free eggs.

(3) Shape of eggs, such as spherical, ellipsoidal, etc.

(4) Presence or absence of ornamentation on egg capsule(chorion).

(5) Presence or absence of oilglobule; if present, the number, diameter, pigmentation, etc; as well as its location on yolksac in newly hatched larva.

(6) Presence or absence of vacuolation or segmentation in yolk; if present the nature thereof such as fine, moderately fine, coarse, etc; colouration of yolk, pigmentation, etc.

(7) Extent of perivitelline space.

(8) Pigmentation pattern of embryo.

(9) Nature of arrangement of muscle fibres, such as crossed, parallel, etc.

(10) Number and disposition of myotomes (myomeres), myosepta and/or vertebrae in relation to location of vent (anus) during larval development.

(11) Disposition and shape of alimentary canal such as straight, coiled, etc.

(12) Changes in proportions of preanal, postanal, predorsal and postdorsal in relation to length of larvae; and changes in body form during development, based on "series method" (Schmidt, 1905).

(13) Structure and shape of body.

(14) Characteristics of head, shape and position of mouth (Vatanachai, 1974).

(15) Appearance as well as disposition of paired and unpaired fins (Ahlstrom and Moser, 1976).

(16) Sequence of changes in important characters during larval development (Ahlstrom and Ball, 1954).

(17) Number and disposition of spines and rays in fins.

(18) Comparison of larval and postlarval features with adult characters (Bertelsen, 1951; Bertelsen, Krefft and Marshall, 1976).

(19) Comparison and contrast between stages of similar size range and/or developmental sequence of closely allied species and/or genera.

(20) Spination on head, type of caudal fin, time of formation of pectoral fin rays, etc (Ahlstrom and Moser, 1976).

Russell (1976) while dealing with identification of eggs, larvae, etc of British marine fishes, departed from some common methods followed by earlier workers and relied mostly on pigmentation which he stated was the best diagnostic character. He did not give much importance to such meristic characters as myotomes, vertebrae, fin ray counts, etc, for distinguishing young stages of various species. It may be noted in this connection that in temperate waters such as in Britain, the number of species belonging to a genus or family is considerably less than in tropical regions, without much overlapping characters including pigmentation pattern. On the other hand in tropical waters, as noted earlier, similarities between young stages of allied species are found to be many, with quite a few overlapping characters. Hence, in order to make fairly accurate and reliable identification of early life history stages of marine fishes in tropical regions, in addition to characters such as pigmentation pattern, it becomes essential to reinforce evidence from other sources as well, such as morphometric, meristic and other data. Nevertheless, difference in pigmentation has served to distinguish between early stages of closely allied species when other characters were not of much value. In the present work, depending upon needs these have been taken into account suitably.

2. 6 TERMINOLOGY OF EARLY LIFE HISTORY STAGES

A perusal of literature on early life history stages of marine fishes shows that various authors have used different terminologies for describing developmental stages, such as "early egg", "late egg", "prolarva", "yolksac larva", "preflexion larva", "postlarva", "prejuvenile", "juvenile", etc (Hubbs, 1943; Jones,S., 1950; Ahlstrom and Counts, 1955; Ahlstrom, 1968 b; Balon, 1971; to mention only a few). Recently, Balon (1976 a) has proposed terms like "cleavage eggs", "propterygiolarva", etc. But, Richards (1976) disagreed with the above and suggested only simplified and established terms and definitions. He has pointed out that most scientists follow the terminology used by Ahlstrom (1968 b) and Moser and Ahlstrom (1970) and that the terms proposed by Balon (1976 a) cannot be applied particularly to developmental stages of marine fishes which exhibit a great deal of diversity. Balon (1976 b) however, did not accept the above contention of Richards (op.cit).

Russell (1976) while describing eggs and planktonic stages of British marine fishes, points out that the terms "larva" and "postlarva" used by earlier workers are quite convenient. The term "larva" is used by Russell (op.cit) to refer to the stage bearing yolksac, this stage becoming terminated when yolk is completely absorbed, marking the end of larval period. The stage extending from this condition till the one in which the specimen resembles adult in most vital characters such as general body form, meristic counts, etc is designated as "postlarva" by Russell (op.cit). The term "prolarva" used by certain authors and the term "yolksac larva" by others correspond to the term "larva" used by Russell. In the atlases on early life history stages of fishes of the mid-Atlantic Bight by Jones,P.W., Martin and Hardy Jr (1978), Hardy Jr (1978 a; b), Johnson (1978), Fritzche (1978) and Martin and Drewry (1978), terms such as "larva" and "prejuvenile" are used. Of these, the term "larva" may be said to correspond to the term "postlarva" used by Russell. The latter author points out that postlarval sequence of development in marine fishes has no sharply demarcated termination and that certain adult characters are already formed before the specimen has lost some other larval characteristics such as pigmentation. According to Russell (op.cit) since the process of metamorphosis in marine teleosts is gradual involving sequences of development during which the specimen continues to change, the use of the term "postlarva" is justified. In view of the above reason, in the present thesis, the term "postlarva" is used. The term "prejuvenile" is used in literature for highly modified pelagic developmental stages such as Tholichthys, Ptax, etc which are neither postlarval nor juvenile in character and are strikingly different from juvenile condition (Ahlstrom, 1968 b). Such stages were not encountered during the present study; and hence, the question of usage of the term "prejuvenile" in this thesis does not arise.

In the course of present studies it was observed that during juvenile phase of development also the specimens differed from adults in such features as morphometric proportion, colouration, etc. In other words, during juvenile development also some adult characters were observed to have not yet developed, although other features were already formed. Hence, as in the case of postlarva, juvenile sequence of development also may not be said to have a sharply demarcated termination at an early age or size, but the developmental processes of certain characters may be delayed till the specimen becomes older and reaches a fairly large size. In view of the above reason, use of the term "juvenile" is followed to the phase of life history in which many adult characters are established but certain developmental features still persist.

3 STUDIES AND DISCUSSION

3. 1 SYSTEMATIC POSITIONS OF SPECIES

Nomenclature of fishes dealt with in the present work and their placement in Families as well as other taxa are largely as per the classification followed by Nelson (1976). However, with regard to Family Chanidae, although Nelson (op.cit) relegates it to Order Gonorynchiformes, most workers are known to place it still in Order Clupeiformes or its equivalent, in a variety of ways. Ontogenetically, the only species in this Family, *Chanos chanos* bears closest similarity to development of Clupeiform fishes (*vide*: Delsman, 1929 b; Chaudhuri, Juario, *et al*, 1978; Liao, Juario, *et al*, 1979). Hence, in the present account Family Chanidae is placed in Order Clupeiformes. Nomenclature of Subfamilies in Family Clupeidae is as followed by Whitehead (1972) and in other Families as given by Nelson (1976).

Phylum Chordata
  Superclass Gnathostomata
    Class Osteichthyes
      Subclass Actinopterygii
        Infraclass Teleostei
          Division Taeniopaedia

Superorder Clupeomorpha

Order Clupeiformes

Family Clupeidae

Subfamily Dorosomatinae

Nematalosa nasus (Bloch)

Subfamily Clupeinae

Sardinella clupeoides (Bleeker)

Sardinella sirm (Walbaum)

Sardinella fimbriata (Valenciennes)

Sardinella albella (Valenciennes)

Subfamily Pristigasterinae

Ilisha melastoma (Schneider)

Ilisha megaloptera (Swainson)

Family Chanidae

Chanos chanos (Forsskål)

Family Engraulidae

Subfamily Engraulinae

Thryssa dussumieri (Valenciennes)

Thryssa hamiltonii (Gray)

Thryssa mystax (Schneider)

Stolephorus tri (Bleeker)

Superorder Acanthopterygii

Order Perciformes

Suborder Mugiloidei

Family Mugilidae

Liza dussumieri (Valenciennes)

Liza macrolepis (Smith)

Liza tade (Forsskål)

Suborder Polynemoidei

Family Polynemidae

Polynemus sextarius (Bloch and Schneider)

Suborder Percoidei

Superfamily Percoidae

Family Sillaginidae

Sillago sihama (Forsskål)

Family Gerreidae

Gerres oblongus (Cuvier)

Gerres setiferus (Hamilton)

Family Theraponidae

Therapon jarbua (Forsskål)

Family Mullidae

Upeneus (Pennon) bensasi (Temminck and Schlegel)

Family Centropomidae

Lates calcarifer (Bloch)

Suborder Acanthuroidei

Family Siganidae

Siganus javus (Linnaeus)

Suborder Scombroidei

Family Scombridae

Rastrelliger kanagurta (Cuvier)

Order Scorpaeniformes

Suborder Platycephaloidei

Family Platycephalidae

Subfamily Platycephalinae

Platycephalus indicus (Linnaeus)

In the following section 3. 2, comprising results of the present studies, all the Families are arranged in the same serial order as given above, such as "(A) Family Clupeidae", "(B) Family Chanidae", etc. Arrangement of various species also follows the same serial order as given above. And, since the work carried out under each species constitutes the mainstay of the present thesis, the subsections embodying the results under various species are given prominence by allotting subsection numbers at species levels such as "3. 2. 1 Nematalosa nasus (Bloch)", ..., "3. 2. 19 Gerres setiferus (Hamilton)" and so on, instead of giving importance at Family levels.

3. 2 DEVELOPMENT AND SYSTEMATICS OF EARLY LIFE HISTORY STAGES

(A) Family Clupeidae

The Family Clupeidae is represented in Indian waters by the genera Sardinella, Ilisha, Hilsa, Pellona, Opisthopterus, Dussumieria, Escualosa, Anodontostoma, Nematalosa, etc. Of these, the sardines Sardinella spp are economically the most important, with upto 2,00,000 tonnes of annual production from a single species, S.longiceps in the south-west coast and upto 90,000 tonnes of annual production from all other species such as S.gibbosa, S.fimbriata, S.albella, S.sirm, S.dayi, S.clupeoides, etc, along both the coasts. The Indian shad Hilsa ilisha supports fishery in brackish water ecosystems such as Lakes Chilka in north-east, Pulicat in south-east and Vembanad in south-west as well as in estuarine regions along both the coasts. The Indian herrings Ilisha, Pellona and Opisthopterus contribute to fisheries along both the coasts; and the White sardine Escualosa thoracata is of local fishery importance in south-west coast. On the whole, Family Clupeidae is responsible for more than 20 % of marine and estuarine fishery production in India.

3. 2. 1 Nematalosa nasus(Bloch)

Nematalosa nasus, popularly called "Long ray bony bream", is distributed all along Indian coasts and is invariably met with in fish catches from inshore waters, estuaries, lagoons, backwaters, etc. Frequently, this species, along with the related one Anodontostoma chacunda, contributes to small scale fisheries in different localities. Previous work on this species from Indian waters are those of Bapat and Bal (1950) on food of its young from Bombay region, Jones,S.and Sujansingani (1954) on its breeding in Chilka Lake, Chacko, Rajagopal and Mohanakrishnan (1966) on its bionomics and fisheries in Ennore and Pulicat backwaters, Annigeri (1967) on maturation and spawning in Mangalore and Kowtal (1970) on eggs and early larvae from Chilka Lake. Only the last work deals with early life history stages, from north-east coast of India; and the present account is on eggs, larvae and postlarvae collected from nearshore waters of Porto Novo.

(a) Eggs (Figs 2 - 4)

Eggs identified as those of N.nasus were collected on 7 -2 -1978, 9 -2 -1978 and 22 -3 -1978, in postmonsoon period. They were pelagic, spherical, transparent and ranged in diameters from 0.945 mm to

1.0 mm, in various stages of development. Each egg contained eight golden-yellowish oilglobules ranging in diameters from 0.036 mm to 0.081 mm. The oilglobules were usually found near tail end of the embryo.
A narrow perivitelline space was present all around the yolk, which was spherical and vacuolated with individual vacuoles fairly large in size.

In an early stage of development studied at 07.30 hour on 7 -2 -1978, anterior half of the embryo was indicated with developing optic vesicles and formation of myosepta, as shown in Fig 2. When examined on the same day at 16.00 hr (Fig 3), the embryo was well formed with optic capsules, their lenses, tail region and myotomes. In a still advanced stage of development at 12.00 hr on 9 -2 -1978 (Fig 4), the embryo was almost ready for hatching. Also, at this stage a few black pigment spots could be noted on dorsal side of the embryo.

(b) Larvae (Figs 5, 6)

A just hatched larva from a batch of eggs reared in the laboratory on 7 -2 -'78 and its salient features such as globular shape, large yolksac, prominent finfold and oilglobules is shown in Fig 5. It measured 3.072 mm with body tapering towards caudal end. Yolksac was rounded off posteriorly and alimentary canal was almost straight with a marked bend at anal region. A series of black pigment spots was present at base of finfold dorsally. Thirtyfive myotomes could be counted with precision in preanal region and about six in postanal region, the actual number of myotomes in hinder part of the body could not be made out distinctly owing to imperfect nature of myosepta and dominant nature of notochordal vacuolation there. The myosepta were disposed at a slight angle anteriorwards. Preanal length of the larva was 85.6 % of its total length.

A second larval stage, measuring 4 mm (Fig 6) was obtained by rearing an egg kept for hatching on 9 -2 -'78. The specimen studied at 10.00 hr on 10 -2 -'78 had many progressive developmental features such as reduction of yolksac, formation of heart, development of pectoral finbud, prominent auditory vesicles and movement of dorsal row of pigment spots to below notochordal region and above alimentary canal. A slight invagination was present below eye region, marking the formation of mouth. Eyes remained unpigmented and anus opened below thirtyfifth myotome in this stage also. Although hindermost myotomes were only indistinctly recognizable, about ten myotomes could be counted in postanal region. Preanal length in this stage was reduced to 77.2 % of total length.

(c) Postlarvae (Figs 7 - 10)

Four postlarval stages were available for study, one obtained by rearing in the laboratory and three others collected from plankton.

4.87 mm (Fig 7):- This stage was the result of newly-hatched larva reared to 24 hours old and studied at 14.00 hr on 23 -3 -'78. The characteristic features of this stage were full utilization of yolk, formation of mouth and partial pigmentation of eyes. Pectoral fin has become larger and pigmentation along dorsal aspect of alimentary canal has become more pronounced than in 4 mm larva. Opercular cleft has developed as a ventro-dorsal constriction behind the head. Alimentary canal has remained straight with a minor constriction anteriorly, marking hind end of oesophagus. Number and disposition of myotomes remained the same as in the previous stage and the larval finfold continued to be prominent. Preanal proportion showed only a negligible reduction, to 77 % of total length. All these features showed that at 24 hrs the specimen was in an early postlarval condition.

6.78 mm (Fig 8):- The present postlarva as well as the succeeding two were collected from plankton off Porto Novo on 16 -3 -'78. Body appeared much elongated and broader than before. Larval finfold has disappeared, head region has become more pointed, jaws have become well developed, eyes were pigmented black and pectoral fins have assumed a fan shaped appearance with faint indications of future rays. Dorsal fin was indicated between 22nd and 28th myotomes with about five rays and caudal fin showed radiating rays. Anal fin was also seen, between 31st and 39th myotomes with basal elements and rays. Mid- and hind-gut regions have widened dorsoventrally, with similarly disposed foldings of epithelium. Myosepta were distinctly angular or 'V' shaped; and there were 30 preanal and 15 postanal myotomes, the number and disposition being identical with adult vertebral condition. Preanal length was 72.3 % and predorsal length 62.5 % of total length. When compared with 4.87 mm postlarva, pigmentation in this stage appeared much reduced, with only a few spots in postopercular region, one behind pectoral fin and two a little behind it.

<u>9 mm</u> (Fig 9):- Apart from increases in length and breadth of body, the progressive changes noted in this stage were development of dorsal, caudal and anal fins, increased pigmentation and development of minute conical teeth on maxilla.

Dorsal and anal fins extended between 24th and 30th and between 31st and 39th myotomes respectively. Nine rays could be counted in dorsal fin and 17 in anal fin. Pigmentation consisted of black spots, one infront of opercular cleft, two posterior to pectoral fin and a group of six in foregut region. There were two pigment spots anteriorly and one posteriorly above midgut region. In anal region, one pigment spot was present just above vent. Proportions of preanal and predorsal lengths in relation to total length have decreased slightly, to 71.8 % and 58.6 % respectively.

10.69 mm (Fig 10):- In this stage further development of fins and pigmentation could be seen. Ten dorsal rays, twentyfive caudal rays and sixteen anal rays were visible. Two pigments have appeared at the base of lower caudal region, two infront of operculum ventrally, two in pectoral region and a series of four in foregut region. One large pigment was characteristic in midgut and another above anus. Formation of pelvic fin was faintly indicated. Preanal and predorsal proportions have decreased to 66.6 % and 54.7 % in total length respectively.

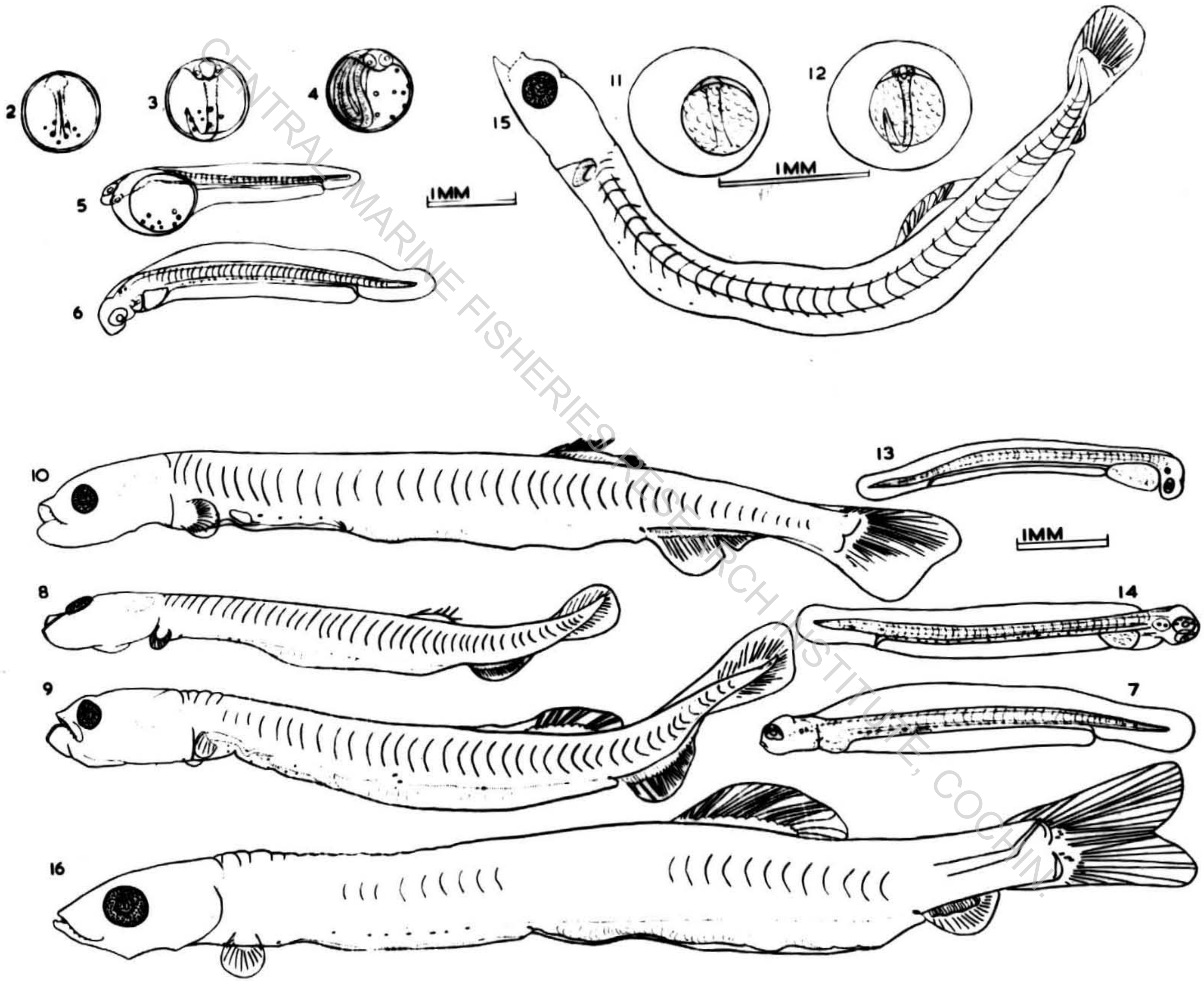
(d) Systematics

Identification of present early life history stages as those of N.nasus was based on

PLATE II

Figures 2 - 10. Eggs, larvae and postlarvae of *Nematalosa nasus*: Figs 2, 3 and 4. Eggs in three stages of development; Fig 5. Newly hatched larva; Fig 6. 4 mm larva; Figs 7 - 10. Postlarval stages, Fig 7. 4.87 mm; Fig 8. 6.78 mm; Fig 9. 9 mm; and Fig 10. 10.69 mm.

Figures 11 - 16. Eggs, larvae and postlarvae of *Sardinella clupeoides*: Figs 11 and 12. Eggs in two stages of development; Figs 13 and 14. Larval stages, Fig 13. 3.65 mm; Fig 14. 4.5 mm; Figs 15 and 16. Postlarvae, Fig 15. 10.27 mm; and Fig 16. 13.18 mm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circumstantial evidence of coincident occurrences of the eggs and postlarvae in plankton and mature as well as spent specimens in inshore fish catches at Porto Novo during February and March 1978 as well as on diagnostic characters of the stages reared in the laboratory and collected from plankton. Delsman (1926 d) has considered certain eggs as belonging to Dorosoma chacunda and D.nasus (N.nasus). Later (1933 b), based on more valid and adequate data, he revised his earlier contention and assigned the former egg to Clupeoides lile and the latter to D.chacunda. Eggs of D.chacunda which also belongs to the same Subfamily as N.nasus have a diameter of about 1 mm, contain 6 - 12 oilglobules and well developed embryos show pigmentation (Delsman, 1926 d; 1933 b). But for these similarities, the early larvae obtained from the eggs of N.nasus can very well be differentiated from those of D.chacunda in having only 35 preanal myotomes as against 37 in the early larvae of the latter(Delsman, op.cit). The 3.072 mm, 4.0 mm and 4.87 mm larvae obtained presently by rearing the eggs have 35 preanal and 10 postanal myotomes, the total number 45 corresponding with adult condition, as against 41 in D.chacunda. Devanesan and Chidambaram (1941) assigned certain eggs to Anodontostoma chacunda(D.chacunda) collected from south-west coast of India. But, the newly-hatched larva from the above egg was stated to have 35 preanal and 12 postanal myotomes and 4.35 mm postlarva 25 preanal and 22 postanal myotomes. The early larva obtained from certain eggs assigned by Chacko (1950) to A.chacunda from south-east coast had only 26 preanal myotomes. Number and disposition of myotomes in the larvae described by Devanesan and Chidambaram (1941) and Chacko (1950) are different from the larvae of D.chacunda described by Delsman (1926 d; 1933 b).

Eggs of N.nasus can be distinguished from those of Sardinella spp (Delsman, 1926 c; Nair,R.V., 1960 a; Bensam, 1970) in having a narrow perivitelline space and 8 - 9 oilglobules. Eggs of Thryssa spp do not contain oilglobule and those of Stolephorus are elliptical (Delsman, 1929 a; 1931 a). Eggs of Kowala coval(Clupeoides lile) are smaller in size(0.77-0.82 mm), have a wider perivitelline space than in the eggs of N.nasus and contain 3 to 20 small oilglobules (Delsman, 1926 d; 1933 b; Nair,R.V., 1952 a). In these characters the eggs of N.nasus are distinct from those of allied species.

Kowtal (1970) first identified the free eggs of N.nasus. The ripe, unfertilized eggs collected and preserved by him in 4 % formalin ranged in diameters from 0.73 to 0.95 mm and contained 8 to 9 oilglobules of 0.034 to 0.085 mm. Planktonic eggs collected by him ranged in diameters from 0.91 to 1.17 mm and had 8 to 9 oilglobules of 0.034 to 0.085 mm diameter. Kowtal (op.cit) has also given an account of larvae measuring 2.5 mm(newly hatched), 3.46 mm(12 hrs), one day old and two days old stages. The 3.072 and 4.0 mm larvae in the present study are comparable to 2.5 and 3.46 mm stages given by him. Apart from difference in length, the former differ from the latter in the presence of pigmentation only. Two days old larvae obtained by Kowtal measuring 3.3 mm may be compared to 4.87 mm in the present account. The basic difference between the two is that in the former the anus has made a forward movement covering two myotomes, while in the latter the anus was situated still at the 35th myotome.

The last three postlarval stages in the present account have 30 preanal and 15 postanal myotomes, the number and disposition corresponding to adult vertebral condition. Bensam (1971 b) described five postlarval stages of closely related Anodontostoma chacunda, which differ from the postlarvae of N.nasus in the number and disposition of myotomes. Also, in A.chacunda the caudal fin shows indication of its bifurcation at 8.7 mm itself, but in N.nasus only at 10.69 mm. Apart from these, difference is also seen in pigmentation of the postlarvae of the two species.

Among various clupeoid fishes found at Porto Novo, apart from species such as Sardinella albella and S.sirm which have only 42 or 43 vertebrae, S.fimbriata may be said to possess a vertebral number (45 - 47) which might overlap the vertebral number of N.nasus(45). But, the larvae assigned to S.fimbriata (Clupea fimbriata) by Delsman (1926 c) show 40 preanal myotomes whereas in early larvae of N.nasus number of preanal myotomes is only 35 and in later stages it becomes still lesser, to 30. Preanal myotome number in postlarvae of Clupea (Sardinella) spp dealt with by Delsman (op.cit) ranged from 39 in 5.5 mm to 34 in 22 mm and 27.5 mm stages. Thus, postlarvae of N.nasus can be well distinguished from those of S.fimbriata and a few other species by the lesser preanal myotomes. In the postlarvae of S.gibbosa on the other hand (Bensam, 1970), 33 preanal and 12 postanal myotomes are present in 4.26 mm and 5.36 mm stages and 30 preanal and 15 postanal in 6.72 and 17.30 mm specimens, the latter condition being the same as in the postlarvae of N.nasus described here. In the postlarvae of S.gibbosa, pigmentation is in the form of a series of chromatophores from pectoral region upto anus while in the postlarvae of N.nasus pigmentation consists of only a few spots in foregut region and one or two in mid- and hind-gut regions. Besides, indication of bifurcation in caudal fin can be recognized in 7.7 mm stage of S.gibbosa, but only in 10.69 mm postlarva of N.nasus. Postlarvae of S.dayi (Bensam, 1973) can be differentiated from those of N.nasus in having 34 preanal and 12 postanal myotomes. In the course of present work a few postlarvae of S.fimbriata were also studied (vide: 3. 2. 4) and these showed differences in disposition of myotomes and pattern of pigmentation from the present material.

Postlarvae of N.nasus may be distinguished from those of Chanos chanos (Delsman, 1926 f; 1929 b) in having a crossed arrangement of muscle fibres as against a parallel one in C.chanos. Presence of a series of mid-lateral pigments in the postlarvae of Chanos and the number as well as disposition of myotomes are of diagnostic value in separating the larvae and postlarvae of these two.

3. 2. 2 Sardinella clupeoides (Bleeker)

Sardinella clupeoides is a little known sardine although it is widely distributed in the Indo-Pacific area including south-east Asian region (Whitehead, 1972). From Indian coastal waters it was reported from both south-east and south-west areas (Bennet, 1965). This species has a strong similarity to S.leiogaster; but could be distinguished from it by the fact that its body depth is 24 - 27 % in standard length, number of lower gill rakers is 26 - 30 and dorsal fin origin is slightly nearer to snout than to caudal lobe, as against body depth 22 - 24 % in standard length, number of lower gill rakers 31 - 36 and dorsal fin origin equidistant between snout and caudal lobe in S.leiogaster (Whitehead, 1972). Not much is known of the fishery potential of this species, but it was observed in a few numbers in sardine fishery at Tuticorin during 1965 - 1977 and at Porto Novo during 1977 -'78. Nevertheless, it is as much commercially important as the allied species S.sirm, S.leiogaster, etc. Till now no information was published on early life history stages of this species. As such, the present section on a couple of stages in its embryonic development and a few larval and postlarval stages obtained by hatching eggs in the laboratory and collected from plankton may be of interest.

(a) Eggs (Figs 11, 12)

Eggs were collected on two occasions from plankton off Porto Novo, 1 -2 -'78 and 14 -4 -'78. They were pelagic, spherical, transparent and ranged in diameters from 0.913 to 0.956 mm. Yolk was spherical, colourless and vacuolated with diameters ranging from 0.505 to 0.526 mm. A large perivitelline space was present and yolk did not contain oilglobule. Two stages in embryonic development were available: In an earlier stage with embryo faintly indicated bearing optic vesicles (Fig 11); in a later stage embryo was fully formed with a well defined head and tail, the latter partly free from yolk. Embryo and yolk were devoid of pigmentation.

(b) Larvae (Figs 13, 14)

By rearing eggs in the laboratory, two stages in larval development were obtained, earlier one by rearing an egg collected on 1 -2 - '78 and a later stage collected on 12 -4 - '78. In the former measuring 3.65 mm (Fig 13), judging by the fact that it has hatched during the night of 1 / 2 -2 -'78 and examined on the morning of 2 -2 - '78, it may be said that the larva might not be more than about six to ten hours old. Body was elongated with an uniform depth except at head region and yolk. Head was partly bent over yolk and there were 38 preanal and about 5 postanal myotomes. The larva was devoid of pigments.

A more advanced larva obtained by rearing a similar egg hatched out during the night of 12 / 13 -4 -'78 and examined on the morning of 14 -4 -'78 and calculated to be about twentyfour hours older than the previous one measured 4.5 mm (Fig 14). The most important change observed was appearance of pigmentation in the form of two series of spots along alimentary canal, one above the other. The lower series was almost continuous from behind yolksac till vent and the upper one was discontinuous in midgut region. A pigment spot was present above the vent in mid-lateral region and a partly branching pigment about half way in postanal region. Besides, eye capsules showed beginning of pigmentation and a partly branching pigment was present in snout region. Yolksac was very much reduced, but mouth was not yet formed. There were 43 myotomes of which 37 were preanal and 6 postanal, indicating a forward movement of vent covering a single myotome. Preanal length was 82.3 % of total length.

(c) <u>Postlarvae</u> (Figs 15, 16)

<u>10.27 mm</u> (Fig 15):- Date of collection was 1 -2 -'78.

Body was elongated and larval finfold was absent. Jaws have developed, upper one with minute conical teeth and lower one slightly longer than upper. Pectoral fin has developed as a membraneous fan shaped structure and eyes have become black pigmented. In the foregut four pigment streaks and in lower caudal region three pigment spots were present. Dorsal fin has developed between 24th and 34th myotomes with about nine rays. Caudal fin was somewhat club-shaped with about twelve rays. Anal fin was indicated as a triangular formation behind vent. Preanal length was 81.4 % and predorsal length 56.6 % of total length. There were 37 preanal and 6 postanal myotomes.

<u>13.18 mm</u> (Fig 16):- Date of collection was 10 -2 -'78.

Body has become somewhat cylindrical, head somewhat pointed and caudal fin forked. About 14, 20 and 14 rays could be counted in dorsal, caudal and anal fins. Beginning in the development of pelvic fin was discernible as a small bud at the end of foregut. Mid- and hind- guts showed dorsoventral foldings of inner epithelia. Pigmentation consisted of a short series of black spots in foregut, a few pigments at base of upper and lower caudal lobes and a single black pigment above vent. Preanal length has become decreased to 76.3 % and predorsal length to

55.5 % of total length. Disposition of myotomes has changed due to further forward shifting of vent, resulting in 35 preanal and 8 postanal.

(d) Systematics

The present eggs and postlarvae were available in plankton from February to April 1978; and mature as well as partly spent specimens were collected at Porto Novo during the same period. Mature specimens examined have revealed that just before ripeness ovarian ova ranged in diameters from 0.45 to 0.51 mm. In sardine eggs, at mature and ripe conditions egg capsule and perivitelline space are absent; and only after the ova come into contact with water that the egg capsule develops and gradually increases in size, thus giving rise to perivitelline space(vide: Miller, 1952). The size of yolk and its other characters in early stages of development remain the same as that of ripe ova; and hence similarities in size, shape and other characters between ripe ova and yolk of eggs in early stages could be of diagnostic value. Based on such considerations, the present eggs could be assigned to S.clupeoides. This was confirmed by the number and disposition of myotomes in larvae hatching out of the eggs as well as in postlarvae collected. In 3.65 and 4.5 mm larvae obtained by hatching out eggs in the laboratory, there were 38 preanal and 5 postanal as well as 37 preanal and 6 postanal myotomes respectively, making a total of 43. In adults of this species examined at Porto Novo there were 28 to 29 preanal and 14 to 15 postanal vertebrae, making a total count of 43, as also found by Delsman (1926 c). It may be noted in this connection that disposition of myotomes in larval and postlarval development of Clupeiform fishes undergoes a change consequent on forward movement of anus.

Delsman (1926 c) while commenting upon certain unidentified eggs, "e and f", opined that they might belong to Clupea clupeoides, C.sirm or C. longiceps. Of these, "f" measured 2 mm with diameter of yolk amounting to 1 mm and an oilglobule was absent in it. John (1951) assigned certain eggs measuring 2.12 mm and without oilglobule and larvae having 37 preanal and 6 postanal myotomes from Madras coast to Sardinella sirm which showed similarities to egg "f" of Delsman (1926 c), thus indicating that the latter was only that of S.sirm. The egg "e" dealt with by Delsman (op.cit) measured about 1.75 mm and contained 4 - 6 small oilglobules. In the absence of adequate data it is rather difficult to comment upon the identity of the above egg; but, it may be pointed out that in the eggs of Sardinella an oilglobule may be either absent or usually only one may be present. As such, the possibility of egg "c" belonging to a species of Sardinella is rather doubtful.

Eggs of S.clupeoides could be differentiated from those of S.fimbriata (Delsman, 1926 c) by the fact that in the latter the diameters ranged from 1.4 to 1.55 mm and yolk measured about 0.8 mm with an oilglobule of 0.1 mm. The eggs assigned to Clupea leiogaster by Delsman (op.cit) varied from 1.42 to 1.63 mm with the yolk measuring about 1 mm; and they did not contain an oilglobule. Eggs of C.perforata (S.albella, vide: Whitehead, 1972) (Delsman, 1933 c) did not exceed 1.1 mm and had contained an oilglobule of 0.075 mm. Eggs assigned by Nair,R.V.(1960 a) and UNDP/FAO(1976 a) to S.longiceps are much larger and had an oilglobule. Similarly, eggs of S.gibbosa (Bensam, 1970) were smaller in size measuring 0.589 to 0.749 mm, yolk measured 0.577 to 0.599 mm and had an oilglobule. Such characters could be utilized to separate the eggs of S.clupeoides from those of other species of Sardinella, described so far.

Nair,R.V. (1960 a) while commenting on the eggs identified by John (1951) as of S.sirm and by Chacko and Mathew (1956) as of S.albella appears to have treated Clupea leiogaster and S.sirm as synonyms;

and this author as well as Bensam (1970) treated C. brachysoma and S.albella as synonyms. But, the recent work of Whitehead (1972) shows that Clupea brachysoma (Sardinella brachysoma), S.sirm and S.leiogaster are separate species and that only C.perforata is synonymous with S.albella. As such, identification of certain eggs by John (1951) as of S.sirm and by Chacko and Mathew (1956) as of S.albella could be fairly correct.

The 3.65 and 4.5 mm larvae of S.clupeoides could be compared to similar stages of S.fimbriata, S. leiogaster, S.sirm, S.albella, S.longiceps and S.gibbosa (Delsman, 1926 c; 1933 c; John, 1951; Nair,R.V., 1960a; Bensam, 1970; UNDP/FAO, 1976 a). Larvae of S.clupeoides could be distinguished from those of S.fimbriata, S. albella, S.longiceps and S.gibbosa in the absence of an oilglobule. The 4.5 mm larva of S.clupeoides has many features in common with a similar stage given by Delsman (1926 c, Fig 17) as of S.leiogaster; but pigmentation in S.clupeoides appears to be more and the number of preanal myotomes is one less than in S.leiogaster. In the larva obtained from egg "f" assigned to S.sirm (vide: John, 1951), number of preanal myotomes was considerably more, amounting to 39 in 5 mm stage. In 3.4 and 3.6 mm larvae of S.longiceps reported by UNDP/FAO (1976 a) there are 40 - 41 preanal and about 7 postanal myotomes. Such features could be used to distinguish larval stages of these species.

Based on the stage of development of caudal fin and other features of developmental sequences, 10.27 mm postlarva of S.clupeoides could be compared to 5.36 and 6.72 mm stages of S.gibbosa(Bensam, 1970). The distinct feature of difference between the two was the lesser pace of development in S.clupeoides than in the other. Preanal myotomes in S.clupeoides is 37 while in S.gibbosa it is only 33. A comparison of 13.18 mm postlarva of the former with 9.92 - 13.45 mm stages of latter similarly reveals a higher preanal myotome number in S.clupeoides (35) and lower number in S.gibbosa (30). Also, the comparison shows lack of pigmentation at the base of upper caudal lobe in the postlarvae of S.clupeoides. But for progressive development of pelvic fin, 18.7 mm postlarva of S.dayi (Bensam, 1973) could be compared to 13.18 mm stage of S.clupeoides; and distinguished from each other by difference in disposition and number of myotomes, which is 34 preanal and 12 postanal in S.dayi but 35 preanal and 8 postanal in S.clupeoides. Postlarvae of S.longiceps described by UNDP/FAO (1976 a) ranging from 4 to 17.6 mm contain 38 - 40 preanal and 7 - 9 postanal myotomes.

3. 2. 3 Sardinella sirm (Walbaum)

Sardinella sirm is one of the three species belonging to the subgenus Amblygaster, the other two being S.clupeoides and S.leiogaster (Whitehead, 1972). This species could be easily distinguished from the other two in having a series of ten to twenty dark, blue spots along the flanks. It is widely distributed in Indo-Pacific; and in India it is often found in fishermen's catches of sardines, particularly along south-east coast. Notes on general biology of the species are given by Nair,R.V.(1960 b), Ronquillo(1960); on age and growth by Gnanamekalai (1964) and eggs and early larvae by John (1951). No information is available so far on postlarval development of this fish.

(a) Postlarvae (Figs 17 - 19)

10.46 mm (Fig 17):- Date of collection was 30 -9 -'77. Head was 6.3 and body depth 8.3 in total length, body depth being almost uniform but for postanal region and head. Lower jaw was slightly longer than upper which had a few conical teeth. Two pigment spots were present in auditory region. Pectoral fin was semicircular with indications of rays. Dorsal fin has developed between 24th and 29th preanal myotomes, with about 15 rays. A pigment spot was noticed above anal region. Anal fin has developed between first and seventh postanal myotomes with indications of about twelve rays. Caudal fin was prominent and forked, with about 18 rays. Preanal length was 69.6 % and predorsal length 54.2 % of total length. There were 42 myotomes, 31 preanal and 11 postanal.

<u>13.47 mm</u> (Fig 18):- Date of collection was 15 -9 -'78.

Apart from increase in length, the significant changes noted in this stage over the previous were an increase in pigmentation, development of ventral fin and change in disposition of myotomes. Head and body depth have become more prominent, being 4.1 and 7.8 in total length respectively. The two pigment spots observed in auditory region earlier have become more prominent and a pigment has appeared in the region of isthmus. A series of five pigment streaks has appeared in post-pectoral region. The anal pigment has become more prominent and infront of it four sunken pigments have appeared. In postanal region there was a partly branching chromatophore at middle of anal fin, a sunken pigmented area behind it and one sunken pigment each above and below the end of vertebral column.
At the base of lower caudal lobe there was a group of pigments. Pectoral fin has become more prominent

and pelvic fin was indicated with about six rays. Dorso-ventral foldings of inner wall of alimentary canal could be seen prominently. Dorsal and anal fins have become more prominent, with about 15 and 16 rays respectively. About 20 rays could be counted in caudal fin. Preanal and predorsal proportions have decreased to 68.3 % and 52.2 % of total length respectively. There were 28 preanal and 14 postanal myotomes.

14.14 mm (Fig 19):- Date of collection was 30 -7 -'77. This stage did not show much change from the previous one. There was a slight increase in pigmentation in foregut region and a zone of pigments has appeared in midgut region. Preanal and predorsal proportions have become further reduced to 66 % and 50.6 % of total length respectively. Number and disposition of myotomes remained the same as in previous stage.

(b) Systematics

Among the many species of *Sardinella*, *S.sirm* alone has a vertebral number amounting to 42, while *S.leiogaster* and *S.clupeoides* have 43 each. The 10.27 mm stage of *S.clupeoides* dealt with in the present thesis (*vide*: 3. 2. 2) may be considered to be of a comparable length as 10.46 mm postlarva of *S.sirm*. Apart from the considerably less advanced developmental

PLATE III

Figures 17 - 19. Postlarval stages of *Sardinella sirm*:

Fig 17. 10.46 mm; Fig 18. 13.47 mm; and Fig 19. 14.14 mm.

Figures 20 - 26. Eggs and postlarvae of *Sardinella fimbriata*:

Figs 20 - 23. Four stages in development of the egg;

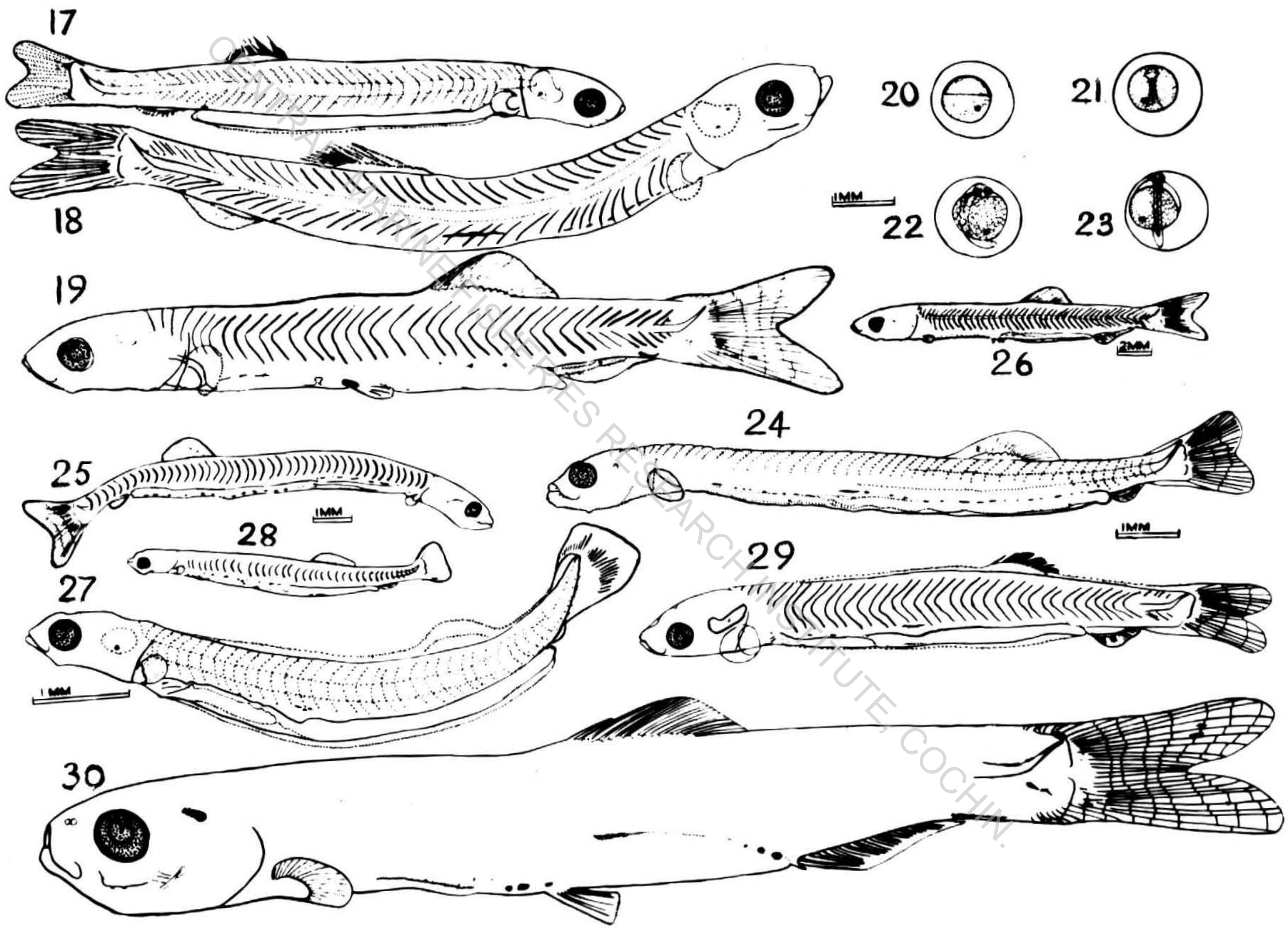
Figs 24 - 26. Postlarvae, Fig 24. 11.43 mm; Fig 25. 12.3 mm; and

Fig 26. 21.5 mm.

Figures 27 - 30. Postlarvae and juvenile of *Sardinella albella*:

Figs 27 - 29. Postlarvae, Fig 27. 6.64 mm; Fig 28. 8.45 mm;

Fig 29. 11.00 mm; Fig 30. Juvenile, 19 mm.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sequence of the former as may be seen from more slender body, club shaped caudal fin, etc, the number of preanal myotomes in the former was 37 while in the latter it was only 31. Similarly, 13.18 mm postlarva of S. clupeoides comparable to 13.47 mm stage of S.sirm, differs from it in having 35 preanal myotomes as against 28 in the latter. Also, the shorter series of pigmentation in foregut region, presence of sunken pigments in hindgut behind anal fin and absence of pigmentation at the base of lower caudal lobe could be used to segregate the two comparable stages. Besides, pelvic fin in the postlarva of S.sirm was fairly well developed when compared to the condition in S.clupeoides.

Delsman (1926 c, Figs 28 - 30) described certain postlarvae and expressed the opinion that based on number and disposition of myotomes they could be assigned to S.fimbriata. Total number of myotomes in these as well as in 9, 11.5 and 16 mm postlarvae described by Delsman (op.cit), ranging from 43 to 44, suggests that these probably belong to a clupeoid species having a similar number of vertebrae such as Sardinella brachysoma, S.leiogaster, S.clupeoides, Hilsa kanagurta, H.kelee, etc. John (1951) appears to have identified the eggs of S.sirm from Madras.

The larva hatching out of the egg is comparatively large measuring 6.5 mm with 37 preanal and 6 postanal myotomes. Even in 24 hours old stage the number and disposition of myotomes remained the same as above.

In its developmental sequence, the 10.46 mm postlarva of S.sirm could be compared to 11 mm postlarva of S.fimbriata (Delsman, 1926 c) and 9.92 mm stage of S.gibbosa (Bensam, 1970). The distinct character by which the postlarva of S.sirm could be separated from the other two is the number and disposition of myotomes, which is 31 preanal and 11 postanal in S.sirm, 33 preanal and 13 postanal in S.fimbriata and 30 preanal and 15 postanal in S.gibbosa. Apart from this, a series of pigments was observed in the anterior part of alimentary canal in S.fimbriata but an almost continuous series in the whole region of it in S.gibbosa. The 13.47 and and 14.14 mm postlarvae of S.sirm comparable to 13.45 and 18.70 mm postlarvae of S.gibbosa (Bensam, 1970) and S.dayi (Bensam, 1973) respectively differ from them in the number as well as disposition of myotomes. Also, the 17.72 mm postlarva of Kowala coval (Bensam, 1971 a) and 12.8 and 15.57 mm postlarvae of Anodontostoma chacunda (Bensam, 1971 b) could be distinguished from 13.47 and 14.14 mm stages of S.sirm in that there are 28 preanal and 12 postanal myotomes in K.coval and 30 preanal and 11 postanal myotomes in A.chacunda, as against 28 preanal and 14 postanal myotomes in S.sirm.

In having a lower number of myotomes, postlarvae of S.sirm might resemble those of Thryssa and Stolephorus (Delsman, 1929 a; 1931 a); but, the former could be easily distinguished from the latter cases in that in advanced postlarval development post-larvae of Thryssa and Stolephorus would have only 17 to 24 preanal myotomes resembling adult condition. Besides, at advanced developmental stages the mouth in Thryssa and Stolephorus would have assumed the characteristic inferior position with a prominent snout, rather than the feature noticed in sardines with lower jaw surpassing upper.

3. 2. 4 Sardinella fimbriata (Valenciennes)

Popularly called 'fringe-scale sardine', this is another clupeoid widely distributed in Indo-Pacific and contributing to fisheries of some importance in many maritime localities. In India it is found in sardine catches along both east and west coasts. General biology of this species is dealt with by Nair, R.V. (1960 b), Ronquillo (1960) and Radhakrishnan

(1967). Delsman (1926 c) has described eggs, larvae and postlarvae presumed to be of this species from Java coast. Notes on juveniles are given by Dharmamba (1967). A perusal of literature shows* that so far no comprehensive account of its eggs and larvae was reported from India; as such, an account of the same based on material collected at Porto Novo is given in the present section.

(a) Eggs (Figs 20 - 23)

Eggs identified as of S.fimbriata were collected on a single day, 4 -4 -'78 from plankton. They were pelagic, spherical, transparent and varied in diameters from 1.36 to 1.41 mm. Yolk was vacuolated and ranged in diameters from 0.80 to 0.89 mm. A single golden yellow oilglobule of 0.102 to 0.109 mm diameter was present. Perivitelline space was wide.

Four stages in embryonic development were observed in the collections. In the earliest one examined at 7.30 hr (Fig 20) embryo was not yet indicated, but blastoderm was growing over yolk mass. In the next stage studied at 09.00 hr (Fig 21), embryo was indicated, optic vesicles were formed and a few myosepta could be made out in anterior region. In another egg observed at 13.00 hr (Fig 22) embryo was fairly well formed, optic capsules have developed

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* Bapat(1955) and Venkataramanujam(1975a) assigned eggs almost similar to the present ones to this species. But, adequate information on development and systematics, including postlarvae from India is not available.

but tail region was not fully indicated. In still another egg at 16.00 hr the same day (Fig 23) tail region was in a more advanced stage of development and auditory capsules could be seen. None of the eggs reared in the laboratory hatched out the next day; but were found in dead condition.

(b) Postlarvae (Figs 24 - 26)

11.43 mm (Fig 24):- Date of collection was 23 -10 -'77.

This stage had an almost uniformly elongated body but for snout and postanal region. Larval finfold has disappeared, lower jaw was a little longer than upper jaw which was provided with a few conical teeth. Pectoral fin remained as a membraneous fan shaped structure behind opercular region. Dorsal fin has appeared as a triangular structure above 27th to 36th preanal myotomes, far behind middle region of body, with about 11 rays. Caudal fin showed an early stage of bifurcation, with about 20 ray elements. Anal fin with rays not quite distinct has developed below 1st to 5th postanal myotomes. There was a series of black pigment streaks above alimentary canal, covering almost all of its length. In midgut region and above anus the streaks were more prominent. Three pigment spots were present ventrally towards the end of foregut and a single one near vent. In caudal fin a few black pigment streaks were observed at the base of lower caudal lobe and a couple of spots in middle region. Preanal length was 88.5 % and predorsal length 58.7 % of total length. There were 39 preanal and 7 postanal myotomes, the total number corresponding to adult vertebral condition.

12.3 mm (Fig 25):- Date of collection was 18 -2 -'78.

Apart from a little increase in length registered over previous stage, the principal change noted in the present one was the movement of pigments in mid- and hind- gut regions to a ventral position. But pigments above vent and the series above foregut region remained in the same position as in previous stage; and pigmentation in caudal fin has become more prominent. About 15 and 20 rays could be counted in dorsal and caudal fins. Pelvic fin has not yet made its appearance. Preanal length was 76.4 % and predorsal length 57.7 % of total length. Number and disposition of myotomes in this stage remained the same as in previous one.

21.5 mm (Fig 26):- Date of collection was 5 -8 -'77.

Body has become more massive and deeper. Dorsal fin has moved considerably forward, occupying almost middle region and it contained about 21 rays. There were about 36 ray elements in caudal fin and about 21 in anal. Ventral fin has made its appearance in the form of about six rays at the end of foregut region. Pigmentation was mostly in the form of black spots along ventral side of body, at the base of upper and lower caudal lobes and at the base of lower caudal peduncle. In head region there was a sunken pigment behind eye and another one infront of operculum. Inner wall of mid- and hind- gut showed dorso-ventral foldings. Preanal length was 67.7 % and predorsal length 46.8 % of total length. Disposition of myotomes has changed to 33 preanal and 13 postanal.

(c) Systematics

The only other sardine which has an overall egg diameter similar to that of S.fimbriata* is S.longiceps. At Porto Novo this species was not observed during the present study, thus minimising the possibility that these eggs could be of the latter species. Besides, size of yolk in the eggs of S.longiceps should not be less than 1 mm (Devanesan, 1943) while it is only in S.fimbriata that the yolk is about 0.8 mm in diameter, as observed by Delsman (1926 c) also. Eggs assigned by Delsman (op.cit) to Clupea (Sardinella) fimbriata ranged in overall diameters from 1.4 to 1.55 mm with yolk of about 0.8 mm diameter and oilglobule of about 0.1 mm. Delsman (op.cit) has confirmed his identification

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* Bapat(1955) and Venkataramanujam(1975a) have collected eggs almost similar to the present ones and assigned them to S.fimbriata.

by pointing out similarities in vertebral number of adults and myotome number of larvae hatching out. Eggs of Clupea perforata (Sardinella albella, vide: Whitehead, 1972) described by Delsman (1933 c) were of 1.1 mm diameter, yolk measured about 0.57 mm in diameter and the colourless oilglobule was of 0.075 mm diameter. Eggs of S.albella studied by Chacko and Mathew (1956) ranged in overall diameters from 1.0 to 1.2 mm, yolk measured 0.94 to 0.98 mm and oilglobule measured 0.1 mm. Eggs of another closely allied species, Sardinella jussieu (S.gibbosa) (Bensam, 1970) were of 0.589 to 0.749 mm in overall diameter, yolk measured 0.577 to 0.599 mm and oilglobule measured 0.12 mm. In view of these distinct differences among the eggs of species related to S.fimbriata, there does not appear to be adequate ground for questioning the identity of present eggs as those of S.fimbriata.

Although the attempt to hatch out the eggs in the laboratory did not meet with success, the three postlarvae provide some stages in further development of this fish. The 5.5 mm postlarva assigned by Delsman (1926 c) to this species contained 39 preanal and about 8 postanal myotomes. The 7.7, 11, 13.5 and 14.25 mm postlarvae described by Delsman (op.cit). contained only 31 to 35 preanal myotomes and 9 to 12 postanal myotomes; and, as stated by him, total number of myotomes in these do not correspond with adult vertebral number, thus pointing out that these could not belong to S.fimbriata. But, 22 and 27.5 mm postlarvae described by Delsman (op.cit) had 34 preanal and about 12 or 13 postanal myotomes, total number corresponding with adult vertebral number and thus confirming his identification.

Among postlarvae in the present account, 21.5 mm stage could be compared to 22 mm larva described by Delsman (1926 c). There were 33 preanal and 13 postanal myotomes in former and 34 preanal and 12 - 13 postanal in latter; and the total number as wellas general disposition of myotomes in the two agree with each other. Also, but for presence of preventral pigmentation in the former, the general pattern of pigmentation appears to be the same in both cases. It may be noted in this connection that in 27.5 mm postlarva described by Delsman (op.cit) preventral pigmentation appears to be absent.

In total number of myotomes, postlarvae of S.fimbriata may be said to resemble those of S.gibbosa, S.dayi and S.longiceps, the vertebral numbers of which are 44 - 46, 46 and 46 - 48 respectively. Of these, 11.43 mm postlarva of S.fimbriata in the same developmental sequence as 9.92 mm stage of S.gibbosa (Bensam, 1970) differ from each other in that in the former there are 39 preanal and 7 postanal myotomes while in the latter there are 30 preanal and 15 postanal myotomes. The former, even if compared to 13.45 mm postlarva of S.gibbosa shows difference in disposition of myotomes. Also, between 21.5 mm postlarva of S. fimbriata and 22.24 mm postlarva of S.gibbosa (Bensam, 1970), the main feature of difference is number and disposition of myotomes which is 33 preanal + 13 postanal in S.fimbriata but 29 preanal + 16 postanal in S.gibbosa.

Between S.fimbriata and S.dayi, 21.5 mm postlarva of the former may be compared to 18.70 and 20.25 mm postlarva of latter (Bensam, 1973). One fact which appears striking is that in some developing features postlarvae of S.dayi show a quicker pace of development than those of S.fimbriata. For instance, development of ventral fin in S.fimbriata appears to be delayed because 12.3 mm stage comparable to 18.70 mm postlarva of S.dayi does not show ventral fin at all. Infact, only 21.5 mm postlarva of S.fimbriata which is an advanced stage almost reaching juvenile condition, shows the sign of ventral fin. And, but for development of ventral fin, 18.70 and 20.25 mm postlarvae of S.dayi may be said to be in the same stage of development as

11.43 and 12.3 mm postlarvae of S.fimbriata. Also, disposition of myotomes in postlarvae of S.dayi amounting to 34 preanal + 12 postanal in 18.70 mm and 32 preanal + 14 postanal in 20.25 mm show a quicker pace of development than in S.fimbriata. It appears from the above facts that but for development of ventral fin and quicker forward movement of vent, other general developmental sequences in S.dayi appear to be more delayed than in S.gibbosa and S.fimbriata.

Nair,R.V.(1960 a) has described eggs and larvae assigned to S.longiceps. Yolk in the above eggs is stated to be of an "average diameter of 0.85 mm", whereas in gonadial Stage V condition a few eggs are stated to "have become ripe and show a modal diameter of 51 - 52 micrometer divisions (1.00 - 1.02 mm)"; and in Stage VI condition the ripe ovarian ova are stated to have "a modal diameter of 49 - 50 micrometer divisions (0.96 - 0.98 mm)". Raja (1969) while dealing with ripe ova of this species states the minimum diameter as 0.90 mm and maximum as 1.23 mm. The present writer had during 1960 - 1964, found ripe ova of S.longiceps to be of 1.01 to 1.19 mm in diameter. As stated earlier, in the development of sardine eggs, the ripe ova on being shed into water, get hydrated and egg capsule develops from the ovum and swells up in diameter;

but the size of ovum forming the yolk remains the same (vide: Southwell and Prashad, 1918; Jones,S. and Menon, 1951 a; Miller, 1952) and is of diagnostic value in identification of planktonic eggs in early stages of development. Size of ripe ova of S.longiceps as given by Nair,R.V.(op.cit) and others and the size of ovum in planktonic eggs in early development given by him are different from each other. This contradiction throws doubt on specific identity of the eggs and larvae dealt with by Nair,R.V.(1960 a); and the eggs described by him appear to belong to S.fimbriata and not to S.longiceps. UNDP/FAO (1976 a) have given an account of eggs of S.longiceps, with diameters in the range of 1.02 - 1.4 mm. But, neither the size range of yolk in early development nor figures of eggs are given, which could have facilitated a comparative study. In their developmental sequence, 11.43 mm postlarva in present collections may be compared to 13.1 mm of S. longiceps, given by the above authors. But, the former differs from latter in having only 7 postanal myotomes as against 8, 88.5 % of preanal proportion as against only 81 %, only 12.7 % of head length in total as against 16.6 %, appearance of bifurcation of caudal as against club shaped condition and less prominent pigmentation. In 12.3 mm postlarva of S.fimbriata from the present collections, pigment spots in mid- and hind- gut regions have occupied a ventral position whereas even in 13.1 mm postlarva of S.longiceps described by UNDP/FAO (op.cit), pigments have still occupied a dorsal position. Such features can be used to separate postlarvae of these two species.

3. 2. 5 Sardinella albella (Valenciennes)

Like many other species of Sardinella, this species is widely distributed in Indo-Pacific and supports coastal fisheries in many centres. Earlier work from India is on its fishery and biology by Sekharan (1955) and Chacko and Mathew (1956), synopsis of its fishery and biology by Nair,R.V.(1960 b) on maturity and spawning by Radhakrishnan (1961) and on food by Sekharan (1971). Delsman (1933 c) has given an account of its eggs and early larvae from Java coast; and in the present section a few of its postlarval stages and an early juvenile are described.

(a) Postlarvae (Figs 27 - 29)

6.64 mm (Fig 27):- Date of collection was 30 -9 -'77.

This stage showed remnants of larval finfold and body was fairly wide in middle, tapering gradually towards head region. Jaws appeared somewhat pointed, lower one longer than upper and the latter with minute conical teeth. Eyes were pigmented black and pectoral fin was membraneous and semicircular. Dorsal fin has developed above 24th to 31st preanal myotomes with indications of many rays. Caudal fin was rather paddle shaped with many rays under development. Pigmentation was rather sparse and consisted of a spot in oesophageal region, a group of three sunken ones above midgut and three spots in hindgut region, two above and one below. Preanal length was 84.8 % and predorsal length 62 % of total. There were 33 preanal and 10 postanal myotomes, total number corresponding with adult vertebral number.

<u>8.45 mm</u> (Fig 28):- Date of collection: 1 -10 -'77.

Larval finfold was much more reduced in this stage than in previous one. Body has become somewhat streamlined and caudal fin showed beginning of bifurcation. Pectoral fin continued to be membraneous and semicircular. Dorsal fin has moved forward and occupied a position above 23rd to 29th preanal myotomes. Anal fin was situated below 1st to 5th postanal myotomes. Precise number of rays in none of the fins could be made out fairly well. Pigmentation in foregut appeared to have increased and was in the form of a series of six spots. Preanal length was 78.7 % and predorsal length 56.1 % of total length. Number of preanal myotomes has decreased to 32 and of postanal myotomes increased to 11.

11.00 mm (Fig 29):- Date of collection: 10 -10 -'77.

This stage represented a transitional one between early postlarval condition and later ones. The slender body of early postlarva has changed to a deep and more massive one. Maxillary bone was formed and pectoral fin still remained membraneous and semicircular. Dorsal fin occupied almost the same level as in previous stage but anal fin has extended below 1st to 7th postanal myotomes. Caudal fin has become forked. There were about 11 dorsal and 20 caudal rays, the latter showing 3 to 4 segments. Number of rays in pectoral and anal fins was not quite distinct. There was some reduction in pigmentation of foregut when compared to previous stage; but, a pigment has appeared in post-optic region. Preanal length was 71.4 % and predorsal length 55.6 % of total length. Number and disposition of myotomes remained the same as in previous stage.

(b) Juvenile (Fig 30)

A single early juvenile stage measuring 19 mm was collected from mouth of Vellar Estuary on

30 -9 -'77. Body has become much more massive and assumed a sardine-like appearance, although the characteristic morphometric features of adults have not yet been formed. Pectoral fin has become somewhat fan shaped and about 16 striations could be counted in it representing elements of future rays. Dorsal fin has moved much more forward than in previous stage and occupied a position above 19th to 28th preanal myotomes. Caudal fin had about 40 ray-elements, most of which 2 - 9 segmented. Anal fin has become longer and showed about 21 rays. Pelvic fin has developed, occupying a level a little infront of level of origin of dorsal. It contained about 6 rays. Pigmentation was in the form of a sunken area behind eye, a continuous streak behind pectoral, two small spots behind it, two large branching chromatophores infront of pelvic region, a sunken spot behind them, a series of three branching chromatophores in anal region, a sunken area behind anal fin, four sunken pigments in caudal peduncular region, one branching chromatophore at the base of upper caudal region, a few streaks at the base of lower caudal and two pigments in upper caudal lobe posteriorly. Preanal and predorsal proportions have decreased to 62 % and 42.3 % of total length respectively. There was a further decrease in number

of preanal myotomes to 29 and a corresponding increase in postanal number to 14, the disposition approaching adult vertebral condition of 27 preanal and 16 postanal.

(c) Systematics

As judged by presence of mature and spent specimens in the fishery, S.albella was observed to spawn off Porto Novo during April - May to September - October. Delsman (1933 c) came across certain eggs smaller than those of Clupea fimbriata and assigned them to C.perforata (S.albella, vide: Whitehead, 1972). Larvae hatching out of these eggs had 37 preanal and 7 to 9 postanal myotomes. Delsman (op.cit) while dealing with vertebral numbers of a sample of sardines from Java coast, divides it into three groups based on number of postventral scutes and of vertebrae. In the first group with 13 postventral scutes, there are 26 to 27 preanal and 16 to 17 postanal vertebrae, whereas in other groups vertebrae are more in number amounting to a total of 45 to 46. Commenting on such a variation, Delsman (op.cit) has doubted the presence of a related species with a more number of total vertebral count; and in this connection he has pointed out the urgency of reexamining the question of number of sardine species and/or races belonging to the genus Clupea (Sardinella). In a recent synopsis of various species in this genus, Whitehead (1972) lists 17 species as occurring in Indo-Pacific region, not to mention of other genera considered under Clupea from this region earlier. As such, specific identity of eggs assigned by Delsman (op.cit) may be questioned, particularly because of the presence of 44 to 46 myotomes in the larvae from them. Chacko and Mathew (1956) have given an account of embryonic and larval development of S.albella from south-west coast of India. They have found 27 preanal and 3 postanal myotomes in newly hatched larva, but 37 preanal and 5 postanal myotomes in a more advanced stage, the total myotome number almost amounting to adult vertebral number. UNDP/FAO (1976 a) give a vertebral number of 45 for both S.fimbriata and S.albella from south-west coast of India as against 42 - 43 in samples examined at Tuticorin (Bensam, 1973) and at Porto Novo, in south-east coast. Hence, it remains to be shown as to whether S.albella occurring along south-east and south-west coasts of India belong to two different stocks with differential vertebral ranges.

Postlarvae of S.albella could be compared to those of allied species described, viz., S.gibbosa (Bensam, 1970), S.dayi (Bensam, 1973), S.clupeoides (vide: 3. 2. 2), S.sirm (vide: 3. 2. 3) and S. fimbriata (vide: 3. 2. 4). Number of myotomes in postlarvae of S.gibbosa, S.dayi and S.fimbriata should be much more than in those of S.albella. Thus, for instance 6.64 postlarva of S.albella has 33 preanal and 9 postanal myotomes while in 6.72 mm of S.gibbosa there are 33 preanal and 12 postanal myotomes. Juvenile stages of these species also exhibit differences in number and disposition of myotomes: 19 mm of S.albella with 29 preanal + 13 postanal could be differentiated from 22.24, 28 and 21.5 mm juveniles of S.gibbosa, S.dayi and S.fimbriata with 29 + 16, 34 + 12 and 33 + 13 myotome numbers respectively. S.sirm and S.clupeoides have total vertebral number of 42 - 43; but, disposition of myotomes differs with varying stages of development. In newly hatched larva of S.sirm of 6.5 mm dealt with by John (1951) 37 preanal and 6 postanal myotomes are present, such a condition persisting even after 24 hours. But, in 6.64 mm stage of S.albella disposition of myotomes is 33 preanal and 10 postanal. In S. clupeoides also the early larva has 38 + 5 myotomes; and 10.27 and 13.18 mm postlarvae have 37 + 6 and 35 + 8 myotomes respectively.

Among other clupeoids, postlarvae of Kowala coval (Bensam, 1971 a) differ from those of S. albella in having only 40 total number of myotomes and postlarvae of Anodontostoma chacunda (Bensam, 1971 b) in having only 41. Apart from this basic difference, variations also do exist in sequences of development. In having a total of 43 myotomes the early postlarvae resemble those of Hilsa kelee described by Rao, K.S. (1973). But, these two could be differentiated from one another by the fact that in postlarvae of H.kelee continuous series of pigments are present along dorsal as well as ventral aspects of alimentary canal. Such a pattern is absent in early postlarvae of S.albella.

3. 2. 6 Ilisha melastoma (Schneider)

Ilisha melastoma has a widely recorded distribution in Indo-Pacific, including Sri Lanka, Andamans, Singapore, Sumatra, etc. In India it is known to occur along both east and west coasts including estuaries. No information is available so far on early development of this fish; and in the present section a few postlarvae are described.

(a) Postlarvae (Figs 31 - 34)

5.61 mm (Fig 31):- Date of collection: 1 -2 -'78. The specimen was in an early stage, with remnants of larval finfold. Body was almost of uniform depth except in postanal region. Mouth was well developed and somewhat terminal in position. Eyes were pigmented black and pectoral fin was membraneous and fan shaped. Caudal region was somewhat oval, without indications of rays. Dorsal and anal fins were not yet indicated. Pigmentation consisted of three spots in foregut and two in hindgut. There were 36 preanal and about 8 postanal myotomes. Preanal length was 84.6 % of total. From various early developmental features, it was obvious that this stage was not much older than a late larval condition.

8.67 mm (Fig 32):- Date of collection: 3 -1 -'78.

Body was elongated and larval finfold has disappeared. A few minute conical teeth have appeared in upper jaw. Dorsal fin with indications of a few rays has appeared above 23rd to 30th preanal myotomes and beginning of anal fin was discernible behind vent. Caudal region appeared as a sort of wedge shaped structure with indications of a few rays. Pectoral fin has still remained membraneous and fan shaped. A series of pigment spots was present above alimentary canal and the pigment spot above vent was more prominent than others. As compared to previous stage, anus has moved forward by a single myotome, with 35 preanal and 8 postanal counts. Preanal length has decreased to 81.2 % and predorsal was 58.1 % of total.

<u>12.76 mm</u> (Fig 33):- This postlarva as well as the next one were collected on 10 -8 -'77. Significant changes noted in this stage over the previous were progressive development of anal, dorsal and caudal fins and some change in pigmentation. Body was elongated and slender and head has assumed a somewhat globular shape. Pigmentation in midgut region has partly disappeared, but in postanal region a few pigments have appeared along base of anal fin and behind it. In head, a single pigment was seen dorsally and another ventrally infront of isthumus. In caudal fin a small group of pigments was present at the base of lower caudal region. In dorsal, caudal and anal fins about 16, 20 and 15 rays respectively were present. Ventral fin has not yet made its appearance. Preanal myotome number has decreased to 31 and postanal increased to 12. Preanal and predorsal proportions have become further decreased to 71.1 % and 53.31 % of total length respectively.

<u>14.74 mm</u> (Fig 34):- The notable changes observed in this stage were formation of pelvic fin and progressive development of anal fin. The former has appeared as a projection below 19/20 preanal myotomes region with a few rays directed posteriorly. Anal fin has become a considerably long

triangular structure with its base extending from behind anus till lower end of caudal peduncle. About 18 developing rays could be counted in it. There were 15 dorsal and 30 caudal rays. Pectoral fin still remained as a membraneous, fan shaped structure, without indications of rays. Pigmentation consisted of a few streaks behind pectoral fin in foregut region, a prominent chromatophore above vent, a large branching one above hind end of anal fin, a sunken pigment behind it, three sunken ones in caudal peduncular region, two above and one below urostyle and a few pigments at the base of lower caudal lobe. Number and disposition of myotomes continued to be the same as in previuos stage. Preanal and predorsal lengths have become still further reduced to 68.5 % and 53.2 % of total respectively.

(b) Systematics

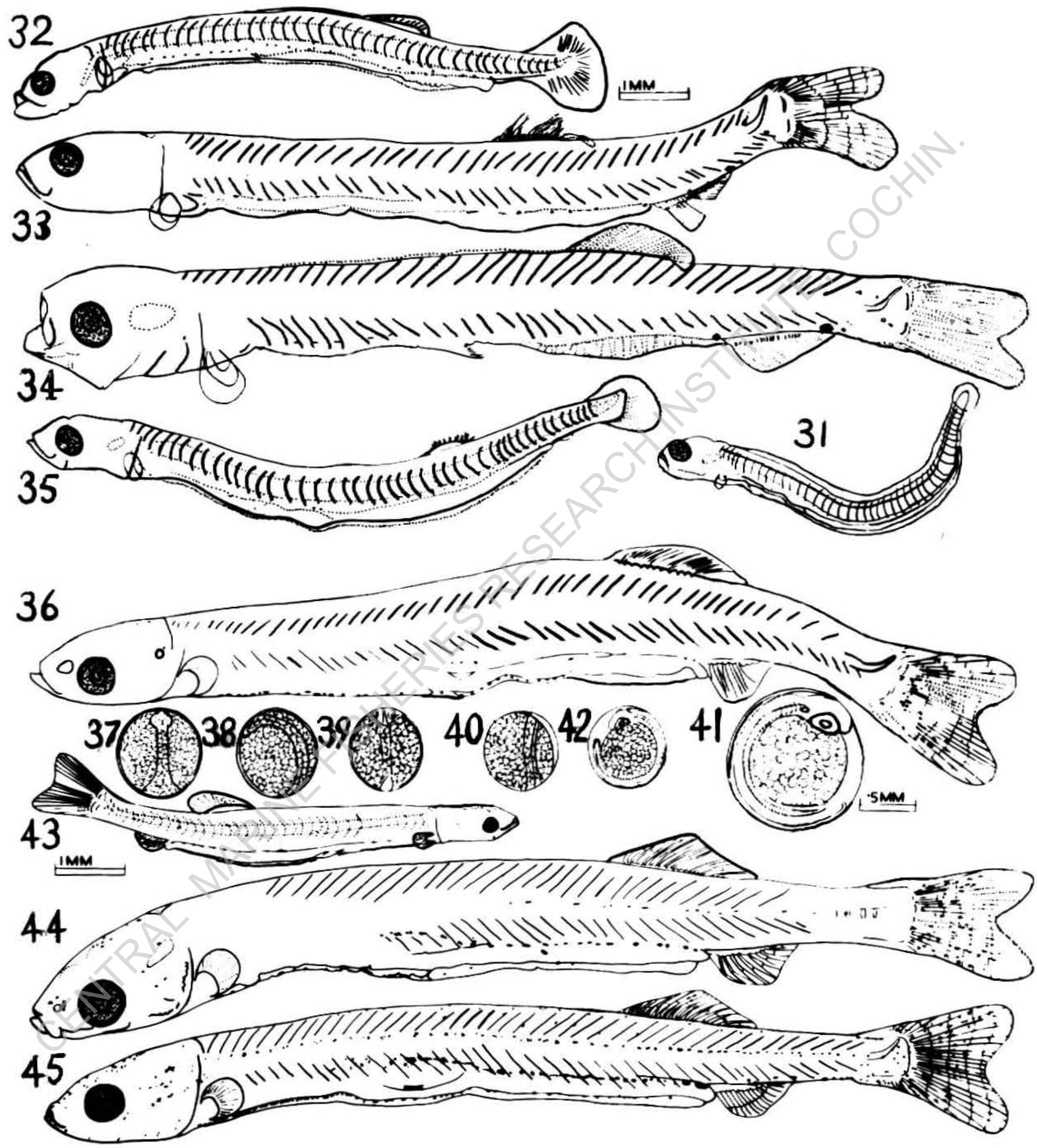
Number of vertebrae in adult I.melastoma is 20 preanal and 22 - 24 postanal, with total mean value at 43. This tallies with total number of myotomes in the present postlarvae. Besides, structure of anal fin in advanced postlarvae with fin base extending from behind anus till the base of caudal region, thus foreshadowing the condition in adults, serves to confirm the identification. Postlarvae of Kowala coval (Bensam,

PLATE IV

Figures 31 - 34. Postlarval stages of Ilisha melastoma: Fig 31. 5.61 mm; Fig 32. 8.67 mm; Fig 33. 12.76 mm; and Fig 34. 14.74 mm

Figures 35 and 36. Postlarvae of Ilisha megaloptera: Fig 35. 9.18 mm; and Fig 36. 14.45 mm.

Figures 37 - 45. Eggs and postlarvae of Chanos chanos: Figs 37 - 42. Eggs in various stages of development, Figs 37, 38 and 39. Sketches of live eggs; Figs 40, 41 and 42. Sketches of eggs in formalin; Figs 43 - 45. Postlarval stages, Fig 43. 10.5 mm; Fig 44. 14.6 mm; and Fig 45. 14.01 mm.



32
1MM
33
34
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31
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37
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40
42
41
.5MM
43
1MM
44
45

1971 a) and Anodontostoma chacunda (Bensam, 1971 b) could be distinguished from those of I.melastoma in having a smaller number of total myotomes namely 40 and 41 respectively of which 28 - 32 are preanal and 8 - 12 postanal in K.coval and 30 - 31 preanal and 10 - 11 postanal in A.chacunda, as against 31 - 36 preanal and 7 - 12 postanal in I.melastoma.

In having 43 total myotomes, postlarvae of I.melastoma may be said to resemble postlarvae of such species as Sardinella clupeoides (vide: 3. 2. 2). The 8.67 mm postlarva of I.melastoma may be compared to 10.27 mm stage of S.clupeoides. Although postlarva of the former is in a much less advanced stage of development than that of latter, number of preanal myotomes in I.melastoma is only 35 but in S.clupeoides it is 37. Similarly, 12.76 and 14.74 mm postlarvae of I.melastoma when compared to 13.18 mm stage of S. clupeoides reveals only 31 preanal myotomes in the former but 35 preanal in the latter. This is obviously related to a more rapid forward movement of anus in I. melastoma than in S.clupeoides and is also related to future position of vent in the two cases, below 20th vertebra in I.melastoma but below 28th or 29th vertebra in S.clupeoides. However, in postlarvae of S.sirm (vide: 3. 2. 3), 13.47 and 14.14 mm postlarvae show the position of vent below 28th myotome, pointing out that the pace of forward movement of vent in this case is much more quick than in I.melastoma and S.clupeoides. In such cases the elongated structure of anal fin base could be taken as a valid character in separating postlarvae of I.melastoma from those of S.sirm.

Postlarvae of I.melastoma differ from those of I.megaloptera (vide: 3. 2. 7) in having a lower number of myotomes. 8.67 mm of the former could be compared to 9.18 mm of the latter. In I.melastoma there are 39 preanal and 11 postanal myotomes. Similarly, 14.74 mm postlarva of I melastoma differs from 14.45 mm of I megaloptera in having 31 preanal + 12 postanal myotomes as against 37 preanal + 14 postanal in I. megaloptera. Besides, the pace of development of anal fin appears to be much more quick in I.melastoma than in I.megaloptera.

Delsman (1930 a) has given a description of eggs and larvae assigned to Pellona elongata, P. amblyuroptera and P.ditchoa. Among these, Delsman (op.cit) himself has stated that separation of P. elongata and P.amblyuroptera as two distinct species is very much doubtful. Of various specific names given by Delsman (op.cit) and based on the work of Whitehead (1972), about seven species appear to be valid, namely

Ilisha elongata, I.macrogaster, I.megaloptera, I. pristigasteroides, I.melastoma, I.kampeni and Pellona ditchela. Apart from descriptions of eggs and early larvae of I.elongata by Delsman (1930 a) from Java coast, Uchida (1958 a) has given an account of eggs, larvae, postlarvae and juveniles of this species from Japan. One significant fact noted in postlarval development of I.elongata given by Uchida (op.cit) is that although preanal vertebral number in this species is only 20 - 23, number of preanal myotomes in postlarvae remains as high as about 40 in 15 mm and about 36 in 17 mm, thus showing that forward movement of anus to attain adult condition in Ilisha is much delayed when compared to other clupeids having a similar number of vertebrae. For instance, in Opisthopterus tardoore (Bensam, 1968 b) which has 50 vertebrae, preanal myotome number becomes 30 in an early postlarval condition itself, measuring only 3.76 mm. As against this, a delayed forward movement of vent is observed in I.megaloptera also (vide: 3. 2. 7).

In early larval stages assigned by Delsman (1930 a) to Pellona ditchoa (I.melastoma, vide: Whitehead, 1972), myotome complement is 29 - 30 preanal and about 15 - 20 postanal. From the account given by Delsman (op.cit), another species P.hoeveni (Pellona ditchela, *vide*: Whitehead, 1972) also occurs along Java coast with 18 preanal and 24 - 25 postanal vertebrae. Although Delsman (*op.cit*) assigned the above eggs and larvae to *P.ditchoa* (*I.melastoma*), validity of this identification is not brought out cogently because of overlapping range of vertebrae in *P.ditchela*, *I.melastoma* and *I.kampeni*, all of which seem to have occurred in Java coast. It may be noted in this connection that Whitehead (1972) while mentioning about work done by various authors on different clupeoid species of India, includes descriptions of eggs and larvae made by Delsman (1930 a) under *Ilisha elongata* and *Pellona ditchela* only and not under *I. melastoma* which is the present valid name for *Pellona ditchoa*. From synonyms given by Whitehead (*op.cit*) it is obvious that most Indian authors have mistakenly considered species of *Ilisha* as those of *Pellona*. Of the species of *Pellona*, only *P.ditchela* appears to be available in Indian region. Ramaiyan (1977) has given a description of this species based on a single specimen collected at Porto Novo. But, the present writer could not collect this species at Porto Novo during 1977 - 79.

3. 2. 7 Ilisha megaloptera (Swainson)

This is a commercially important clupeoid fish found in India synonymised with Ilisha filigera (Valenciennes) (vide: Whitehead, 1972), widely distributed in Indo-Pacific and supporting minor fisheries wherever it occurs. In India it is caught in gill nets, boat seines and trawl nets. Meenakshisundaram and Marathe (1963) have mentioned about its fishery in Bombay. At Porto Novo it is found in a few numbers occasionally, although the other two species I.melastoma and I.kampeni occur more frequently. The two postlarvae reported below were collected at Porto Novo on 1 -2 -'78.

(a) Postlarvae (Figs 35, 36)

9.18 mm (Fig 35):- Body was elongated with greatest depth at region of dorsal fin. Snout was rather pointed and acute with lower jaw a little longer than upper. A few minute conical teeth were present in upper jaw. Pectoral fin was membraneous and fan shaped. Dorsal has appeared above 28th to 32nd preanal myotomes with indications of a few rays. Caudal has developed as a club shaped structure with a few rays in middle and lower regions. Anal has developed as a short, triangular extension behind anus. Pigmentation was sparse and was in the form of a few black spots on lateral side of foregut and dorsal to hindgut region. In caudal fin a few black pigment spots were observed in its upper, middle and lower aspects. There were 39 preanal and about 11 postanal myotomes. Preanal and predorsal proportions were 81.3 % and 60.6 % of total length respectively.

<u>14.45 mm</u> (Fig 36):- The significant changes noted in this stage over previous one were, apart from increase in length, an increase in pigmentation, progressive development of all fins and change in disposition of myotomes. Larval teeth present in upper jaw in previous stage seemed to have disappeared with further development, replacing the larval condition. Pectoral fin showed indications of a few rays. Dorsal has become larger, with about 14 rays. Caudal has become forked, with about 28 ray elements. Anal fin has become larger with about 7 rays; but there was no indication of pelvic fin. Pigmentation consisted of a few spots on head, one each behind isthumus and pectoral fin, an almost continuous series along ventral side of fore- and hind- guts, four sunken ones above midgut, two a little behind them, another two above anal region and two behind anal fin. In caudal fin pigmentation has increased and become diffuse, particularly at the bases of middle and lower caudal

regions. There were 37 preanal and 14 postanal myotomes; and, when compared to previous stage in which anal fin was situated far behind level of dorsal, in the present one anal fin has moved forward to a level just behind hinder end of dorsal base. Preanal and predorsal lengths have decreased to 65.4 % and 57.2 % of total respectively.

(b) Systematics

In adults the vertebral number ranged from 47 to 52 while in postlarvae there were 50 myotomes. Among different species of clupeoids occurring in Porto Novo, only one species may be said to possess a vertebral number similar to that of I.megaloptera, namely Opisthopterus tardoore which has 50 vertebrae. Eggs and larvae of the latter have been described by Bensam(1968b); and in an early postlarval condition itself, 3.76 mm, disposition of myotomes becomes 30 preanal and 20 postanal. As such , the present postlarvae with 37 - 39 preanal myotomes could not be treated as those of O.tardoore. Another species of Ilisha having a similar vertebral number namely I.elongata is not recorded at Porto Novo at all. Infact, the only Indian record of this species is that of Pellona leschenaulti Valenciennes from Pondicherry (vide: Whitehead, 1972) and there is no subsequent record of it at all from Indian waters, thus casting doubt as to its existence in India.

In larvae and postlarvae assigned to Pellona elongata (I.elongata, vide: Whitehead, 1972) by Delsman (1930 a) and Uchida (1958 a), anus is situated considerably posteriorly, unlike the condition in cases like O.tardoore (Bensam, 1968 b). Thus, in larva of "the second morning" (Delsman, op.cit), it is placed at the end of 37th myotome and in larvae described by Uchida (op.cit) anus remains below 36th or 37th myotome even in 17 mm stage. From figures and descriptions given by Uchida it is obvious that further forward movement of anus to attain the condition in adults namely 21 -23 preanal and 28 - 30 postanal vertebrae takes place in later developmental sequence only. Such a condition was observed earlier in Hilsa ilisha (Jones,S. and Menon, 1951 a) where in the newly hatched larva of 2.3 mm there are 40 preanal myotomes; and it is only in 20 mm stage that anus is placed near 29th myotome. Even in O.tardoore, although 30 preanal + 20 postanal condition of myotomes is attained at such an early stage as 3.76 mm (Bensam, 1968 b), even till 19 mm juvenile condition given by John (1951) the same disposition continues and attainment of adult condition of 17 preanal and 33 postanal myotomes appears to have been still delayed. In its developmental sequence, 9.18 and 14.45 mm postlarvae of I.megaloptera may be compared to 15 mm postlarva of I.elongata described by Uchida (1958 a). Main features of difference between the two appear to be the disposition of myotomes and developmental condition of anal fin. Postanal myotome number in I.elongata is about 15 or 16 while in I. megaloptera there are 11 - 14 postanal myotomes. Infact, in larvae and postlarvae described by Uchida (op.cit) about 55 or 56 total myotomes appear to be present, whereas Delsman (1930 a) has given the vertebral number of this species from Java coast as 50 to 51 only. It is not known as to whether number of vertebrae in Japanese specimens of this species amounts to more than 50 to 51. Apart from this, anal fin in I. megaloptera appears considerably shorter than in I. elongata and I.melastoma (vide: 3. 2. 6). It is probable that the pace of development of anal fin in I. megaloptera is much lesser than in the above two species.

Venkataramanujam(1975a) assigned certain postlarvae measuring 12 - 17 mm and having about 47 myotomes, 28 preanal and 19 postanal, to Thryssa. But, in various species of Thryssa from India there are not more than 45 total vertebrae, thus casting doubt on their identity as of Thryssa. Also, presence of as high as 19 postanal myotomes precludes their identity as of Sardinella either. From the number and disposition of myotomes in the above material, it appears as though the postlarvae might belong to a species such as Ilisha megaloptera.

(B) Family Chanidae

This Family is represented by a single genus and species Chanos chanos, popularly called Milkfish. It is mostly marine and brackish and occasionally found in freshwater; and is distributed in Indian and tropical Pacific areas. Being euryhaline and having a quick growth in the first year of its life, it is one of the most valuable culturable fishes in south-east Asian countries and is extensively cultured in Indonesia, Philippines and Taiwan. It breeds only in sea and does not attain sexual maturity in culture ponds. In view of this, the only source of its seeds for culture purposes is the naturally occurring fry centres along coastal waters, estuaries, creeks, mudflats, etc, from where it is collected for stocking operations. For details on culture of this fish, Bardach, et al (1972) may be referred to.

3. 2. 8 Chanos chanos (Forsskål)

Recently, Tampi and Bensam (1976) have reviewed biological aspects of this fish from Indian waters. Based on occurrence and availability of its fry it is inferred that the fish spawns during February - May along south-east coast of India. But, inspite of occurrence of fry in large numbers in India (Tampi, 1968), the only report on collection of its eggs from India is that of Chacko (1950) in Gulf of Mannar, based on earlier identification of Delsman (1929 b) from Java. However, detailed descriptions and figures of the material are not given by Chacko (op.cit). Recently, Chaudhuri, Juario, et al (1978) and Liao, Juario, et al (1979) have succeeded in artificial fertilization and induced spawning as well as rearing larvae in the laboratory at Philippines, thus bridging the gap in our knowledge on early life history stages. In the absence of adequate knowledge on eggs and postlarvae from Indian waters, the present account on these and a few early juvenile stages collected at Porto Novo may be of interest.

(a) Eggs (Figs 37 - 42)

A total of 18 eggs were collected from plankton off Porto Novo on 30 -1 -'78; and attempts to collect more eggs subsequently did not meet with success. They were pelagic, spherical and contained finely vacuolated light - yellowish yolk, without oilglobule. Perivitelline space was quite narrow and almost imperceptible in live, healthy eggs, but for the region of head and tail. Three representative stages in embryonic development were observed on the day of collection. In the earliest stage measuring 1.12 mm in living condition (Fig 37), embryo was in an early stage, with optic vesicles, about seven myosepta and Kupfer's vesicle. In another egg of 1.18 mm in living condition (Fig 38), embryo has assumed an almost 'C' shaped structure with progressive differentiation of trunk. In the third live egg of the same diameter (Fig 39), head, trunk and part of tail have become prominent. Optic capsules were fully formed and tail region appeared as a bud undergoing progressive development.

All sixteen eggs reared for obtaining early larvae were found on the following morning sinking to the bottom in partly dead condition. Of these, three eggs had shown some more progressive features in development. In an egg of 1.09 mm in formalin (Fig 40), dorsal side of embryo showed pigment spots. In another egg of 1.208 mm in formalin (Fig 41) auditory vesicles were visible, tail has become longer and pigment spots were observed on larval finfold and head. About 42 myosepta could be counted in this stage. Length of embryo inside egg amounted to 2.62 mm. In another egg of 1.16 mm, also in formalin (Fig 42), embryo appeared fully developed with well marked head, trunk, tail and larval finfold. Pigments were present on larval finfold and head. Length of embryo within the egg amounted to 2.74 mm in formalin.

(b) Postlarvae (Figs 43 - 46)

Three postlarvae were collected, one from plankton sampled off Porto Novo and the other two from fry collections made at the mouth of Vellar Estuary.

10.5 mm (Fig 43):- Date of collection: 27 -2 -'78.

Body was elongated and of uniform depth but for anterior and posterior regions. Snout appeared slightly flattened dorso-ventrally and mouth was somewhat terminal with lower jaw slightly longer than upper. Pectoral fin was membraneous and somewhat club shaped. Dorsal fin has developed above 22nd to 28th preanal myotomes with about 16 rays. Anal has developed below 32nd preanal and 3rd postanal myotomes with about 13 rays. Caudal was in an early stage of bifurcation, with about 20 rays. Pigmentation consisted of a few spots behind optic region, a streak before isthumus, a ventral pigment below pectoral fin, two streaks on dorsal aspect, one at ventral aspect of foregut and a series of nine pigments along dorsal aspect of hindgut. In caudal fin a few pigment spots were present at bases of upper and lower lobes.

Posterior half of alimentary canal showed dorso-ventral foldings of inner epithelium. There were 32 preanal and 11 postanal myotomes, the total number agreeing with adult vertebral number. Muscle fibres in myotomes showed a parallel arrangement and not a crossed one. Preanal and predorsal proportions were 69.7 % and 52.8 % of total length respectively.

<u>14.6 mm</u> (Fig 44):- This stage as well as the following one were collected from mouth of Vellar Estuary on 3 -3 -'78, in fry collection net. Notable changes in this over the previous were progressive development of fins and an increase in pigmentation. Maxillary bone appeared prominent. Dorsal fin had about 14 rays, anal fin about 9 and caudal about 20. Pectoral fin did not show indication of rays. A couple of chromatophores was found in snout and a few pigment spots above optic region and at the side of operculum. Along ventral aspect of alimentary canal a series of spots was present and at dorsal aspects of mid- and hind- gut a series of sunken pigments. In posterior mid-lateral region of body a few pigments were observed. Caudal fin was fairly well pigmented. Number and disposition of myotomes in this stage as well as the following one remained the same as in the previous; and muscle fibres had a parallel arrangement. Preanal and

and predorsal proportions were 67.5 % and 55.3 % of total length respectively.

14.01 mm (Figs 45, 46):- Although this postlarva appeared smaller than the previous one, more progressive developmental features particularly in pigmentation necessitate its treatment as a stage older than the previous. However, preanal and predorsal proportions were higher (69.0 % and 59.8 % respectively of total length), thus showing an earlier developmental sequence. Pigmentation has increased considerably in head including operculum, ventral aspect of alimentary canal along lateral line region, on dorsal and caudal fins and behind ventral fin. Besides, on dorsal side of head (Fig 46), above mid and hind brain a group of black, branching chromatophores was present. Also, two large pigment spots were found above vent and a row of sunken pigments along dorsal aspect of mid- and hind- gut regions. Pectoral fin still remained membraneous without indications of rays. Dorsal, anal and caudal fins have become much more developed with about 14, 12 and 24 rays respectively.

(c) Juveniles (Figs 47 - 50)

A few juveniles in size range of 16.25 - 18.5 mm were collected from mouth of Vellar Estuary on 3 -3 -'78. In 16.25 mm (Fig 47), most of postlarval features have disappeared. Body has become elongated and streamlined and head has become more pointed. Mouth although partly terminal in position, showed beginning of progressive growth of snout. Pectoral fin was still membraneous with basal region showing indications of a few rays. Origin of pelvic fin could be seen as a small triangular bud at ventral side of body below the level of origin of dorsal fin. Dorsal, anal and caudal fins contained about 14, 14 and 28 rays respectively. Pigmentation has become intensified as well as diffused, extending almost all over, including anal fin. Sunken black pigments representing peritonial wall of body cavity could be seen in mid- and hind- gut regions. Anus has further moved forward, decreasing preanal myotome number to 31 and increasing postanal number to 12. Preanal and predorsal proportions were 65.8 % and 54.9 % of total respectively. In a 16.5 mm specimen examined, pelvic fin has developed further, with about 7 rays (Fig 48).

In a 18.5 mm specimen, the snout has overgrown lower jaw (Fig 49), approaching the condition of adults. Head was 4.62 of total length, body depth 6.16 of the same, dorsal situated almost at mid dorsal region and origin of ventral below level of origin of dorsal. Pectoral fin has become more developed (Fig 50);

and, although retaining a fan shaped appearance, had about 10 rays. Dorsal fin had 16 rays, pelvic and anal fins about 10 each and caudal about 34 elements. Pigmentation has become considerably more, extending almost all over body.

(d) Systematics

Characteristic features of eggs given here in comparison with eggs identified by Delsman (1929 b) and artificially fertilized, as dealt with by Chaudhuri, Juario, et al (1978) and Liao, Juario, et al (1979) confirm the present identification. More distinct features of the eggs of *C.chanos* are the absence of oilglobule and presence of only a narrow perivitelline space and finely vacuolated condition of yolk with a light yellow tinge. Length of fully developed embryo amounting to 2.74 mm in an advanced condition (Fig **42**) is almost equivalent to the length of newly hatched larva described by Delsman (1929 b) and Chaudhuri, Juario, et al (1978). The latter authors have noted certain markings on egg capsules artificially fertilized in Philippines. Such markings were not found on capsules of present eggs.

The postlarvae described in this account could be identified as those of *C.chanos* based on parallel arrangement of muscle fibres in myotomes as well as on number and disposition of myotomes. Adult vertebral number of a few specimens examined at Porto Novo was 30 preanal and 13 postanal, as recorded by Delsman (1929 b). Senta and Kumagai (1977) while studying vertebral variations of Chanos fry collected from various parts of Indo-Pacific, have found a mean vertebral number of 43.08 in Indian specimens, but higher values in specimens from Thailand, Indonesia, Philippines and Tahiti. Based on these studies, the above authors opine that there may be atleast four sub-populations of Chanos in tropical Indo-Pacific waters.

Delsman (1926 f) has given an account of a few larvae assigned to this species from Java coast. Of these, 10 mm stage could be compared to 10.5 mm in the present account. The two stages are almost in the same stage of development with basic similarities in all essential features. The 12 mm stage given by Delsman (op.cit) may be compared to 14.6 mm, in the present collections, in the absence of any other stage of equivalent length. The only difference in the two cases is in the pattern of pigmentation which may be attributed to difference in sizes. Besides, Delsman (op.cit) has observed variations in pigmentation of Chanos larvae studied by him.

Chacko (1942) has given a note on rearing of *Chanos* larvae in laboratory. Later, Chacko (1950) has given a brief note on eggs and early larvae collected from Gulf of Mannar. Chacko and Mahadevan (1956) have collected certain eggs resembling those of *Chanos* from off Nellore; but, these are stated to be smaller in size than the ones reported by Delsman (1929 b) and hence could not be assigned to *Chanos*, according to them.

Blanco and Villadolid (1951) gave an account of a postlarva measuring 12.5 mm and a juvenile of 13.5 mm. The present postlarvae differ from 12.5 mm stage of the above authors in that development of pelvic fin in the former is delayed till about 16.5 mm, but in the material reported by the above authors pelvic fin has already developed. Another significant point of difference is that in the postlarva described by them there are "53 or more myotomes", whereas in *Chanos* there are only 43 vertebrae. Besides, the large and "oblique mouth" instead of a small and terminal mouth as in adult *Chanos* is a significant feature of difference. In 13.5 mm juvenile also fifty one myotomes are stated to be present. Mouth in this juvenile also is oblique and appears as quite large rather than terminal and small with snout rather overhanging lower jaw as in present material and adult condition. These are characteristics which are fundamentally different from those of Chanos; and hence specific identity of postlarva and juvenile dealt with by Blanco and Villadolid (1951) is open to question. Presence of "about 53 or more myotomes" reported by them points out the possibility that the material described by them could belong to Dussumieria, vertebral number of which varies from 52 to 56.

The 10.5 mm postlarva artificially bred by Liao, Juario, et al (1979) may be compared to an identical stage in the present account (Fig 43). These resemble each other in all essential features, including number and disposition of myotomes. The 14.6 mm postlarva in the present collections does not show so much pigmentation as in 12.9 and 13.3 mm stages given by them. Similar differences in pigmentation are also seen between comparable stages in the two accounts. In the present 16.25 mm juvenile lower jaw is only slightly longer than upper while in 15.9 mm artificially bred by them in Philippines, lower jaw is significantly longer than upper. Such differences between material collected at Porto Novo and obtained by induced breeding and rearing in Philippines perhaps point out to some differences in the characteristics of the two stocks.

(C) Family Engraulidae

In Indian waters this Family is composed of Stolephorus, Thryssa, Thrissina, Setipinna and Coilia and is responsible for an average annual production of about 50,000 tonnes, from both the coasts. Stolephorus contributes to bulk of the landings (about 34,000 t), supported mostly by S.heterolobus, S.devisi and S. bataviensis. Thryssa hamiltonii, T.purava, T.mystax, Thrissina baelama, Coilia dussumieri, C.ramcarti, Setipinna phasa, S.taty, etc are the other species of commercial importance.

3. 2. 9 Thryssa dussumieri (Valenciennes)

Thryssa dussumieri is one economically important anchovy found along both the coasts of India. Earlier work on this species includes occurrence of its larvae off Bombay by Bal and Pradhan (1947; 1951), food habits of young stages by Bapat and Bal (1950), from the same locality, notes on eggs and early larvae by Chacko (1950) from Gulf of Mannar and maturation and spawning off Waltair by Dharmamba (1960). But, no comprehensive account of eggs and larvae is available so far.

(a) Eggs (Figs 51 - 53)

The eggs were collected on 9 -9 -'77 from plankton. They were pelagic, spherical, measuring 0.901 - 0.98 mm in diameter and did not contain oilglobule. Yolk was vacuolated and perivitelline space was quite narrow. In the earliest stage of development measuring 0.901 mm at 09.00 hr (Fig 51), embryo was indicated with developing optic vesicles and about seven myosepta. In another egg examined at 13.00 hr, measuring 0.96 mm (Fig 52), embryo was in a more progressive stage with optic vesicles and a fairly well developed tail. In still another egg of 0.98 mm at 17.00 hr (Fig 53), the embryo may be said to be almost fully formed and ready for hatching.

(b) Larva (Fig 54)

A single egg reared on 9 -9 -'77 was found to have hatched out at 09.30 hr on following morning. From the appearance of the larva (Fig 54) it was obvious that this stage was not the newly hatched one. However, from fully formed condition of embryo in the previous evening, it appeared that the egg would have hatched out by about 21.00 hr the same night. Hence, the present larva could be taken to represent a stage of about 10 - 12 hours old.

It measured 3.96 mm; head was prominent, mouth was not yet formed although a slight invagination could be seen just behind level of eyes ventrally; and eyes remained unpigmented. Yolk was not yet fully utilized and larval finfold was not quite wide. Auditory capsules could be seen behind optic region. There were 29 preanal and 13 postanal myotomes. Precise number of myotomes in postanal region could not be ascertained owing to imperfect myosepta and prominent notochordal vacuolation.

(c) Postlarva (Fig 55)

A single postlarva measuring 4.67 mm was collected from plankton on 30 -9 -'77. Larval finfold was present, but in a reduced condition and caudal region appeared somewhat globular. Significant changes observed were formation of mouth, pigmentation of eyes, development of pectoral fin as a membraneous semicircular or fan shaped structure and appearance of a few pigments on body. A few black pigment spots were present in fore- and hind- gut regions, a single spot in postanal region and a few in dorsal and ventral aspects of caudal end. Lower jaw appeared a little longer than upper one. Number of preanal myotomes was 29; and 13 postanal myotomes could be counted.

(d) Systematics

T.dussumieri was found to spawn off Porto Novo during May - September period. Mature ova of this species examined there during the period when eggs were collected ranged from 0.7 to 0.8 mm, as also observed by Dharmamba (1960) earlier. It may be noted in this connection that in eggs of Clupeiformes with narrow perivitelline space, diameter of planktonic eggs in early stages is only slightly more than diameter of mature or ripe ova, unlike the condition in sardines where perivitelline space increases considerably. This results in much larger egg diameter in the latter than in eggs with little perivitelline space, such as Opisthopterus (Bensam, 1968 b). As such, it is reasonable to expect a diameter of about 0.8 - 0.9 mm in planktonic eggs of T.dussumieri. In early larva of T.dussumieri about 42 myotomes were present, which tallies with adult vertebral number of 42.

Eggs described by Delsman (1959 a) and Vijayaraghavan (1957) as of Engraulis grayi (T.hamiltonii) ranged in diameters from 1 to 1.1 mm and those assigned by Delsman (op.cit) to E.mystax were of 0.8 - 0.9 mm. These two species have 45 vertebrae each; and the larvae from them also should have 45 myotomes. 3.96 and 4.67 mm stages of T.dussumieri described in the present section may be compared to similar stages of E.grayi figured by Delsman (op.cit) and 4 and 4.5 mm stages given by Vijayaraghavan (op.cit). Although there are many features in common between larvae of E.grayi and T.dussumieri, the crucial difference is in total myotome number, which is only 42 in T.dussumieri but 44 to 46 in E.grayi. Also, in postanal region there are 14 to 16 myotomes in E. grayi, but only 13 in T.dussumieri. Chacko (1950) gave brief notes on eggs and early larva assigned by him to this species. Although size of eggs given by him tallies somewhat with that of present eggs, number of preanal myotomes in early larva amounting to only 17 in such an early stage as recorded by him suggests that the eggs and larva assigned by Chacko (op.cit) to this species cannot belong to it. It may be noted in this context that number of preanal myotomes in early larvae of clupeoids is considerably more than in adult condition because of backward position of vent. It is only as development progresses that vent moves forward and only in late postlarval or early juvenile condition that it occupies adult position. But, placement of anus below 17th myotome in an early larval stage like 2.5 mm larva, which is the condition in adults with 17 - 18 vertebrae in preanal region, points out that the identification made by Chacko (op.cit) of eggs and larvae of T.dussumieri cannot be taken as valid.

Nair,R.V.(1952 b) described eggs and early larvae of an unidentified species of Thrissocles (Thryssa) from Madras. The egg measured a diameter of 0.92 mm and the newly hatched as well as one day old larvae contained 30 preanal and 13 postanal myotomes. In this respect, the present larvae bear similarity to the ones described by Nair,R.V.(op.cit); but in length there are differences. Ripe ova of Thrissocles purava studied by Palekar and Karandikar (1952) had a diameter of 0.92 - 1.26 mm, which amounts to the size of eggs reported by Nair,R.V.(op.cit). Rao,K.S. and Girijavallabhan (1973) described eggs and early larvae of Thrissocles mystax, ranging in diameters from 0.912 to 1.270 mm and larvae with 30 preanal and 10 - 13 postanal myotomes. There are 45 vertebrae in adult T.mystax; and the presence of only 43 myotomes even in an advanced condition as three days old stage, measuring 4.62 mm, appears to be rather contradictory to identification of this species based on this important character. Also, diameter of the eggs of T.mystax given by Delsman (1929 a) is different from the diameter of eggs given by Rao,K.S. and Girijavallabhan (op.cit). On the other hand, size ranges of these eggs and ripe ova of T.purava given by Palekar and Karandikar (1952) are similar to each other.

3. 2. 10 Thryssa hamiltonii (Gray)

This is a common anchovy found in Indian waters and supporting fisheries all along. Earlier work on this species is that of Delsman (1929 a) and of Vijayaraghavan (1957) on its eggs and larvae and Masurekar and Rege (1960) on maturity and spawning.

(a) Eggs (Fig 56)

The eggs, few in number, were collected on 12 -4 -'78. They were spherical, pelagic, tranparent, unpigmented, without oilglobule, having a narrow perivitelline space and measured from 1.12 to 1.18 mm in diameter. On the day of collection at 10.00 hr, the eggs were all in fairly well advanced stages of embryonic development (Fig 56), with formation of head, trunk, tail and myosepta. On the following morning at 08.30 hr the eggs were found to have hatched out.

(b) Larva (Fig 57)

From the developmental stage of larva observed at 08.30 hr on 13 -4 -'78 (Fig 57), it was obvious that the process of hatching would have taken place only a few hours before. It measured 4.67 mm, larval finfold was prominent and pigmentation was absent. There were 32 preanal and 14 postanal myotomes.

(c) Systematics

T.hamiltonii was observed to spawn off Porto Novo during February - July, in 1978. Total number of myotomes in the larva corresponds with adult vertebral number of 45. Eggs assigned by Delsman (1929 a) and Vijayaraghavan (1957) to this species have an almost similar range of diameters as in present case. In larval stages described by the former and in larvae and postlarvae described by the latter, there are 30 preanal myotomes which is different from the present material of 32 preanal and about 14 postanal. It may be noted in this connection that disposition of myotomes in clupeoid larvae is subject to variation; as such, this difference may not be taken as a vital factor in deciding their specific identity.

Eggs assigned by Rao,K.S. and Girija-vallabahan (1973) to *T.mystax* have a diameter range of 0.912 to 1.270 mm; and the larvae as well as postlarvae possess 30 preanal and 13 postanal myotomes. The total number of myotomes given by them is only 43, whereas in adults there are 44 - 45 vertebrae. The presence of only 43 myotomes even in a postlarval stage as three days old condition described by Rao,K.S. and Girija-vallabahan (*op.cit*) when the total myotome number usually gets stabilized corresponding to adult condition,

PLATE V

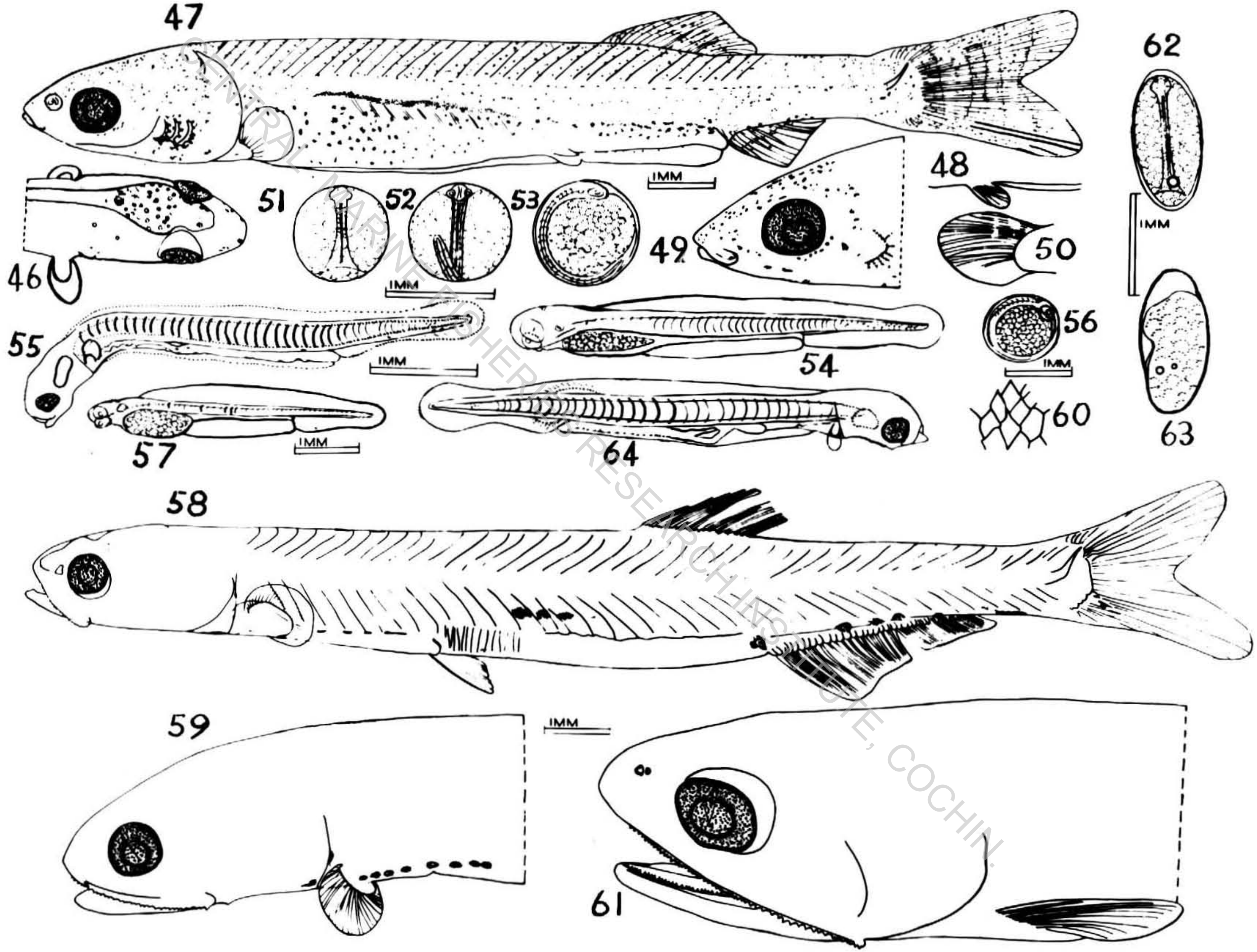
Figures 46 - 50. **Juvenile stages of** Chanos chanos**(continued):**
Fig 46. Dorsal view of head region in 14.01 mm; Fig 47. 16.25 mm;
Fig 48. Showing development of pelvic fin a 16.5mm stage;
Fig 49. Lateral view of head region in a 18.5 mm juvenile, showing growth of snout over lower jaw; Fig 50. Pectoral fin in 18.5 mm.

Figures 51 - 55. Eggs, larva and postlarva of Thryssa dussumieri:
Figs 51 - 53. Three stages in development of egg; Fig 54. 3.96 mm larva; Fig 55. 4.67 mm postlarva.

Figures 56 and 57. Egg and 4.67 mm larva respectively of Thryssa hamiltonii.

Figures 58 - 61. Postlarvae of Thryssa mystax: Fig 58. 18.83 mm;
Fig 59. Head and trunk region of 23 mm; Fig 60. **Markings on skin** of 23 mm stage; Fig 61. Head region of 26.5 mm juvenile.

Figures 62 - 64. Eggs and postlarva of Stolephorus tri: Figs 62 and 63. Live and dead eggs respectively; Fig 64. 4.69 mm postlarva.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throws doubt on validity of its identity. It may also be noted in this connection that eggs identified by Delsman (1929 a) as of T.mystax have diameters ranging from 0.8 to 0.9 mm only unlike the material collected by Rao,K.S. and Girijavallabahan (op.cit).

3. 2. 11 Thryssa mystax (Schneider)

Thryssa mystax is another anchovy supporting minor coastal fisheries in Indian subcontinent and south-east Asian region. Earlier work on this species includes description of a larval stage by Gopinath (1946), some aspects of its biology by Venkataraman (1956), maturation and spawning by Dharmamba (1960), feeding and spawning by Ganapati and Rao,K.S.(1962), occurrence and size range of juveniles by Basheeruddin and Nayar (1962) and distribution of larvae and juveniles in Mahanadhi Estuary by Rao,N.G.S.(1967).

(a) Postlarvae (Figs 58 - 61)

Three late postlarvae identified as of this species were collected from mouth of Vellar Estuary in October, 1977, using a fry collection net. Earliest stage collected on 9th, measuring 18.83 mm

(Fig 58) had an elongated and somewhat streamlined body. Head has assumed the shape characteristic of engarulids with a wide mouth; and lower jaw was a little longer than upper. Maxillary bone showed a number of minute conical teeth and did not surpass eye. Pectoral fin had a somewhat membraneous and semicircular or fan shaped appearance with a number of developing rays. Pelvic fin was well formed, with about six rays. Dorsal was situated behind middle region of body, with about 15 developing rays. Anal fin was long with about 37 ray elements. Caudal was forked, with about 32 elements. Pigmentation was sparse and in the form of a ventral streak behind operculum, two vertical streaks infront of pectoral fin, a series of six spots in foregut region, a streak at pelvic base, a group of three brownish branching chromatophores above midgut, a large branching chromatophore above anus, four branching ones at the base of anal fin, a sunken pigmented area behind anal end and four streaks at the base of lower caudal lobe. Number of preanal myotomes was 27 and of postanal myotomes 18, the total number corresponding to adult vertebral number. Preanal and predorsal proportions were 61.1 % and 50.8 % of total length respectively.

In another specimen of 23 mm (Fig 59) collected on the same day as the previous one, some more changes were observed. Snout has grown further, thus making the mouth distinctly inferior as in adults. Maxillary has grown considerably, surpassing eye region and reaching almost middle region between snout and operculum. There were a number of pointed, conical teeth on maxillary, premaxillary and dentary bones. Pectoral fin remained somewhat semicircular. Dorsal fin has moved forward and its origin in this stage was well infront of middle of body. Morphometric data of the postlarvae were: standard length 20 mm; snout 0.74 mm; eye diameter 0.87 mm; maxilla 2.5 mm; head 4.2 mm; snout to dorsal origin 11 mm; snout to pelvic base 7mm; snout to anal origin 12.5 mm; anal base 5.5 mm; and body depth 3 mm. There were about 12 pectoral, 15 dorsal, 40 anal and 40 caudal ray elements. Precise number of pelvic fin rays could not be made out. Pigmentation consisted of a ventral blackish pigment just above region of isthumus, another one at base of operculum, a series of eight blackish chromatophores behind pectoral region, a small spot at pelvic base, one large and one small black sunken spot in anal region and a series of twelve black spots along anal fin base. Skin of body showed somewhat tetragonal markings(Fig 60) indicating areas of future scales. Ventral scutes have not yet made their appearance. Disposition of myotomes has changed to 24 preanal and 21 postanal. Preanal and predorsal proportions have become reduced to 54.3 % and 47.8 % respectively of total length.

A larger specimen of 26.5 mm was collected on 12 -10 -'77 (Fig 61), the morphometric data of which were: standard length 23 mm; snout 1 mm; eye diameter 1.3 mm; snout to dorsal origin 11 mm; snout to pelvic base 9 mm; snout to anal origin 14 mm; anal fin base 6 mm; and body depth 4 mm. Pectoral fin has assumed a somewhat triangular shape characteristic of adult condition. There were about 12 pectoral, 16 dorsal, 40 anal and 40 caudal ray elements. Most dorsal and anal ray elements showed three to five segments while most caudal elements showed five to eleven segments. Eight preventral and eight postventral scutes have developed. Pigmentation was in the form of a series of 14 spots along anal base. Number and disposition of myotomes continued to be the same as in previous, but preanal and predorsal proportions have become further reduced to 52.8 % and 41.5 % of total length respectively.

(b) Systematics

T.mystax was observed to spawn off

Porto Novo from July - August to October - November during 1977 - '79. The total number of myotomes in the postlarvae correspond to adult veterbral condition. Seven species of Thrissina - Thryssa group have been collected from Porto Novo during the present study, viz., Thrissina baelama, Thryssa setirostris, T.mystax, T. dussumieri, T.purava, T.vitrirostris and T.malabarica. Of these, only T.mystax and T.dussumieri were observed in fish catches at Porto Novo in mature and spent stages. T.dussumieri has only 41 vertebrae and T.mystax has 45. In adults of latter maxillary bone surpasses opercular bone whereas in 26.5 mm postlarva, it is much lesser than that. It may be noted in this connection that in the above postlarva maxillary bone is still in a state of growth and has not yet attained adult condition.

Vijayaraghavan (1957) has described some stages in postlarval development of Engraulis grayi (T.hamiltonii). From figures and description given by him, it appears that even 20 mm to 30 mm postlarvae have retained larval finfold in posterior part of body. Uchida (1958 b) has described embryonic, larval and postlarval development of Japanese anchovy Engraulis japonica. The slow development of pectoral fin and gradual formation of snout during its postlarval history are similar to the condition in T.mystax.

However, in adult E.japonica maxillary bone falls much short of opercular end; and hence the comparatively shorter maxillary bone in juvenile of 37.5 mm length.

Nair,K.K. (1940) and Jones,S. and Menon (1951 c) have described larval development of the Gangetic anchovy Setipinna phasa (Engraulis telera). The 13 - 25 mm postlarvae of S.phasa described by the above authors differ from the present material in the number and disposition of myotomes, 31 - 34 preanal + 14 - 17 (total 48) in the former and 24 - 27 preanal + 18 - 21 (total 45) in the latter. In S.phasa, Nair,K.K. (op.cit) found 25 - 27 preanal vertebrae in postlarvae of 30 - 32 mm while this author as well as Jones,S. and Menon (op.cit) have found that the anus shifts forward to below 19th vertebra in 50 mm stage. In adult T.mystax there are 20 - 21 preanal and 24 - 25 postanal vertebrae; and from a study of 26.5 mm postlarva it is apparent that such a disposition is attained only during further growth. In S.phasa, scutes develop only by 30 - 32 mm stage and adult number is attained only by 50 mm (Nair,K.K., 1940; Jones,S. and Menon, 1951 c). In T.mystax however, scutes are seen in 26.5 mm stage itself and adult condition is expected to be attained in further growth. Thus, a quicker pace of development is recognizable in postlarval growth of T.mystax than in S.phasa.

3. 2. 12 Stolephorus tri (Bleeker)

Stolephorus tri is a whitebait widely distributed in Indo-Pacific and contributes to fisheries wherever it occurs. Earlier work on this species includes food habits of young stages by Bapat and Bal (1950) and eggs and larvae by John (1951) and Vijayaraghavan (1957).

(a) Egg (Figs 62, 63)

A single egg was isolated from plankton on 4 -3 -'78 (Fig 62). It was elliptical, pelagic and measured 1.41 mm in length and 0.62 mm in breadth. Yolk was also elliptical, vacuolated and with a narrow perivitelline space. There was a single light brownish yellow oilglobule of 0.14 mm diameter. In the egg examined at 09.00 hr, embryo was indicated, with optic vesicles and a few anterior myosepta. It was reared in laboratory; but, when examined on the following morning it was found to have died, with the oilglobule split up into a large and a small component (Fig 63).

(b) Postlarva (Fig 64)

A single postlarva of 4.69 mm was collected from plankton on 30 -9 -'77. As may be seen from general features, it could be said that this was in an early stage of development. Larval finfold was still present. Head has become prominent and eyes were pigmented black. Maxillary bone has become distinct. and lower jaw was longer than upper. Larval opercular cleft was visible as a dorsoventral streak in post-cephalic region. Pectoral fin appeared somewhat club shaped and membraneous, with striations indicating future rays. Dorsal and anal fin rudiments could be seen above level of anal region and behind it respectively as thickenings of larval finfold. Striations were present in caudal region, representing rays. Alimentary canal appeared to have undergone some progressive development and hindgut showed dorsoventral foldings of inner epithelium. The postlarva was devoid of pigmentation. There were 25 preanal myotomes; and about 12 or 13 myotomes could be counted in postanal region. Determination of precise number of myotomes in postanal region was rendered difficult owing to indistinct nature of myosepta. Preanal and predorsal proportions were 72 % and 65 % of total length respectively.

(c) Systematics

The other two species of Stolephorus observed at Porto Novo during the present study were S.indicus and S.commersonii, the eggs of both of which are provided with a knob (Delsman, 1931 a). Among eggs without a knob which Delsman (op.cit) has come across, the one with an oilglobule of 0.05 mm in diameter was assigned to S.heterolobus, one with oilglobule of 0.07 - 0.08 mm to S.tri and one with oilglobule of 0.10 - 0.12 mm to S.baganensis. As per recent thinking on systematics of various species of Stolephorus reviewed by Whitehead (1972), species S.baganensis with macrops element is considered as S.macrops and that without macrops element alone is considered to be S.tri proper. As such, it appears that eggs assigned by Delsman (1931 a) to S.baganensis var megalops belong to S.tri; and eggs actually assigned by him to S.tri appear to belong to some other species. On the other hand, eggs attributed to S.baganensis by Delsman (op.cit) appear to belong to S.macrops.

Many features of the present egg such as length and diameter of oilglobule are similar to those of S. baganensis var megalops described by Delsman (op.cit), although breadth of the two is different. John (1951) assigned certain eggs measuring 1.7 to 1.8 mm long, 0.7 to 0.77 mm broad and with an oilglobule of 0.04 mm, collected from off Madras to Anchoviella (Stolephorus) tri and expressed opinion that this probably belongs to a variety of this species. Since John (op.cit) appears to have based his identification mostly on that of Delsman (1931 a), the eggs assigned by the former to A.tri appear to belong to some other species and not to the real S.tri, as pointed out for the eggs described by Delsman (op.cit). The eggs identified by Vijayaraghavan (1957) as of this species had an average length of 1.73 mm and breadth of 0.58 mm and oilglobule was of 0.091 mm. In such features eggs described by Vijayaraghavan (op.cit) differ from those given by Delsman (op.cit).

Among various species of Stolephorus, only S.commersonii has 39 - 40 vertebrae and S.tri has 38 vertebrae, thus serving to confirm the present identification of postlarva as that of S.tri. This specimen could be compared to 4.8 mm postlarva described by Vijayaraghavan (1957). Based on such a comparison, there does not appear to be any major difference in basic characteristics of the two stages.

Venkataramanujam(1975a) considered certain eggs of 1.78 mm length and 0.58 mm breadth and usually containing one oilglobule, as belonging to Stolephorus tri. The above eggs differ from the present ones in their size. The 13.2 mm postlarva assigned to Stolephorus by the above author had 40 myotomes, pointing out that the above stage could belong to a species like S.commersonii.

(D) Family Mugilidae

Grey mullets constituting this Family are found in coastal marine and brackish water, some species even entering fresh water. Distributed in both tropical and temperate areas, most species are both of capture and culture value (vide: Bardach, et al, 1972). They are euryhaline and possess a quick growth rate during the first year of their life, thus forming a valuable culturable resource. In India, the genera Mugil, Liza, Rhinomugil and Valamugil are more common; and M.cephalus, L.macrolepis, L.dussumieri, etc are important in traditional culture operations in many parts of the country. At present, experiments are being undertaken by various agencies to demonstrate production in various culture ecosystems. Also, attempts are under way to locate and exploit natural seed resources areas as well as at induced breeding of various species for artificial seed production.

3. 2. 13 Liza dussumieri (Valenciennes)

Liza dussumieri is both of capture and culture importance, found in seas, estuaries, backwaters along both east and west coasts. At Porto Novo, this species was the most dominant mullet observed during 1977 - '79. Occurrence of larvae and postlarvae off Bombay in north-west coast is reported by Bal and Pradhan (1946; 1947; 1951). Jacob and Krishnamurthy (1948) observed its breeding and feeding habits in Ennore Creek in south-east. It is cultured in many parts of Indo-Pacific (Bardach, et al, 1972) and is known to attain a length of about 15 to 19 cm in culture ponds in ite first year, with a maximum of 25 cm, although in sea it reaches even upto 40 cm. Recently, Reddy (1978) has made observations on its systematics and biology from Porto Novo. In the present section eggs, larvae, postlarvae and juveniles are described.

(a) Eggs (Figs 65 - 68)

Mature ova of L.dussumieri examined in August and September 1977, varied in diameters from 0.42 mm to 0.46 mm and ripe ova ranged from 0.45 to 0.55 mm, with average at 0.50 mm (Fig 65). Ripe ova contained an oilglobule of 0.145 mm to 0.156 mm, with average at 0.15 mm. Yolk was neither segmented nor vacuolated but was clear, leaving a narrow perivitelline space. Coinciding with availability of spawning stock at Porto Novo, large number of eggs resembling the ripe ova in all basic features were found in plankton. Planktonic eggs measured between 0.531 and 0.570 mm with average at 0.55 mm; and oilglobule measured from 0.154 to 0.165 mm with average at 0.15 mm. Thus, there was not much difference in sizes between ripe ova and planktonic eggs, a condition also observed in another mullet Liza macrolepis by Natarajan,A.V.and Patnaik(1973). This was obviiuosly due to lack of significant "swelling up" after the ova were shed in water and fertilized.

Two stages in embryonic development of planktonic eggs were available in the collections. In the earlier stage observed at 09.30 hr on 29 -9 -'77 (Fig 66), embryo was in an early stage of development with head appearing as a rhomboidal structure, trunk almost fully formed and tail under progressive growth. Pigmentation of embryo and oilglobule was characteristic. There were two patches of light yellowish brown pigments in head region and black pigment spots intermingled with light yellowish brown chromatophores on trunk and tail. Similar black pigment spots intermingled with light yellowish brown chromatophores were present on oilglobule also. The latter has occupied an anterior position, near head region. In a later stage examined at 13.00 hr on same day (Fig 67), embryo was almost fully formed, with optic vesicles, trunk, tail and larval finfold. Pigmentation of embryo and oilglobule remained almost the same as in previous stage but for additional development of a light yellowish brown band mid way between end of yolksac and tail. Light yellowish brown pigmentation on optic capsules has become more distinct.

Process of hatching was observed for embryo hatching out at 14.00 hr on 26 -9 -'77. As in all fish eggs, hatching was accompanied by repeated twitching movements of embryo, splitting up of egg capsule (Fig 68) and emergence of embryo as newly hatched larva. Head emerged out first followed by trunk and tail, the latter lashing out the empty egg capsule. Newly hatched larva remained somewhat curved to begin with, but soon stretched out itself and became almost straight.

(b) Larvae (Figs 69, 70)

Newly hatched larva at 14.00 hr on 26 -9 -'77 measured 1.31 mm (Fig 69). Yolksac was large and rounded off posteriorly, with oilglobule occupying its anterior aspect. Pigmentation consisted of blackish brown pigments above and behind eyes, black pigments a little behind it, a vertical band of light yellowish brown pigments in mid postanal region and yellowish brown pigments on oilglobule. Preanal length was 46 % of total length. There were 7 preanal and 17 postanal myotomes.

Among larvae hatching out on 26 -9 -'77, a few were reared in laboratory for further stages in development. On the following day at 14.00 hr when the larvae were 24.00 hrs old, a representative stage measured 2.03 mm (Fig 70). Body has become elongated and yolksac was considerably reduced, but oilglobule still remained prominent. Black pigments present on dorsal side have moved to ventral side and were mostly in the form of two prominent patches, one above anal region and another a little behind it. Infront of eye region two black pigment spots have appeared. The pigment band observed in postanal region in the previous stage was still present. Eyes have become partly pigmented with light yellowish brown chromatophores; and above eye region a patch of pigments was present. Preanal length has undergone a significant reduction, to 32.4 % of total length. As disposition of myotomes continued to be the same as in previous stage, reduction in preanal proportion of body appeared to be not due to forward shifting of anus but perhaps be due to disproportionate elongation of postanal region.

The larvae continued to be reared in the laboratory on 27 -9 -'77 for further stages in growth had passed on to postlarval condition on the next day.

(c) Postlarvae (Figs 71 - 74)

Four postlarval stages were available for study, the earliest one reared in laboratory and the other three collected from plankton during September-October, 1977.

1.94 mm (Fig 71):- This stage reared in laboratory was 48 hrs old. There was a slight decrease in length when compared to previous larval stage. Formation of mouth, pigmentation of eyes, disappearance of yolk, appearance of pectoral fin, development of postlarval opercular cleft, etc have marked the beginning of postlarval condition. Mouth opening was rather small and pectoral fin was membraneous and semicircular. Body has become wider than in previous stage, particularly anteriorly. Pigmentation was in the form of a few black pigment spots behind auditory and pectoral regions and a series of yellowish brown chromatophores along ventral side of body. Proportion of preanal length as well as number and disposition of myotomes remained the same as in the previous larval stage.

4.00 mm (Fig 72):- Date of collection: 30 -9 -'77. Remnants of larval finfold were still present and body has assumed a considerably large size, with head forming the most prominent region and body tapering gradually behind. The postlarva was translucent and became whitish in formalin. Eyes were prominent and second dorsal fin was indicated with about 9 rays. Caudal fin was somewhat semicircular with about 14 rays, many of which showed two segments. Pectoral fin remained membraneous and semicircular without indication of rays, but anal fin showed about 10 rays. Pigmentation was sparse and consisted of blackish brown chromatophores below pectoral region, at the base of operculum, above pectoral fin, at dorsal end of operculum, a sunken oblique patch behind it and a series of five black spots along anal base. Body depth at anal region has increased, from 0.48 mm in previous stage to 1 mm in present one. Preanal proportion of body was 32 % of total, the same condition as in previous stage. Number of preanal myotomes has decreased to 6 and that of postanal myotomes increased to 18, obviously by forward shifting of anus covering one myotome.

<u>4.56 mm</u> (Fig 73):- Date of collection: 3 -10 -'77.

This stage did not show much significant changes over previous one. Appearance of a few pointed teeth in upper jaw, a few additions to the number of dorsal, caudal and anal fin rays, appearance of a few branchiostegals in opercular region, squarish appearance of caudal fin and an increase in pigmentation along dorsal and ventral aspects of gut have marked the features as more advanced than in previous postlarva. Although number and disposition of myotomes remained the same as in previous stage, there was a slight increase in preanal length, forming 35 % of total.

7.27 mm (Fig 74):- Date of collection: 6 -10 -'77.

This postlarva was characterized by development of first dorsal fin in the form of about seven soft spines, bifurcation of caudal fin with about 28 ray elements most of which were 3 to 5 segmented, progressive development of anal fin with about 12 rays and indication of ventral fin below level of pectoral. Precise number of rays in both pectoral and pelvic fins could not be ascertained. Pigmentation continued to be sparse, although increased a little more; and was in the form of a streak of sunken blackish area marking peritonial wall, another oblique streak at the base of anus, a pigment patch at the region of isthumus, another infront of anal fin and a series of 12 black pigments along the base of anal fin and behind it. Proportion of preanal length has increased, forming 40 % of total. Number of preanal myotomes has increased to 7 and that of postanal decreased to 17, obviously due to backward movement of anus.

(d) Juveniles (Figs 75 - 78)

A large number of juveniles was collected during September - October 1977 from plankton as well as fry net catches made at the mouth of Vellar Estuary. Among them, three stages appeared representative in juvenile growth.

10.18 mm (Fig 75):- The most important changes observed in this stage over the previous postlarva were progressive development of all fins, elongation of body particularly in postanal region backward movement in position of anus and considerable increase in pigmentation. About 7 spines were present in first dorsal fin, 10 in second dorsal, 38 elements in caudal, 12 in anal, 10 in pectoral and 3 in pelvic. Head was 4.1 in total length, eye diameter 3 in head, snout 3.8 in head and body depth at origin of first dorsal 5.4 in total length. Preanal length has increased much more, reaching 50 % and predorsal length 26.4 % of total length. Pigmentation consisted of blackish brown branching chromatophores in snout, above and behind eye region, a few in pectoral region, a series along dorsolateral aspect of body from behind head till base of upper caudal lobe and another series along ventrolateral aspect of body from behind pelvic fin till the base of lower caudal lobe. At the hind end of head dorsally a group of three prominent blackish brown chromatophores was present on either side of midlateral line. Small, stellate chromatophores were present all along body from behind pectoral region till the base of caudal peduncle. Disposition of myotomes in this stage was 9 preanal and 15 postanal.

12.45 mm (Fig 76):- Significant changes registered in this stage were further elongation of body, progressive development of all fins and increase in pigmentation. Head has become 3.5 in total length, eye diameter 3.3 in head, body depth at origin of first dorsal 5.2 and preanal length 52 % of total length. Dorsal fins appeared to have shifted backwards, thus making predorsal length 42.7 % of total. Shape of pectoral fin has changed from somewhat semicircular condition to almost triangular. Pelvic fin has become longer with about 5 rays. A notable change in pigmentation was disappearance of branching chromatophores from dorsolateral and ventrolateral aspects and development of a midlateral series of pigment spots as well as downwardly branching chromatophores from opercular region till the base of caudal peduncle. At the hind end of cranium dorsally, pigments appeared highly diffused. Disposition of myotomes has changed to 10 preanal and 14 postanal.

14.00 mm (Figs 77, 78):- This stage has almost acquired many juvenile characters of fingerlings. Standard length was 11 mm, head 3.3 mm, snout to insertion of first dorsal 5.75 mm and to insertion of second dorsal 8 mm, snout to pelvic 4.75 mm and snout to insertion of anal 7.5 mm. Preanal length continued to be about 52 % of total length as in previous stage. Pigmentation has assumed a diffused form with a number of blackish brown chromatophores on body including head. In premaxillary and in region behind it dorsally as well as in dentary and at the angle of mouth, many chromatophores were present. Above eyes and at hind part of brain dorsally, pigmentation was in the form of three groups, two placed infront and one a little behind it middorsally, forming a somewhat triangular pattern. In opercular region laterally, there were a number of branching chromatophores including a large one, giving a yellowish brown colouration. Pigmentation along dorsolateral, ventrolateral and midlateral aspects has also increased. At the base of caudal peduncle a vertical patch of pigments was present. Vertebral (myotome) disposition corresponded to the adult condition of 11 preanal and 13 postanal.

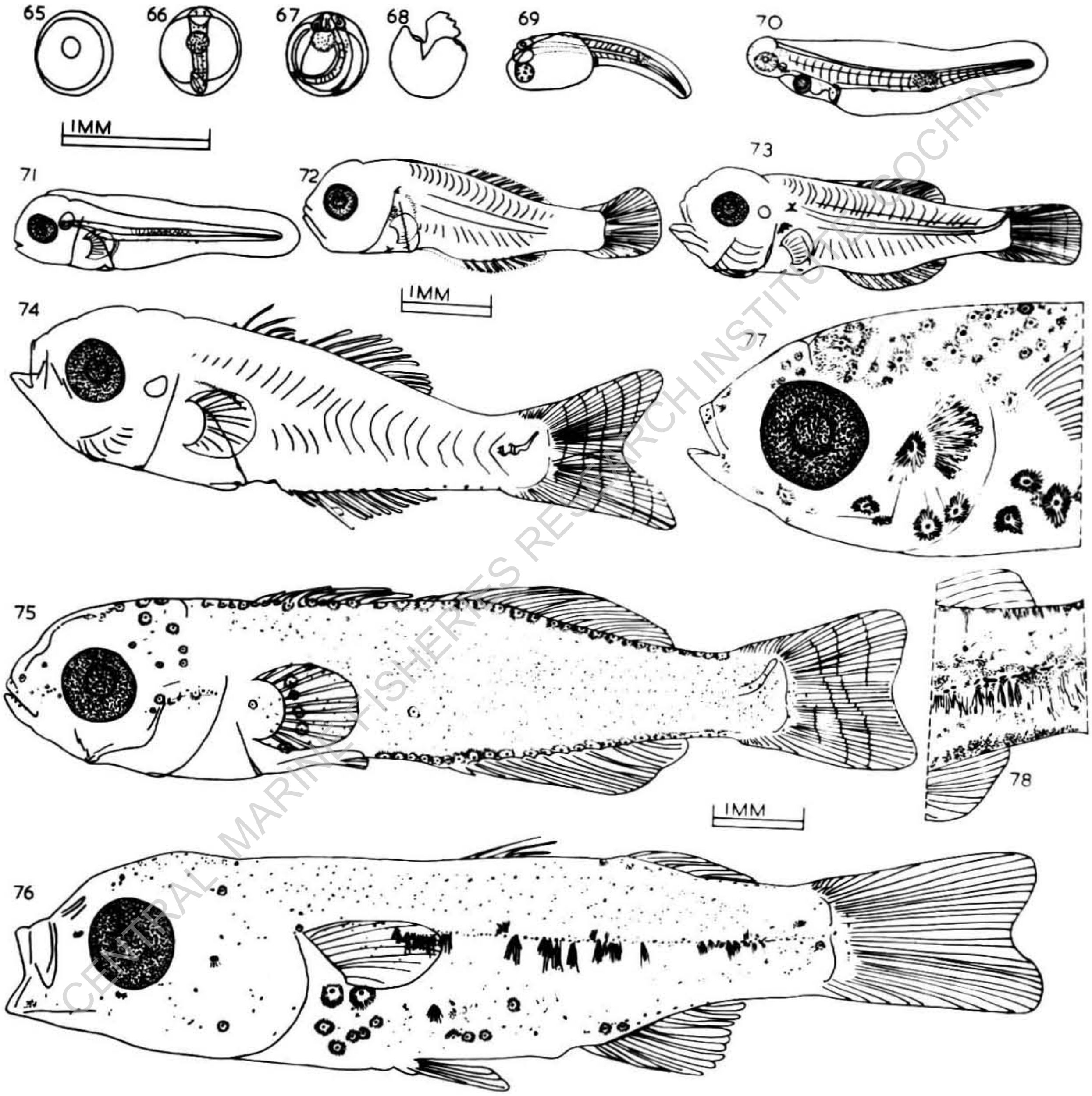
(e) Systematics

L.dussumieri was observed to be the most common mullet in estuary, backwaters and sea off Porto Novo during 1977 -'79, as also found earlier by Reddy (1978). The above author has studied some aspects on the biology of this species at Porto Novo and found that breeding period of this species is rather prolonged, from December to August including late spawning during September - February, thus suggesting perennial spawning. Ripe ova of this species were found by Reddy (*op.cit*) to range in diameters from 0.38 mm to 0.4378 mm; and in ripe specimens examined by the present writer, the ova ranged in diameters from 0.45 to 0.55 mm, thus indicating the possibility that overall variations in diameters of ripe ova are from 0.38 to 0.55 mm. Similar variations in size of fertilized eggs amounting to 0.48 to 0.80 mm have been observed in another mullet, *Mugil cephalus* by Chaudhuri, Bhowmick, *et al* (1978).

Our knowledge on eggs, larvae, postlarvae, etc of Indian grey mullets is chiefly based on the work of Pakrasi and Alikunhi (1953) on *Mugil corsula*, Pillay (1954) on postlarvae of *M.tade*, Nair,G.S.(1957 b) Kuthalingam (1961 c) and Chaudhuri, Bhowmick, *et al* (1978) on *M.cephalus* and Natarajan,A.V.and Patnaik(1973)

PLATE VI

Figures 65 - 78. Eggs, larvae, postlarvae and juveniles of Liza dussumieri: Fig 65. Ripe egg; Figs 66 and 67. Two stages in development of egg; Fig 68. Empty egg capsule after emergence of embryo; Fig 69. Newly hatched larva; Fig 70. 24 hrs old larva; Figs 71 - 74. Postlarval stages, Fig 71. 1.94 mm; Fig 72. 4.0 mm; Fig 73. 4.56 mm; Fig 74. 7.27 mm; Figs 75 - 78. Stages in juvenile development, Fig 75. 10.18 mm; Fig 76. 12.45 mm; Fig 77 and 78. Head and caudal peduncular regions respectively of a 14 mm juvenile, showing pigmentation.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on Liza macrolepis, although many references have been found in literature on occurrence of fry of many species in different localities, which are not of any value in comparing characters. In the development of M.corsula described by Pakrasi and Alikunhi (1953) an initial forward shifting of anus is evident in early larvae, from 57.7 % preanal length in 2.15 mm larva (newly hatched) to 51.5 % in 3.615 mm (99 hrs old), followed by a backward shifting in postlarval and juvenile condition, from 47.2 % preanal length in 6.435 mm to 52.7 % in 11.9 mm. A forward shifting of anus in larvae of L.macrolepis is discernible in the account given by Natarajan,A.V. and Patnaik (1973), from 62.4 % preanal length in newly hatched larva to 54.6 % preanal length in 6 days old stage. Also, in larvae of M. cephalus obtained from eggs artificially fertilized by Chaudhuri, Bhowmick, et al (1978) anus makes a forward shifting from 57.4 % preanal length in 2 hrs old hatchling to 53.7 % in 72 hrs old stage. In larvae, postlarvae and juveniles of L.dussumieri described in this section, a similar feature is observed, registering a decrease from 46.6 % preanal length in newly hatched larva to 32.4 % preanal length in early postlarva of 1.94 mm; and undergoing an increase from 32 % preanal length in 4 mm postlarva to 40 % preanal length in 7.27 mm postlarva as well as from 50 % preanal length in 10.18 mm juvenile to 52 % preanal length in 14 mm juvenile. But, in larvae of M.cephalus described by Kuthalingam (1961 c) such a forward shifting of anus does not appear to take place, but a backward movement is seen from about 40 % preanal length in 1.1 mm to about 50 % in 1.6 mm, followed by a forward shifting to about 47 % preanal length in 7.2 mm. Pakrasi and Alikunhi (1953) while commenting on movement of vent, point out that adult condition in disposition of anus in M.corsula is attained only in fingerling stage of about 71 mm and that corresponding to shifting in position of anus there was no marked change in disposition of myotomes. Such a condition is observed in L.dussumieri also.

Planktonic eggs of L.dussumieri differ from those of M.corsula described by Pakrasi and Alikunhi (1953) in that the latter are larger (0.90 - 1.035 mm diameter) with a larger oilglobule (0.57 - 0.615 mm) than the former. Eggs of M.cephalus described from India by Nair,G.S.(1957 b), Kuthalingam (1961 c) and Chaudhuri, Bhowmick, et al (1978) range in diameters from 0.48 mm to 0.8 mm with oilglobule in diameters of 0.29 - 0.34 mm. Eggs of L.macrolepis reported by Natarajan,A.V. and Patnaik (1973) have diameters of 0.677 - 0.732 mm and their oilglobules are of 0.292 - 0.347 mm. Eggs of L.dussumieri although fall within the same range of diameters as those of M.cephalus and L.macrolepis, could be differentiated from them in having a smaller oilglobule of 0.154 - 0.165 mm. Pigmentation on yolk is absent in eggs of Liza dussumieri and L.macrolepis (Natarajan,A.V. and Patnaik, op.cit), present in eggs of M.cephalus reported by Nair,G.S.(op.cit), but absent in those of M.cephalus described by Kuthalingam (op.cit) and Chaudhuri, Bhowmick, et al (op.cit).

The principal character by which newly hatched larva of L.dussumieri could be distinguished from those of M.corsula (Pakrasi and Alikunhi, op.cit)and M.cephalus (Nair,G.S., 1957 b; Kuthalingam, 1961 c; Chaudhuri, Bhowmick, et al, 1978) is the smaller size of oilglobule. Also, oilglobule in newly hatched larva of L.dussumieri is placed at anterior extremity of yolksac while in M.corsula and M.cephalus it is located in the middle and in L.macrolepis towards hinder end of yolksac.

The 2.03 mm larva of L.dussumieri may be compared to 3.24 mm larva of M.corsula (Pakrasi and Alikunhi, op.cit), 1.7 mm and 72 hrs old larva of M.cephalus (Kuthalingam, op.cit and Chaudhuri, Bhowmick, et al, op.cit respectively) and 2.123 mm stage of L.macrolepis (Natarajan, A.V. and Patnaik, op.cit). Among all these cases, no feature appears to be distinct enough to facilitate their separation without much difficulty. Even number of myotomes does not appear to be of much use in separating the larvae and assigning them to the species to which they belong, because in almost all species of mullets in India numbering about 18, the total number of vertebrae is found to be only 24; and their preanal and postanal dispositions are also of the same range, from 10 to 12 preanal and 12 to 14 postanal. As such, valid identifications of eggs and larvae of Indian mullets appear to be possible only by comparing ripe ova of the species with planktonic eggs in their early stages of development as well as by resorting to artificial fertilization and rearing.

The 7.27 mm postlarva of L.dussumieri may be compared to 6.435 - 7.11 mm postlarvae of M. corsula (Pakrasi and Alikunhi, 1953) and 7.2 mm postlarva of M.cephalus (Kuthalingam, 1961 c). In the comparison to M.corsula, the postlarvae may be said to be in same stage of development but for bifurcated caudal fin in L.dussumieri. But, while comparing to M.cephalus, larval finfold still appears to be present in the latter and dorsal and anal fins are not yet indicated.

The 8.6 mm and 9 mm larvae of *Mugil tade* described by Pillay (1954) may be compared to 7.27 mm and 10.18 mm stages of *L.dussumieri*. The former may be distinguished from the latter chiefly based on pigmentation and disposition of myotomes. In the former, pigmentation is in the form of a lateral row of chromatophores, another row from the base of anal fin to caudal, some on dorsal aspect of head and two rows above the side of viscera. There are 11 preanal and 13 postanal myotomes (vertebrae). This condition is different from lack of such pigmentation in 7.27 mm postlarva of *L.dussumieri* including absence of a lateral row of chromatophores in 10.18 mm stage. Disposition of myotomes is also 7 preanal and 17 postanal in the former and 9 preanal and 15 postanal in latter stages of *L.dussumieri*, as against 11 preanal and 13 postanal in *M.tade*. In *L.dussumieri*, only by 14 mm juvenile stage that 11 + 13 myotome disposition is seen.

3. 2. 14 *Liza macrolepis* (Smith)

Liza macrolepis (*Mugil troschelli* Bleeker) is another economically important mullet of capture and culture value found in estuaries, backwaters and inshore areas along both the coasts. Basu (1946) has dealt with acclimatization of its fry; Pillay (1947) has given an account of its culture value in India; Jacob and Krishnamurthy (1948) have studied its breeding and feeding habits; Chidambaram and Kuriyan (1952) gave a note on its breeding season, characters and food of fry; Jhingran and Jena (1964) dealt with tagging experiments of this species in Chilka Lake; Thompson (1966) recounted its biology and culture; Luther (1968) studied its maturity and spawning; Natarajan, A.V. and Patnaik (1973) described its embryonic and larval development from Chilka Lake; and Reddy (1978) observed aspects of its biology at Porto Novo.

(a) Eggs (Figs 79, 80)

Planktonic eggs identified as of L.macrolepis were isolated from plankton on 6 -2 -'78. They were pelagic, spherical and ranged in diameters from 0.66mm to 0.72 mm. There was an oilglobule in diameters varying from 0.19 to 0.21 mm. Yolk was spherical and unpigmented, leaving a narrow perivitelline space. Two stages in embryonic development were available. In an earlier one examined at 09.00 hr (Fig 79), pigmentation was absent and embryo showed optic vesicles and formation of anterior myotomes. In a later stage, at 12.00 hr (Fig 80), embryo was fully formed, with well marked head, trunk and tail. In this stage, embryo and oilglobule were well pigmented with black and yellowish brown pigments on head, trunk, tail and oilglobule.

Process of hatching was observed for a larva hatching out at 13.00 hr on 6 -2 -'78. The fully formed embryo showed signs of restlessness and periodic jerking and twitching movements of body, particularly head and tail. At the moment of hatching, the egg capsule was split open and the embryo emerged out of the capsule (Fig 81) with head first and tail last.

(b) Larvae (Figs 82 - 84)

The newly hatched larva soon after its emergence from egg capsule remained somewhat curved for a few seconds, but straightened out soon, measuring 1.32 mm (Fig 82). Alimentary canal did not appear to have established the vent; and, it appeared as though hatching has taken place prematurely, before formation of vent. Yolksac was large and somewhat oval in shape and oilglobule was located at hind end of it. Black and yellowish brown pigments were present along dorsal side of the larva from head region till caudal end, along ventral side behind yolksac and on oilglobule. Length of larva till the end of yolksac was 0.72 mm and that behind yolksac was 0.60 mm, forming 54.5 %

and 45.5 % of total length respectively. A total of 24 myotomes was present.

The larvae hatching out between 13.00 and 14.00 hrs on 6 -2 -'78 were reared in laboratory for further stages. On 7 -2 -'78, at 10.00 hr, the larva examined was about 21 hrs old (Fig 83). It measured 2.08 mm, the greatest body depth was in anal region, tapering gradually towards caudal end and forming a prominent preanal region. This appeared to have resulted in a reduction of preanal length, to 34 % of total. Pigmentation was characteristic and was mostly in the form of yellowish brown pigment spots in head region, on optic capsules, above eyes, in snout, one patch above pectoral region, one above anal region, a small band above it and a vertical band covering the body excluding larval finfold midway in postanal region. Besides, black pigment spots were present on oilglobule and below region of eyes. There were 24 myotomes, 11 preanal and 13 postanal.

Most larvae reared in laboratory died by afternoon of 7 -2 -'78; and only a few had survived till evening of same day. Larvae examined at 16.00 hr on that day were about 27 hrs old (Fig 84). They measured 2.23 - 2.25 mm; and the significant change noted was intensification of pigmentation which has assumed the form of five patches of yellowish brown pigments, three in preanal region and two in postanal. Of the former, the anterior two were only confined to dorsal aspect of body and all other patches extended vertically in the form of bands covering body depth, excluding larval finfold. Preanal length has increased in its proportion when compared to previous stage, attaining 39 % of total. Number and disposition of myotomes continued to be the same as in previous stage.

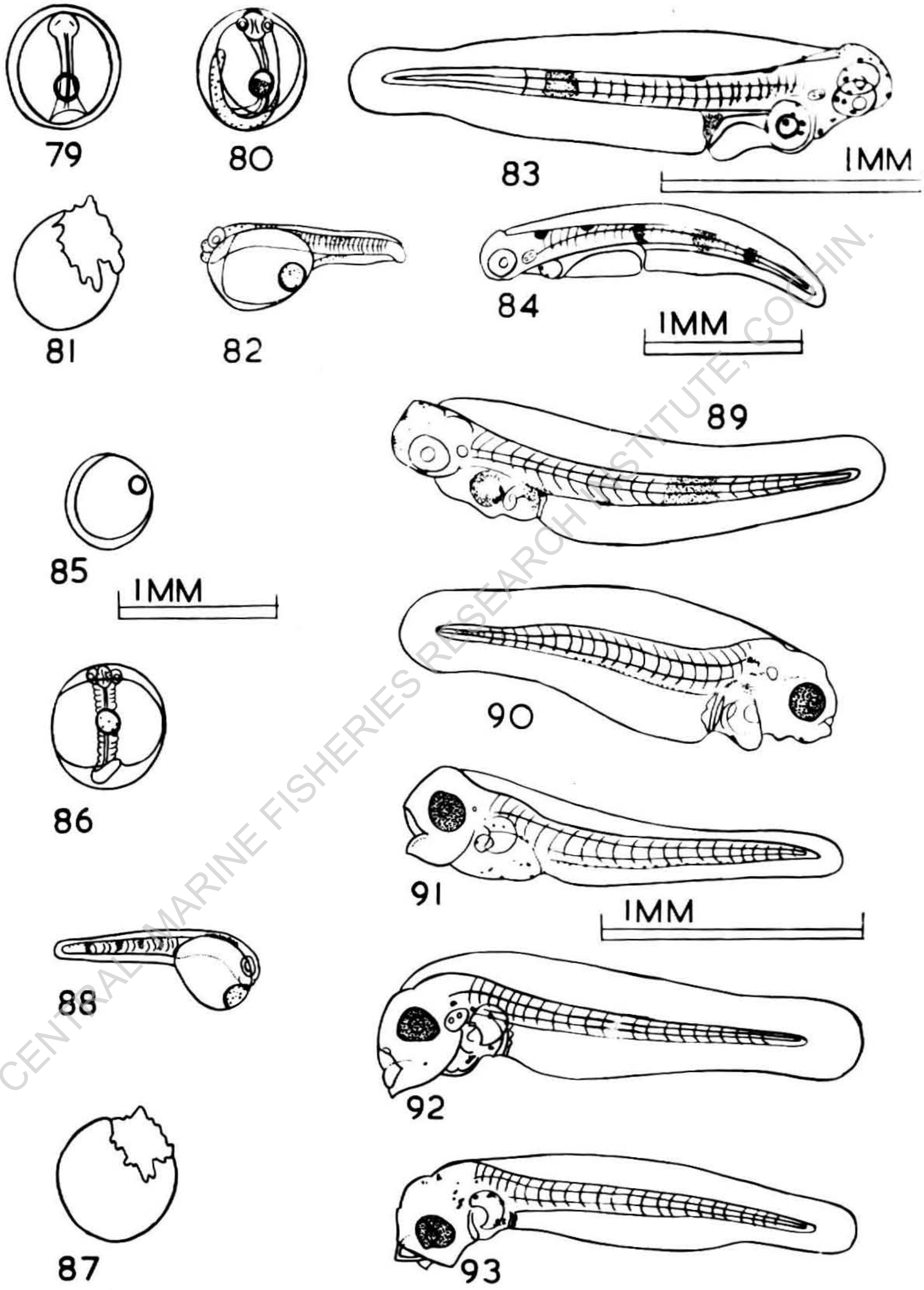
(c) Systematics

Examination of maturity conditions of *L. macrolepis* at Porto Novo during 1977 -'79 has shown that the fish spawns there during January - May period. Mature and spent specimens of this species were available in fishermen's catches during February '78, the only other mullet species occurring along with it in mature and spawning conditions being *L.tade*. Reddy (1978) while studying biology of *L.macrolepis* at Porto Novo has stated that spawning season of this species is an extended one, from January to July. Natarajan,A.V. and Patnaik (1973) have given an account of embryonic and early larval development of this species from Chilka Lake. The oozing eggs obtained by them ranged in diameters from 0.658 to 0.732 mm, planktonic eggs from 0.677 to 0.732 mm and oilglobules

PLATE VII

Figures 79 - 84. Eggs and larvae of Liza macrolepis: Figs 79 and 80. Two stages in development of the egg; Fig 81. Empty egg capsule after emergence of embryo; Fig 82. Newly hatched larva; Fig 83. 21 hrs old larva; Fig 84. 27 hrs old stage.

Figures 85 - 93. Eggs, larvae and postlarvae of Liza tade: Fig 85. Ripe ovum; Fig 86. Developing egg; Fig 87. Empty egg capsule; Fig 88. Newly hatched larva; Fig 89. 21 hrs old larva; Fig 90. 42 hrs old postlarva; Fig 91. 48 hrs old postlarva; Fig 92. 66 hrs old postlarva; Fig 93. 72 hrs old postlarva.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in both cases measured from 0.292 to 0.347 mm. On the other hand, ovadiameters of "oozing ovaries" given by Reddy (1978) varied from 0.468 to 0.504 mm only, thus showing variations between the two cases. Presence or absence of oilglobule in the ova from oozing ovaries is not mentioned by Reddy (*op.cit*), thus throwing doubt as to whether by "oozing ovaries", he has actually considered those ovaries containing ripe ova with oilglobule or not. It may be noted in this connection that a characteristic feature of the eggs hitherto ascribed to grey mullets is the presence of a single, relatively large oilglobule.

The present eggs identified as those of *L.macrolepis* differ from those described by Natarajan,A.V. and Patnaik (1973) in that size range of oilglobules in the present case is slightly smaller, between 0.19 and 0.21 mm, with average at 0.2 mm. In the ripe ova of *Mugil cephalus*, Chaudhuri, Bhowmick, *et al* (1978) have observed differences in the sizes of not only eggs but also oilglobules themselves. It appears quite possible that such variations are present in *L. macrolepis* also; and, apart from size of oilglobule, there does not appear to be any significant difference between planktonic eggs in the present account and those reported by Natarajan,A.V. and Patnaik (*op.cit*).

Regarding larval stages, the newly hatched larva described by Natarajan,A.V. and Patnaik (1973) is longer than that in present work. But, as noted earlier, in the present studies, the larva appears to have hatched out prematurely, as seen from incomplete formation of alimentary canal. As such, the smaller size may be ascribed to this reason. Apart from this, 2.08 and 2.23 mm larvae in the present case could be compared to one day old (2.123 mm) and two days old larvae reported by Natarajan,A.V. and Patnaik (op.cit). Between the two cases, the principal difference appears to be lack of mention by the above authors about the presence of larval pigmentation and the more forward position of anus in present material than in the ones given by them. It may be noted in this connection that in early larval development of mullets anus makes a forward movement, as seen in Mugil corsula by Pakrasi and Alikunhi (1953) and in Liza dussumieri (vide: 3. 2. 13). In the present larvae of L.macrolepis however, a backward shifting in position of anus takes place in larval growth. In the larvae described from Chilka Lake also preanal length is observed to undergo an increase, although not of the same proportion as in the present case. From available information it appears as though in species like M.corsula and L.

dussumieri there is a quick reduction in preanal proportion in early larval development.

3. 2. 15 *Liza tade* (Forsskål)

This is another commercially important mullet, found more abundantly along east coast of India than along west. Basu (1946) reported on the occurrence of its fry; Pillay (1947; 1954) dealt with possibilities of its culture and aspects of its biology; Jacob and Krishnamurthy (1948) noted its breeding and feeding habits; and Thompson (1966) recounted on its spawning period.

(a) *Eggs* (Figs 85 - 87)

Mature, ripe and spent specimens of *Liza tade* were available at Porto Novo during January - May period of 1977 - '79, marking its breeding period there. This is in agreement with the observation of Reddy (1978) from the same locality. Ripe ova of *L.tade* collected during February 1978 (Fig 85) ranged in diameters from 0.54 mm to 0.72 mm, with a clear, unsegmented yolk containing an oilglobule of 0.126 to 0.162 mm in diameter. Perivitelline space was rather narrow; and there was no pigmentation on yolk or oilglobule. Earlier observation on ova of this species is that of Pillay (1954) who has given the diameter range in "nearly ripe" condition as from 681 to 720 micra.

Planktonic eggs were collected on two days, 6th and 7th February 1978, nine on the former occasion and seven on the latter. They ranged in diameters from 0.631 to 0.727 mm, with oilglobule in diameter range of 0.126 to 0.188 mm. Yolk was clear, neither segmented nor vacuolated and left a narrow perivitelline space. All eggs collected on both days were in the same stage of development at 09.00 hr (Fig 86) with well developed head, trunk and tail. A few brownish black pigment spots were present on dorsal side of body, icluding head region. Such pigmentation was seen in oilglobule also.

Process of hatching in all eggs reared in laboratory took place between 12.00 and 14.00 hr on both days of collection. As in other mullets, the process was accompanied by twitching and turning movements of embryo, splitting of egg capsule (Fig 87) and emergence of embryo in a partly curved condition as newly hatched larva.

(b) <u>Larvae</u> (Figs 88, 89)

Newly hatched larva at 12.00 hr on

6 -2 -'78 measured 1.309 mm (Fig 88). Yolksac was large and oilglobule was located at front end of yolksac. There were minute black pigment spots all along dorsal aspect of body, from head to tail. Black spots were also present on oilglobule. A large, black pigment was observed on the body above hind end of yolksac. Alimentary canal did not appear to have been formed. About 16 myotomes could be counted in region behind yolksac; and length of larva infront of hind end of yolksac was 39.49 % of total length.

Larvae hatching out on 6 -2 -'78 were reared in laboratory for more advanced stages. In the stage examined at 10.00 hr on 7 -2 -'78, at an age of 21 hrs and measuring 1.92 mm (Fig 89), body has become considerably elongated and streamlined, but mouth has not yet been formed and eyes remained unpigmented, still marking larval condition. Larval finfold has become more prominent than in previous stage. There were three groups of black pigments on head, anterior and dorsal to eye region and another group below it. On oilglobule and at anus, black pigments and light yellowish green ones were visible. Two prominent black pigment spots, one above anal region and another a little behind it appeared to be characteristic of this stage. In middle of postanal region a vertical band of light yellowish green pigmentation was present. Alimentary canal was fairly well formed and oilglobule was still present. Depth at anal region including larval finfold was 0.4 mm and depth of body proper was 0.11 mm. Preanal length was 32 % of total; and there were 6 preanal and 18 postanal myotomes.

(c) <u>Postlarvae</u> (Figs 90 - 93)

Postlarvae were obtained by rearing eggs collected both on 6 and 7 -2 -'78. On 9 -2 -'78, at 10.00 hr, the larvae were 42 hrs old and measured 1.70mm (Fig 90). Mouth has developed as a small cleft and eyes were pigmented black. Middle region of body was the deepest, measuring 0.5 mm and it tapered gradually posteriorly. Body proper has increaded in depth, to 0.16 mm. Larval opercular cleft has developed as a constriction behind head region; and pectoral fin has developed as a membraneous, semicircular flap. Pigmentation consisted of a large, black, branching chromatophore above pectoral region, a few minute patches behind auditory region, minute black spots in chin, a large black patch at ventral aspect of visceral region and a series of minute black spots along ventral aspect of postanal region. Preanal length has become 30 % of total; and disposition of myotomes was 6 preanal and 18 postanal in this stage also.

In a 48 hrs old stage reared from an egg hatched out on 6 -2 -'78, surviving on 8 -2 -'78 and still measuring 1.70 mm (Fig 91), the principal changes recorded were reduction in depth of larval finfold, increase in size of mouth and slight increase in pigmentation in visceral region. Preanal length has become reduced to 25 % of total. Number and disposition of myotomes in this stage as well as the succeeding ones remained the same as in previous. 66 hrs old postlarva reared from eggs collected on 7 -2 -'78 and examined on 10 -2 -'78, measured 1.75 mm (Fig 92). It was characterized by disappearance of ventral series of pigments and localization of the ones in visceral region, assuming the form of six patches. Preanal proportion in this stage and the succeeding one remained the same as in previous one. In 72 hrs old specimen examined on the same day as the previous one and also measuring the same length (Fig 93), the only difference observed was a slight diffusion of pigments in visceral region and appearance of a few spots on dorsal aspect, above midbrain.

(d) Systematics

Similarities between ripe ovarian ova and planktonic eggs, particularly in diameter ranges and size of oilglobules have served to identify the present eggs as those of *L.tade*. Pillay (1954) studied "nearly ripe" ova of this species from Bengal and gave their diameter range as from 681 to 720 micra. Presence or absence of oilglobule in ova is not mentioned by the above author. As recorded by Natarajan, A.V. and Patnaik (1973) in *L.macrolepis* and as observed in *L.dussumieri* (*vide*: 3. 2. 13), there appears to be only minor variation in size of ripe ovarian ova and planktonic eggs of the concerned mullet species, owing to very little swelling of eggs due to hydration and after fertilization.

Eggs of *L.tade* could be easily distinguished from those of *Mugil cephalus* (Nair, G.S., 1957 b; Kuthalingam, 1961 c; Chaudhuri, Bhowmick, *et al*, 1978) in that the former contain a much smaller oilglobule of 0.126 - 0.188 mm diameter range than the large sized oilglobule of 0.29 - 0.38 mm diameter of the latter. Oilglobule in eggs of *M.corsula* is still larger, of 0.57 - 0.615 mm in diameter (Pakrasi and Alikunhi, 1953). In having a much small sized oilglobule, the eggs of *L.tade* resemble those of *L.macrolepis* (0.19 - 0.347 mm) and those of *L.dussumieri* (0.154 - 0.165 mm). But, eggs of *L.tade* could be distinguished from those of *L.macrolepis* in that in newly hatched larva of *L.tade* oilglobule is situated at the front aspect of yolksac while in newly hatched larva of L.macrolepis it is located at the hind end. In between newly hatched larvae of L.tade and L.dussumieri in both of which the oilglobule is situated at front end of yolksac, the main feature of difference is the presence of a vertical band of light yellowish brown pigments in middle of postanal region in L.dussumieri and its absence in L.tade.

More advanced stages of about one day old in L.tade, L.dussumieri and L.macrolepis show much more features of similarities among one another, including general pattern of pigmentation. However, larvae of L.tade and L.dussumieri could be distinguished from comparable stages of L.macrolepis in possessing a prominent ventral pigment spot a little behind anal region and in the lack of two dorsal pigment patches behind head region. And, between larvae of L.tade and L.dussumieri, the main feature of difference is the presence of dark brownish chromatophores along dorsal and ventral side of postanal vertical band in L.dussumieri and its absence in L.tade.

(E) Family Polynemidae

The "Threadfins", forming this Family are composed of the genera Polynemus, Eleutheronema and Polydactylus; and are found in marine and brackish waters, along both the coasts of India. Average annual production from this resource in the country is about 15,000 tonnes in recent years. The most important species is Eleutheronema tetradactylum, growing upto 1.8 m, supporting fisheries particularly in north-west and north-east areas.

3. 2. 16 Polynemus sextarius (Bloch and Schneider)

Among various species of polynemids occurring in the seas around India, Polynemus sextarius is one, the biology and early development of which are not known, although these aspects of some closely related species such as P.indicus, P.paradiseus and Eleutheronema tetradactylum are studied in some detail. P.sextarius is a common polynemid found at Porto Novo. During 1977 - '79 this species was observed to spawn off Porto Novo during July - September, as evidenced by occurrence of partly spent specimens in fish landings and of postlarvae in plankton.

(a) Postlarvae (Figs 94 - 97)

2.509 mm (Fig 94):- Date of collection: 10 -10 -'77.

Body was elongated with head forming the most prominent region and body tapering gradually towards hinder end. Greatest depth of postlarva was at the region of midbrain. Larval finfold was still present, although in a much reduced form. Caudal region was rounded off posteriorly and showed beginnings of a few rays. Mouth gape was large and lower jaw was slightly longer than upper. Eyes were pigmented black and postlarval opercular cleft has formed. Auditory capsule was large and viscera was short and deep. Pigmentation was rather sparse and was in the form of a few pigment patches in visceral region, one dorsally, a horizontal patch in middle, one spot at side of anus and another in ventral region of viscera. Preanal length was 50.3 % of total length; and there were 9 preanal and 14 postanal myotomes, the total number corresponding to adult vertebral number of 23.

3.60 mm (Fig 95):- Date of collection: 8 -8 -'77.

The postlarva has undergone dorsoventral expansion of body and its anterior half has undergone progressive development. Head has become much more prominent, a series of minute triangular teeth has developed in upper jaw, a few caudal fin rays have formed, dorsal and anal fin origins have been indicated in the form of median thickenings of larval finfold, branchiostegals were visible and pigmentation has increased. Infront of opercular base a triangular spine was present, directed ventrally. Pectoral fin was membraneous and semicircular. At ventral aspect of lower jaw a black, branching chromatophore has appeared; another one at the base of opercle, a prominent pigment patch behind upper end of it, one patch in the middle of hinder wall of viscera, two patches on its ventral aspect, one pigment behind head region dorsally and a series of nine spots at ventral aspect of postanal region. There was slight increase in preanal proportion of the postlarva, forming 51.3 % of total length. There were 6 preanal and 17 postanal myotomes, showing a decrease in preanal number and a corresponding increase in postanal number.

<u>4.85 mm</u> (Fig 96):- Date of collection: 10 -8 -'77.

Significant changes noted in this stage over the previous were appearance of a few conical teeth at the tip of lower jaw (teeth on upper jaw also having assumed a conical structure) and progressive development of dorsal, anal and caudal fins, most rays of caudal having become 2 to 3 jointed. Pigments in the region of viscera have become more enlarged than in previous stage. There were two pigments at the hind end of head dorsally; and in preopercular region laterally a pigment patch has appeared. When compared to previous two stages, preanal length in the present one showed a distinct reduction to 42.2 % of total length. Pre-second dorsal proportion was 54.2 % of total. Number and disposition of myotomes in this stage continued to be the same as in previous.

<u>6.52 mm</u> (Fig 97):- Date of collection: 10 -8 -'77.

Body has become much more elongated, particularly in postanal region. Dorsal and anal fins have become more prominent with about 12 dorsal, 10 anal and 20 caudal ray elements, the caudal region itself having assumed a somewhat oval shape, most of its rays showing 3 to 4 segments. In lower jaw conical teeth have appeared in middle and hinder regions also. Pigmentation continued to be almost of the same pattern as in previous stage, but for postanal region where pigmentation has become localized in the form of two patches, a small one followed by a larger one. Preanal length has become further reduced to 41.5 % of total; and pre-second dorsal length has become 50.1 % of total. Number and disposition of myotomes remained the same as in previous stage.

(b) <u>Juvenile</u> (Fig 98)

The only juvenile measuring 22.4 mm was collected from trawl catches off Porto Novo on 30 -11 -77. Body has become polynemid - like; and snout region has become prominent, making upper jaw much longer than lower one and mouth inferior in position. Along preopercular margin a series of five pointed spines was present, directed backwards. First dorsal fin showed one short and seven long spines. In second dorsal there was an anterior spine followed by twelve rays. There were 33 caudal ray elements, most of which showed 7 to 10 segments. In anal fin there were three spines followed by about 12 rays; in pelvic fin there were about 7 rays; in upper pectoral fin about 12 9 rays; and in lower pectoral fin six free filamentous rays were present. The juvenile was somewhat light brownish in colour in fresh condition and turned slightly flesh-coloured in formalin. Pigmentation was rather sparse and in the form of a group of spots below region of the two dorsal fins, above lateral line region and a few spots above preopercular region. Also, a series of pigments along the border of first two rows of scales on dorsal side was present (not shown in the figure). Preanal proportion has increased to 47 % of total length and predorsal length was 23.5 % of total.

There were 9 preanal and 14 postanal myotomes, the number and disposition corresponding to adult vertebral condition.

(c) Systematics

In 2.509 mm postlarva the number and disposition of myotomes correspond to the adult condition of 9 preanal + 14 postanal. But, in 3.60 to 6.52 mm stages there is a reduction in preanal myotome number to 6 and a corresponding increase in postanal number to 17. However, by the time development reaches juvenile stage, disposition of myotomes attains vertebral disposition as in adults, seen in 22.4 mm juvenile. Similarly, in preanal proportion of postlarvae, an initial increase takes place followed by a decrease and further increase by juvenile condition.

Bal and Pradhan (1946) have given descriptions (but not figures) of four groups or "stages" of postlarvae of Polynemus tetradactylus from Bombay, of which specimens measuring 4 - 6 mm are grouped in "stage I" and specimens upto 18 mm in "stage II". Number and disposition of myotomes in the postlarvae in relation to adult vertebral condition are not mentioned by them. And, from description given by them it appears that pigmentation in comparable stages of present material is in the form of a black spot in the upper jaw and about five black chromatophores along the base of anal fin, which is different from the present material. "Stage II" and "stage III" groups of the above authors, including specimens upto 24 mm may be compared to 22.4 mm juvenile of P.sextarius in the present studies. The former are said to show well defined characters of adult P.tetradactylus excepting general colouration of body. The four free pectoral filaments have also developed in the above species as also the six pectoral filaments in P.sextarius. Also, in P.tetradactylus a median pigment spot is said to be present at the tip of snout, unlike its absence in P.sextarius.

Sarojini and Malhotra (1952) have described larvae and juveniles of Eleutheronema tetradactylum from West Bengal, ranging from 6 to 24 mm. Of these, 6 mm stage may be compared to 6.52 mm larva of P.sextarius. The principal difference between the two is the number and disposition of myotomes which is 9 preanal and about 15 postanal marked in the figure of former as against 7 preanal and 16 postanal in P.sextarius. Apart from this, there is also difference in pigmentation, particularly in posterior region which is in the form of a row of chromatophores on either side of body from anal fin to caudal fin in E. tetradactylum, but only two pigment patches in P.sextarius. Caudal fin in E. tetradactylum is truncate in 6 mm stage, but somewhat semicircular in 6.52 mm of P.sextarius. 24 mm juvenile of the former differs from 22.4 mm of latter in having a pointed snout, only four free pectoral rays and in intensity of pigmentation. particularly in postanal region ventrally.

Jones,S. and Menon (1953) described eggs, larvae and juveniles of Polynemus paradiseus from Hooghly River. 2.5 mm larva of this species is said to be without mouth and anal opening, but position of anus is indicated near 8th myotome. This is different from 2.509 mm stage of P.sextarius in which postlarval characters are already seen. 3.60 - 4.85 - 6.52 mm stages of P.sextarius comparable to 3.5 - 4.3 - 5.6 mm stages of P.paradiseus differ from the latter in having the mouth gape not extending beyond middle of eye and in details of pigmentation. In P.paradiseus Jones,S. and Menon (op.cit) have observed development of free pectoral rays at 8.5 mm; and they extend beyond upper lobe of pectoral fin when the fish reaches 12 mm long. Such comparable stages are not available for P.sextarius; and 22.4 mm juvenile shows full complement of free pectoral rays.

Kuthalingam (1961 a) has given an account of eggs, larvae, postlarvae and juveniles of _Polynemus indicus_ reared in laboratory. 2.4 and 2.8 mm larvae described by Kuthalingam (_op.cit_) may be compared to 2.509 mm postlarva in the present account. Principal difference between the two appears to be the presence of yolk and oilglobule and higher number of myotomes, 12 preanal + 15 - 19 postanal in the former but only 9 preanal + 14 postanal in the present material. Also, 3.6 mm in the present study when compared to 3.8 mm stage given by Kuthalingam (_op.cit_) differs from the latter in that it has "about 23 preanal myotomes", stated in the text but only 12 shown in the figure, as against 6 preanal and 17 postanal in _P.sextarius_. In 9.2 mm postlarva described by Kuthalingam it is stated that there is no change in number of preanal myotomes, thus implying the presence of 23 preanal myotomes in this stage also.

Kowtal (1972) has given an account of eggs, larvae and postlarvae of _Eleutheronema tetradactylum_ from Chilka Lake. Larvae and postlarvae described by him differ from the present material principally in the different myotome number, 27 in the former and only 23 in the latter. Between 2.509 mm stage of _P.sextarius_ and 2.65 mm of _E.tetradactylum_, the latter shows some advanced features such as appearance of teeth on both jaws and more prominent head in latter than in the former. Preanal proportion in the former is 50.3 % of total length but in the latter it is only 47.6 %. 3.85 mm and 4.75 mm stages of E.tetradactylum have 9 preanal and 19 postanal myotomes while in comparable 3.6 and 4.85 mm stages of P.sextarius there are only 6 preanal and 17 postanal myotomes. Besides, in E.tetradactylum preanal length shows a reduction from 43.6 % in 3.85 mm stage to 41.1 % in 4.75 mm stage, while in the present material the reduction is from 51.3 % in 3.60 mm stage to 42.2 % in 4.85 mm stage. In 4.75 mm stage described by Kowtal (op.cit), chromatophores along the base of anal fin are stated as aggregating at five or six places, small black chromatophores near maxillary symphysis and on upper side of pectoral fin. In these respects pigmentation in early life history stages of E.tetradactylum differs from that in early life history stages of P.sextarius.

(F) Family Sillaginidae

Family Sillaginidae comprising the "whitings" and represented by the genera Sillago, Sillaginodes and Sillaginopsis is mostly marine and brackish water, distributed in Indo-Pacific region. Two valid species of commercial importance are reported from India, Sillago sihama and S.maculata. These differ from each other by the presence of conspicuous dark blotches on back and flanks in the latter and absence of such blotches in the former, apart from other characters.

3. 2. 17 Sillago sihama (Forsskål)

Sillago sihama, popularly called "Indian sand whiting" is a much valued fish of both capture and culture importance. Although not cultured on a commercial scale as yet, potentialities for such operations are being experimented upon. Length frequency distribution and aspects of maturity and spawning at Karwar were investigated by Palekar and Bal (1960; 1961); aspects of biology in south-east coast were studied by Radhakrishnan (1954; 1957); and eggs and larvae from Japan were reported by Ueno, Senta and Fujita (1958).

(a) Postlarvae (Figs 99 - 104)

A large number of postlarvae was collected from plankton off Porto Novo during August and September 1977, of which the following six could be considered as representative.

2.87 mm (Fig 99):- This was an early postlarval stage in which mouth was formed, eyes were pigmented but a large amount of granulated yolk was still present and larval finfold was quite prominent. Head was the most prominent part, followed by visceral region and a gradually tapering postanal portion. Lower jaw was slightly longer than upper; and pectoral fin appeared as a circular membraneous area in visceral region laterally. There was a pigment spot at anterior aspect of head, a few pigments in anterior and dorsal aspect of viscera and a series along ventral aspect of postanal region. Fine striations of larval finfold could be seen in caudal end. Preanal length was 37.4 % of total; and there were 7 preanal and 27 postanal myotomes.

3.29 mm (Fig 100):- More important changes noticed in this stage over the previous were formation of larval opercular cleft, reduction in preanal length to 29 % of total, increasing polarization of pigments in visceral and postanal regions and increase in caudal striations. Also, pigment spots have appeared at ventral aspect of viscera. Number and disposition of myotomes in this stage as well as the following two remained the same as in previous one.

3.54 mm (Fig 101):- There was a slight increase in pigmentation at this stage, in the form of two spots at lateral aspect of opercular cleft. Striations have appeared in pectoral fin flap and ray like formations were seen in caudal region, which has assumed a rather truncated shape. Preanal part of the specimen has increased in length, forming 34 % of total.

3.67 mm (Fig 102):- The significant feature of development in this stage was further increase in preanal length to 39 % of total. Pigmentation on ventral aspect of viscera in this as well as previous stages was in the form of a transverse band along its anterior aspect, a patch at its hinder end and two branching chromatophores in between the above two. Postanal pigmentation was in the form of 14 spots ventrally, commencing from a little behind anus.

5.83 mm (Fig 103):- Anal fin in this stage has developed in the form of about 10 rays behind anus on larval finfold, which has become considerably reduced, particularly dorsally. Caudal fin has assumed a truncated shape with indications of a number of rays. Pectoral fin has become somewhat fan shaped and pelvic fin has appeared as a membraneous structure with indications of a few minute rays infront of anal region. Head has become much prominent with greatest depth of the postlarva at the region of midbrain. A few minute conical teeth have appeared in upper jaw. Pigmentation has increased further with a black pigment patch ventrally below level of eyes and another patch a little behind, infront of opercular base. Visceral pigmentation was in the form of a patch above midgut and three pigment patches along base of pelvic fin. Behind opercular region ventrally there were three pigments one infront and two behind pectoral region. Preanal length has increased further, amounting to 40.5 % of total length. There was an increase in number of preanal myotomes to 11 and a decrease in postanal number to 23, obviously by backward shifting in position of anus.

6.85 mm (Fig 104):- This stage was characterised by development of second dorsal fin in the form of about 23 independant rays in postanal region of the body, further development of anal fin with 20 rays and rhomboidal appearance of caudal fin with about 18 rays most of which were segmented 3 to 4 times. Larval finfold has become further reduced and pigmentation has increased particularly in visceral region, with the appearance of a few pigments ventrally. Infront of origin of anal fin a prominent pigment was present, followed by about 18 spots along anal base and a continuous patch behind it, extending upto caudal peduncle. Also, a single partly sunken pigment spot was present in auditory region. Preanal length has further increased to 41.2 % of total length; and predorsal proportion was 46.4 % of total. Number and disposition of myotomes continued to be the same as in previous stage.

(b) Juveniles (Figs 105 - 107)

The following juvenile stages collected in fry net catches at the mouth of Vellar Estuary appeared to be representative in juvenile phase of development.

8.38 mm (Fig 105):- Head continued to be the most important part of the juvenile and postcephalic region tapered gradually towards hinder end. Lower jaw continued to be longer than the upper and a few minute conical teeth have appeared on it also. First dorsal fin has developed in this stage with about 7 spines; and second dorsal fin contained about 21 rays. Pelvic fin has shifted its position from postlarval condition infront of anus to a much forward location below level of pectoral fin. Precise number of rays in pelvic fin could not be ascertained. Caudal fin has developed the beginning of bifurcation with a curvature at its hinder margin. A partly sunken pigmented area has appeared at hind end of brain dorsolaterally. Ventrally, behind larval opercular cleft a pigment was present; at the base of anal fin a series of 15 pigment spots; behind second dorsal fin two patches; laterally infront of caudal peduncle two patches; and along base of caudal fin dorsoventrally a series of pigment spots were present. Preanal length remained almost the same in relation to total as in previous stage; but disposition of myotomes has changed to 12 preanal and 22 postanal. Predorsal proportion was 33 % of total length. The juvenile has assumed a somewhat pale yellowish colouration as in adults, as different from whitish colour of postlarvae.

11.37 mm (Fig 106):- No significant change was observed over the previous but for increase in bifurcation of caudal fin, appearance of a few pigments at the base of lower caudal lobe and anal region. Pale yellowish colouration observed in the previous stage was present in this stage as well as the following ones.

<u>19.06 mm</u> (Fig 107):- Principal changes observed in this stage were increase in number of spines and rays in the fins: first dorsal to 9 spines, second dorsal to 22 rays, anal to 24 rays and pelvic to about 6 rays. Pigmentation has increased, as a group above and behind eyes, two dorsolateral pigments at hind end of head and one pigment in the middle of upper jaw. Disposition of myotomes was 14 preanal and 20 postanal, as in adult condition.

A few more juveniles in size range of 50 mm - 150 mm collected in fry net catches were available for study. These conformed to adult condition in all essential features, but showed a gradual increase in proportion of preanal length. Thus, in 50 mm juvenile preanal length was 40 % of total, as also observed in the previous juvenile stages; but in a 56 mm juvenile preanal length was 44 % of total and in a 150 mm stage it was 48 %. These facts showed a secondary backward shifting in position of anus.

(c) <u>Systematics</u>

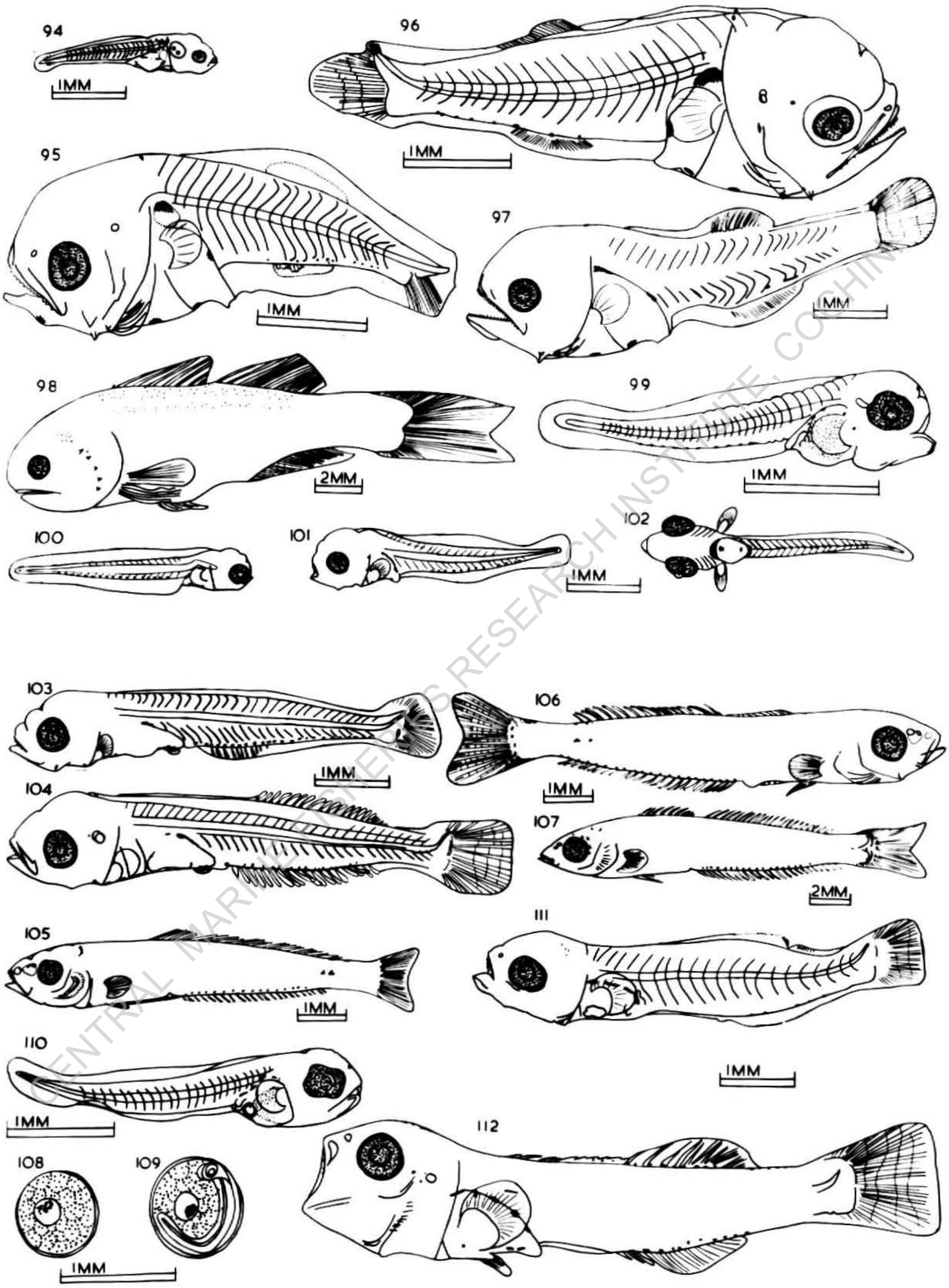
Based on presence of mature and spent specimens of <u>S.sihama</u> at Porto Novo and occurrence of postlarvae and juveniles in plankton and fry net

PLATE VIII

Figures 94 - 98. Postlarvae and juveniles of *Polynemus sextarius*: Figs 94 - 97. Postlarvae, Fig 94. 2.509 mm; Fig 95. 3.6 mm; Fig 96. 4.85 mm; Fig 97. 6.52 mm; Fig 98. 22.4 mm juvenile.

Figures 99 - 107. Postlarvae and juveniles of *Sillago sihama*: Figs 99 - 104. Postlarvae, Fig 99. 2.87 mm; Fig 100. 3.29 mm; Fig 101. 3.54 mm; Fig 102. 3.67 mm; Fig 103. 5.83 mm; Fig 104. 6.85 mm; Figs 105 - 107. Juvenile stages, Fig 105. 8.38 mm; Fig 106. 11.37 mm; and Fig 107. 19.06 mm.

Figures 108 - 112. Eggs and postlarvae of *Gerres oblongus*: Figs 108 and 109. Eggs in two stages of development, in formalin; Figs 110 - 112. Postlarval stages, Fig 110. 2.91 mm; Fig 111. 6.07 mm; Fig 112. 8.58 mm.


94
1MM
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106
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107
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1MM
111
110
1MM
1MM
112
108
109
1MM

collections in coastal areas, it is obvious that spawning season of this fish in Porto Novo lasts from about July to October. In adults of S.sihama there are 34 vertebrae, 14 preanal and 20 postanal. In postlarvae however, disposition of myotomes is 7 preanal and 27 postanal in 2.87 and 3.29 mm stages, 10 + 24 in 3.54 and 3.67 mm, 11 + 23 in 5.83 mm, etc, thus showing a gradual increase in preanal myotome number and a corresponding decrease in postanal number, till adult condition is attained in an advanced juvenile stage.

Earlier work on development of S.sihama is that of Ueno, Senta and Fujita (1958) from Japan. 2.87 mm postlarva when compared to 2.6 mm stage described by the above authors appears to be in a slightly later stage of development and shows difference in pigmentation at preanal part of body ventrally. Alimentary canal in the above larva described by Ueno, et al (op.cit) appears to be elongated, but in the present material it is much shorter. Also, preanal length in the former is 45.7 % of total length* while in the latter it is only 37.4 %. Further, 3.1 mm postlarva described by them shows an increase in preanal length to 45.8 % while in 3.29 mm postlarva of present study there is a reduction in preanal length to 29 %. Similarly, in 5.9 mm of above authors preanal length

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* Percentages based only on the figures given by the above authors and not based on any description.

has become further reduced to 43.8 % of total length while in the present 5.83 mm postlarva, it is only 40.5 % of total. Further reductions to 41 % and 40.3 % are registered in the postlarva of 9 mm and juvenile of 15.5 mm respectively given by Ueno, et al (op.cit); but in 6.85 mm postlarva and 8.38 mm juvenile in the present account preanal length is about 41 %, thus almost reaching the condition as in the above two stages from Japan. In the present postlarvae, reduction in proportion of preanal length was noticed in early stages, from 2.87 mm to 3.29 mm stage, followed by a gradual increase till 150 mm juvenile condition. But, in the Japanese material there is a reduction from 53.2 % in newly hatched larva to 45.7 % in 3 days old (2.6 mm) and further reduction in later stages till reaching 40.3 % in 15.5 mm. In later stages figured by Ueno, et al (1958) there is a gradual increase in preanal proportion from 42.4 % in 13.3 mm juvenile to 44 % in 22.4 mm juvenile. These facts show that although in postlarval development of S.sihama described by Ueno, et al (op.cit) from Japan there is a gradual reduction in preanal proportion, in juvenile development there is a distinct increase. It is not known as to whether such differences are related to geographical differences or to specific or subspecific factors, if any.

(G) Family Gerreidae

The "silver biddies" or "Mojarras" constituting this Family are represented by two known genera of commercial value in Indian waters, *Gerres* and *Pentaprion*. The former can be distinguished from the latter in having an anal fin shorter than soft part of dorsal and having 2 to 4 spines and 7 to 10 rays, as against anal fin longer than soft part of dorsal as well as 5 to 6 spines and about 12 rays in anal fin of latter genus. They are usually marine and brackish water, rarely entering fresh water. *Gerres filamentosus*, *G.oyena*, *G.oblongus*, *Pentaprion longimanus*, etc are commonly found along both coasts of India and are important food fishes.

3. 2. 18 *Gerres oblongus* Cuvier

Gerres oblongus is commonly found in Porto Novo, caught in trawlers, shore-seines, etc. It is also observed in Vellar Estuary and adjacent brackish water areas. A perusal of literature shows that little is known on its fishery and biology.

(a) Eggs (Figs 108, 109)

Two eggs collected from plankton on 10 -10 -'77 and preserved in formalin were identified as those of G.oblongus. They were spherical, ranging in diameters from 0.63 to 0.73 mm, provided with a pigmented oilglobule of 0.21 mm and vacuolated yolk, leaving a perivitelline space. In an earlier stage of development (Fig 108) there was no indication of embryo; and in a later stage (Fig 109) the embryo appeared to be fully formed. Mature, Stage V ovaries of this species examined during this period contained ova of 0.4 - 0.5 mm diameter.

(b) Postlarvae (Figs 110 - 112)

2.91 mm (Fig 110):- Date of collection: 9 -10 -'77.

This was an early postlarva, in which mouth was formed, eyes not fully pigmented but showing a brownish colouration and yolk was not yet fully utilized. Larval finfold was still prominent and the most prominent part of postlarva was its head, from which body tapered gradually towards hinder end. Pectoral fin has already developed, was membraneous and somewhat semicircular. A black pigment spot was present on forehead and a series of partly sunken chromatophores along dorsal margin of viscera. Preanal length was 32.6 % of total length; and there were 7 preanal and 17 postanal myotomes.

6.07 mm (Fig 111):- In this stage, collected on the same day as the previous one, body has become more deep, eyes have become pigmented, larval finfold has become considerably reduced, dorsal and anal fins were indicated and caudal fin was formed with about 18 rays most of which were 2 to 3 segmented. Lower jaw was longer than upper, the latter showing a few minute conical teeth. Pigmentation consisted of four long pigment patches in visceral region dorsally and a series of patches along base of anal fin. Preanal proportion has increased more, forming 37.4 % of total length. Number and disposition of myotomes in this stage and the following one continued to be the same as in previous one.

8.58 mm (Fig 112):- Date of collection: 12 -10 -'77. Body has become elongated, first dorsal fin was indicated and all fins were in progressive stages of development. In second dorsal fin about 14, in caudal about 18 and in anal about 10 rays were present. Caudal fin has assumed a truncated shape; pectoral fin rays have become more marked; and pelvic fin has developed as a paddle shaped structure below visceral region. Pigmentation was in the form of a few spots on dorsal aspect of head behind eye region, a spot at the base of pectoral fin, a series of five large pigment patches on dorsal aspect of viscera, two patches at ventral aspect of hindgut, one pigment streak in midlateral region anteriorly, a series of spots and patches from middle region of first dorsal till region of caudal peduncle at the base of dorsal fins and a similar basal patch from beginning of anal fin till caudal peduncle. Preanal length has become further longer, forming 38.1 % of total length. Pre-first dorsal length was 32.5 % and pre-second dorsal length was 46.5 % of total length.

(c) Juveniles (Figs 113, 114)

13.16 mm (Fig 113):- Much more progressive changes have taken place in this stage collected from fry net catches at mouth of Vellar Estuary on 15 -10 -'77. Body has become more streamlined, mouth has developed a characteristic protrusible condition, first dorsal has developed 9 spines, second dorsal had about 10 rays, caudal fin has become distinctly forked with about 36 segmented rays, anal fin with 3 spines and about 9 rays and pectoral as well as pelvic fins were more clearly defined. Pigmentation consisted of a group of branching chromatophores at hind region of head dorsally, two branching chromatophores behind upper end of preopercle, a patch at margin of opercle in middle, a branching chromatophore at base of operculum, a group of partly sunken pigments in visceral region, two prominent branching chromatophores one at hind end of first dorsal and the other at the hind end of second dorsal, a series of seven chromatophores along base of anal fin, two behind it and two vertical patches at base of caudal fin laterally. Preanal length has become slightly more increased, to 39.8 % of total length. Pre-first dorsal and pre-second dorsal proportions were 30.7 % and 46.3 % respectively of total length.

<u>17.08 mm</u> (Fig 114):- In this stage, also collected on the same day as the previous one, pigmentation has further increased, but not significantly, over previous stage. At hind end of first dorsal fin three branching chromatophores could be seen instead of one as in previous stage, followed by a single chromatophore further behind; and, in caudal peduncular region laterally, two chromatophores have appeared. Pectoral fin has become somewhat triangular; and preanal region has become much more long in proportion, forming 44.5 % of total length. Pre-first dorsal and pre-second dorsal lengths were 27.3 % and 46.3 % of total length respectively.

(d) Systematics

As judged by appearance of mature and spent specimens in local catches, G.oblongus may be said to breed off Porto Novo during September - November period. Identification of present eggs as those of G.oblongus is based on size of mature ova examined and size range of preserved planktonic eggs. Vacuolated condition of yolk and pigmentation of oilglobule are characteristic of the eggs of Gerreidae, as earlier sketched by Rass (1972). Number and disposition of myotomes tallying with adult vertebral condition are confirmatory of their identification. The only other species of Gerres found in mature and spawning condition at Porto Novo during September - November, 1977 was G.setiferus, but postlarvae of it can be differentiated from the present ones in difference in pigmentation and number of first dorsal spines (vide: 3. 2. 19).

Nair, R.V. (1952 c) has given an account of juvenile stages of G.lucidus (G.setiferus), the smallest one of which measured 12 mm. There are many features of resemblence between description and figures given by him and 17.08 mm in present account, particularly pigmentation. G.setiferus has 10 dorsal spines; but, in the specimen described by Nair, R.V. (op.cit) there are only 9 spines, indicating that the specimen described by him actually belong to *G.oblongus* and not to *G.setiferus*.

Shojima (1958 b) has dealt with a few advanced postlarvae and juveniles of *G.oyena* from Japan. While comparing 8.58 mm postlarva of *G.oblongus* to an almost equal sized stage, 9.2 mm of *G.oyena*, it appears that developmental sequence in the former is considerably lagging behind, particularly shown by early stages in development of dorsal and caudal fins. But, 13.16 mm stage of *G.oblongus* appears to be in almost the same developmental sequence as 13.2 mm of *G.oyena*. 17.08 mm of former differs from 18.7 mm of latter mostly in its pigmentation.

3. 2. 19 *Gerres setiferus* (Hamilton)

Gerres setiferus is another species of silver biddy commonly found in Porto Novo and spawning almost during the same period as *G.oblongus* (*vide*: 3. 2. 18). It may be easily distinguished from other species of the genus in the presence of 10 dorsal spines as against 9. Earlier work on this species includes description of a juvenile by Nair (1952 c). In the present section three postlarvae and one juvenile are described.

(a) Postlarvae (Figs 115 - 117)

7.65 mm (Fig 115):- This stage as well as the following two were collected from plankton on 9 -10 -'77. Body was elongated and head was prominent, tapering gradually towards tail. Dorsal fins, caudal, anal, pectoral and pelvic fins were in progressive stages of development. Mouth appeared protrusible already. There were 4 first dorsal spines, 8 second dorsal rays and 14 caudal rays. Pectoral fin was membraneous and semicircular, but rays in it as well as in pelvic fin were not quite discernible. Caudal fin appeared somewhat rhomboidal. Pigmentation was characteristic and in the form of a few patches at mouth, tip of lower jaw, anterior and ventral to eye, a spot at base of operculum, a streak of partly sunken pigments from postoptic region till viscera, a series of about seven branching patches from middle of dorsal fin till caudal peduncle dorsally, a midlateral series from level of second dorsal till caudal, a prominent streak of pigments from behind pectoral till middle of anal and another streak at the base of lower caudal region. Preanal length was 46.2 % of total length. Pre-first dorsal and pre-second dorsal proportions were 34.9 % and 44.4 % of total respectively. There were 10 preanal and 14 postanal myotomes.

<u>9.58 mm</u> (Fig 116):- Body has become more elongated and streamlined; and caudal fin showed an early stage of bifurcation. First dorsal fin contained 9 spines, second dorsal about 12 rays and caudal about 30 segmented rays. In anal fin there were 3 spines followed by about 9 rays. Precise number of pectoral and pelvic rays was not yet discernible. Pigmentation has become more diffused and intensified. There was a prominent group of branching chromatophores on head dorsally, one below and two behind eye, one patch at base of operculum, another at middle of opercular margin, a dorsal series of branching pigments along base of dorsal fins extending upto caudal, a ventral series along base of anal fin extending upto caudal and a midlateral series from visceral region till urostyle. Preanal length in this stage has become further reduced to 40.7 %. Pre-first dorsal and pre-second dorsal proportions were 29.4 % and 49 % respectively of total length. Disposition of myotomes has changed to 7 preanal and 17 postanal.

<u>10.54 mm</u> (Fig 117):- Significant changes noted in this stage over previous one were more marked bifurcation of caudal fin and increase in number of first dorsal spines to 10 and anal fin rays to 10. About 8 pectoral and 5 pelvic rays were

discernible. Pigmentation remained almost as in previous stage. Preanal length has become further reduced to 37.4 %; but, number and disposition of myotomes remained as in previous one. Pre-first dorsal and pre-second dorsal lengths were 31 % and 50 % of total length respectively.

(b) Juvenile (Fig 118)

The only juvenile stage available, measuring 25.08 mm was collected from from fry net catches at the mouth of Vellar Estuary on 15 -10 -'77. Body has already assumed most of Gerreid features. There were 10 dorsal spines, 12 dorsal rays, 36 caudal rays, 3 anal spines and 9 rays, about 10 pectoral rays and one pelvic spine followed by about 7 rays. Pigmentation pattern remained almost the same as in previous postlarval stage with characteristic midlateral series. Preanal proportion has registered an increase to 42.3 %. Pre-first dorsal and pre-second dorsal lengths were 26.5 % and 48.1 % of total length respectively. In a similar sized specimen, disposition of vertebrae has become 9 preanal and 15 postanal.

(c) Systematics

Total number of vertebrae in adults namely 24 tallies with the myotome count of postlarvae;

and their number as well as disposition namely, 9 preanal + 15 postanal in adults as well as the juvenile in present collections are identical. In G.setiferus there are 10 dorsal spines while in other species there are only 9 dorsal spines. As such, presence of 10 dorsal spines in an advanced postlarva (10.54 mm), attaining adult condition is confirmatory of its identity. In smaller postlarvae (7.65 and 9.58 mm), dorsal spines are only under progressive formation and hence their number is different from adult condition. But, presence of characteristic pigmentation in postlarvae, particularly the midlateral series in both the stage recognizable as of G.setiferus as well as in the younger ones, serves to link the latter with the former.

Early postlarvae of G.setiferus may be distinguished from those of G.oblongus by the midlateral series of pigments; and advanced postlarvae as well as juveniles may be differentiated from those of G.oblongus by this character as well as by difference in number of dorsal spines, already specified. Nair,R.V.(1952 c) described a juvenile of G.lucidus from Madras. But, as discussed in the previous section (3. 2. 18), the juvenile described by Nair,R.V. appears to belong to G.oblongus and not to G.setiferus.

(H) Family Theraponidae

Popularly called "Tiger perches", this Family contains three genera, Therapon, Pelates and Helotes, distributed in coastal waters of Indo-Pacific. Although not esteemed as good quality food fishes, these are eaten by poor section of people. Therapon jarbua, T.theraps, T.puta, Pelates quadrilineatus, etc are the common species found along both the coasts of India.

3. 2. 20 Therapon jarbua (Forsskål)

Therapon jarbua is a common Tiger perch found in shallow waters, estuaries, lagoons, backwaters, etc. It is very often found in brackish water culture ponds, causing damage to fish or prawns stocked, because of its predatory habit. At Porto Novo, this species is found to be a common one, although two others have also been recorded, viz, Therapon theraps and Pelates quadrilineatus. Apart from passing references, important work on this species from Indian waters include that of Chacko (1950) on eggs and larva, Nair,R.V.(1952 c) on a few juveniles and Prabhu (1956) on maturity and spawning.

(a) Eggs (Figs 119, 120)

Eggs were collected on two occasions, one on 9 -2 -'78 and another on 22 -3 -'78. They were pelagic, spherical, ranged in diameters from 0.722 to 0.755 mm and contained a large oilglobule measuring 0.44 - 0.45 mm in diameter. They were found aggregated to floating organisms like *Evadne* and their separation from such organisms by a pipette was not quite easy. Perivitelline space was rather narrow; yolk was unsegmented and nonvacuolated, without any pigmentation; but presented a dark, glistening appearance. Oilglobule was highly pigmented with a cluster of black, stellate and branching melanophores and light greenish reticulation. Apart from this, the oilglobule also showed a rather dark, glistening appearance.

Two stages in development of embryo were available for study. In an earlier stage of development collected on 22 -3 -'78 (Fig 119), embryo was indicated with head and trunk and black pigment spots on head and light greenish pigments in postcephalic region and trunk. In a later stage collected on 9 -2 -'78 (Fig 120) embryo was almost fully formed with myosepta and black pigment spots on body.

(b) Larvae (Figs 121 - 123)

Egg collected on 22 -3 -'78 hatched out

at 15.30 hr on the same day. Newly hatched larva (Figs 121, 122) measured 1.67 mm long, was short, sturdy and somewhat oval in shape with its greatest depth in middle of yolksac. Larva was excessively pigmented, mostly in the form of light greenish pigmentation along sides of body excluding larval finfold. Also, a series of black pigment spots was present extending along base of finfold from postcephalic region till tail. Light black pigments were present posterior to eye region and above middle of yolksac. Oilglobule was situated at hind end of yolksac with light greenish pigments all along and with black, branching melanophores on its dorsal and ventral aspects. Preanal length was 64.7 % of total. Myosepta were not distinctly discernible due to excessive pigmentation; but, about 17 preanal and 8 postanal myotomes could be made out.

12 hrs old larva (Fig 123) obtained by rearing an egg collected on 9 -2 -'78 and hatching it, has increased in size to 2.2 mm long. Body has become elongated, but not streamlined. Yolksac has become considerably reduced in size and body was excessively pigmented with light greenish reticulate pigmentation all along viz; from postoptic region till anus and a band of pigments in postanal region. Also, two groups of black pigment spots were present at anterior and

dorsal aspects of yolksac, three groups above anal region and two a little infront of it. The still existing oilglobule had light greenish reticulate pigmentation with a dark colouration at its ventral aspect. Eyes remained unpigmented still, except for presence of a few minute black pigment spots on its hinder aspect. Mouth was not yet formed and preanal length has become reduced to 55.4 % of total. Postanal myosepta were fairly well discernible, showing about 12 myotomes; and myosepta in preanal region were very much obscured, by excessive pigmentation.

(c) Postlarvae (Figs 124 - 127)

2.27 mm (Fig 124):- This stage was obtained by rearing an egg collected on 22 -3 -'78 and living till 24 -3 -'78, when it was 64 hrs old. There was not much increase in its length when compared to 12 hrs old larva; but body has become more streamlined and increased in depth. Eyes have become pigmented, mouth and pectoral fin have developed and yolk was almost fully utilized, marking early postlarval condition. Head and trunk formed the most prominent part of postlarva with postanal region gradually tapering behind. Pectoral fin appeared as a membraneous fold. Pigmentation consisted of black, branching chromatophores along dorsal aspect of alimentary canal, two above it on trunk, a patch above anal region, a partly sunken black pigment spot in snout, another one at hind end of brain, three spots below eye region, a few light brownish branching pigments on lateral side of body in its middle, a patch behind eye and a diffused area below pectoral fin. Preanal proportion as well as number and disposition of myotomes remained the same as in previous larval condition.

4.09 mm (Fig 125):- Date of collection: 18 -2 -'78.

This stage showed many progressive features in its development. Head has become further enlarged, dorsal and anal fins were indicated as median thickenings of finfold, caudal region was under progressive development with indications of many rays and pigmentation has increased. Precise number of rays in dorsal and anal fins was not quite discernible and pectoral fin still remained membranceous, without well marked rays. Pigmentation consisted of a patch at tip of snout, a larger one a little behind it, a patch at the tip of lower jaw, another a little behind it, four patches of downwardly branching chromatophores in trunk and tail dorsally, a series of pigments along midlateral line, another series of 6 or 7 patches along ventral aspect of body, a much expanded and downwardly branching patch at dorsal crest of viscera, two patches behind eye region, one infront and another behind opercle and a series in preanal region ventrally ending at lower angle of preopercle. Preanal length has registered a slight decrease to 53.5 % of total; and predorsal length was 51.5 % of total. Myosepta were discernible clearly, there being 10 preanal and 15 postanal.myotomes.

5.05 mm (Fig 126):- This postlarva collected from fry net catches on 12 -3 -'78 did not show significant features of difference from previous one. All fins were in progressive development with about nine dorsal, 18 caudal and 8 anal rays, most of caudal rays being 3 to 5 segmented. A stellate pigment patch has appeared dorsally in front of dorsal fin; in preopercle four triangular spines have developed; pelvic fin was not yet formed; and pectoral fin showed indications of rays. Preanal length has become further reduced to 52.5 % of total; and predorsal length 52.8 %. Number and disposition of myotomes continued to be the same as in previous stage.

11.36 mm (Plate X, Fig 127):- This stage, also collected on the same day and from the same place (mouth of Vellar Estuary), showed disappearance of most of postlarval characters and appearance of many juvenile features. Body has become much more streamlined, elongated and resembling juveniles. Apart from dorsal fin of previous stage which in fact has represented second dorsal fin, the first dorsal has appeared in this stage, with 11 spines, followed by one spine of second dorsal and about 9 rays. Caudal fin contained about 34 rays, most of which were segmented 5 to 6 times. Anal fin had 3 spines and about 7 rays; pelvic fin had one spine and a few rays and pectoral fin had about 14 rays. Pigmentation consisted of a few spots in snout, one in lower jaw, a group at dorsal aspect of head, a few at opercular region, partly sunken pigments in visceral region, two rows of branching chromatophores at bases of dorsal and anal fins and a series of minute pigments along midlateral line. Upper opercular spine characteristic of Therapon, has appeared. Preanal region has become further reduced to 45.8 % of total length. Pre-first dorsal and pre-second dorsal proportions were 27.3 % and 48 % respectively of total length. Number of preanal myotomes has decreased to 9 and that of postanal myotomes increased to 16, corresponding to adult vertebral disposition.

(d) Systematics

Spent females of T.jarbua was observed in fish catches at Porto Novo coinciding with

PLATE IX

Figures 113 and 114. Juvenile stages of *Gerres oblongus*, of 13.16 mm and 17.08 mm respectively.

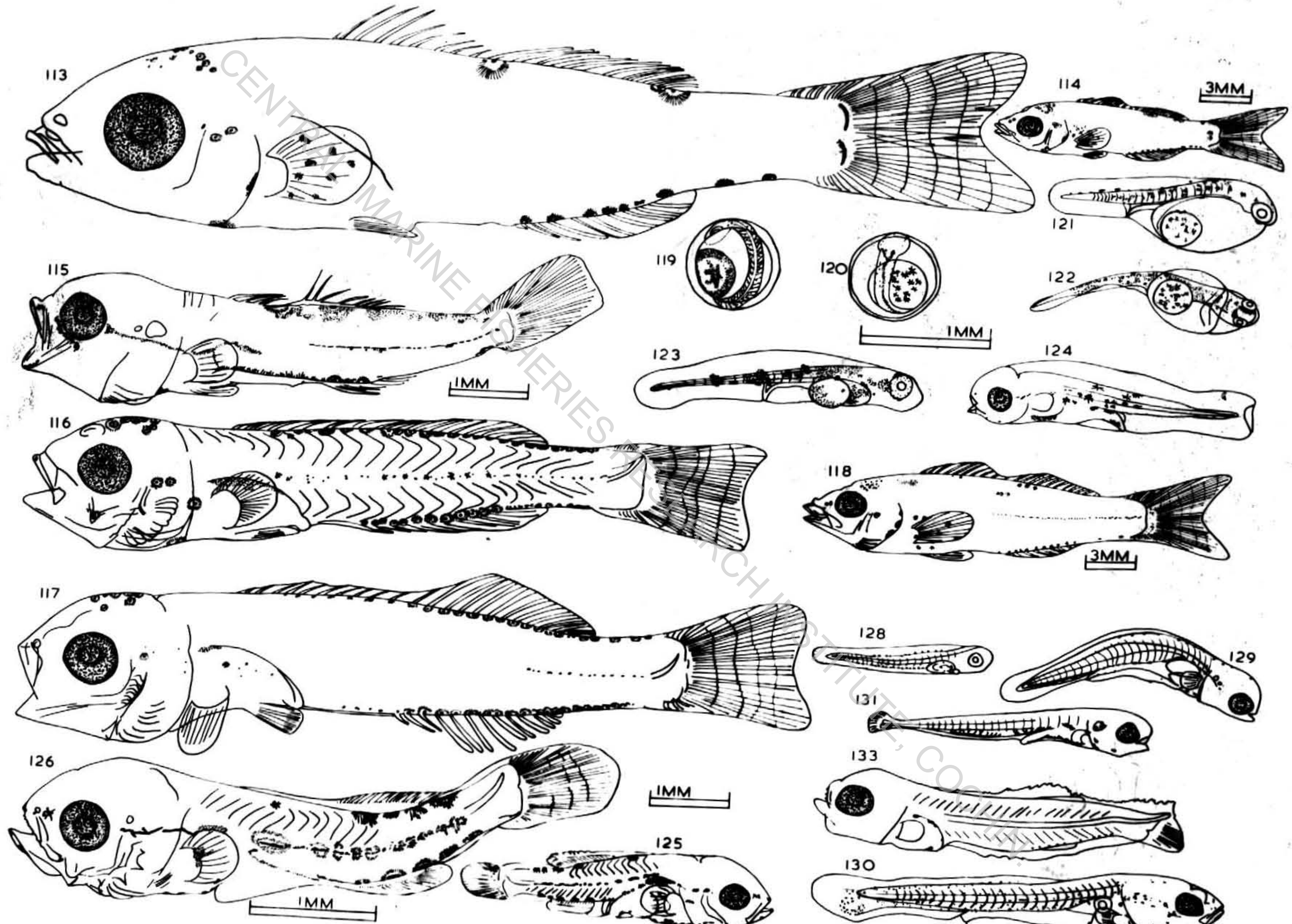
Figures 115 - 118. Postlarvae and juvenile of *Gerres setiferus*: Figs 115, 116 and 117. Postlarvae of 7.65 mm, 9.58 mm and 10.54 mm respectively; Fig 118. Juvenile of 25.08 mm

Figures 119 - 126. Eggs, larvae and postlarvae of *Therapon jarbua*: Figs 119 and 120. Eggs in two stages of development; Figs 121 and 122. Lateral and ventrolateral views respectively of newly hatched larva; Fig 123. 12 hrs old larva; Figs 124 - 126. Postlarval stages, Fig 124. 62 hrs old; Fig 125. 4.09 mm; and Fig 126. 5.05 mm.

Figures 128 - 130. Larva and postlarvae of *Upeneus bensasi*: Fig 128. 2.29 mm larva; Figs 129 and 130. 3.74 and 5.3 mm postlarvae respectively.

Figure 131. 2.13 mm postlarva of *Lates calcarifer*.

Figure 133. 4.81 mm postlarva of *Siganus javus*.


113
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3MM
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1MM
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1MM
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3MM
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1MM
133
125
1MM
130

occurrence of eggs and postlarvae in plankton and fry net catches respectively. Total number of myotomes in larvae and postlarvae and adult vertebral number are identical; and in late postlarval stages disposition of myotomes also corresponds to adult condition. At Porto Novo two other species belonging to the Family Theraponidae were observed, namely *Therapon theraps* and *Pelates quadrilineatus*. An examination of vertebral counts of these two species showed only 24 vertebrae in them, as against 25 in *T. jarbua*. By this difference in vertebral number, larvae and postlarvae of *T. jarbua* could be distinguished from those of the above two species.

Chacko (1950) gave brief notes on eggs and larva of *T. jarbua* from around Krusadi Island. The diameter range of eggs came across by him was 0.4 - 0.5 mm, but in the present case the eggs ranged in diameters from 0.722 to 0.755 mm. There is no mention of presence or absence of an oilglobule or of pigmentation by Chacko (*op. cit*); but, it may be noted here that in eggs of perches an oilglobule is usually present and larvae are highly pigmented. Regarding the difference in size of eggs between the two cases, it may be pointed out that mature ova of this species (not the ripe ones) studied by Prabhu (1956) from the same region ranged in diameters from 0.35 to 0.45 mm. It is obvious that in further development of ova reaching ripe condition before extrusion, the ova would become larger in size than in the mature stage given by Prabhu (op.cit). And, the size of planktonic eggs given in the present account could be the expected one from the size of mature ova; and the diameter range of 0.4 - 0.5 mm given for planktonic eggs by Chacko (1950) appears much smaller when compared with 0.35 - 0.45 mm given for mature ova by Prabhu (op.cit). The latter author, based on ova diameter studies undertaken, states that spawning in this species is short and restricted to a definite period only once in an year, from February March. This seems to be the case in Porto Novo also as observed by occurrence of eggs and postlarvae restricted only to these two months.

Nair,R.V.(1952 c) has described a few juveniles, of which the smallest one is 12 mm in length. From a description given by Nair,R.V.(op.cit) it appears that the specimen dealt with by him have assumed most of juvenile characters. Blanco and Villadolid (1951) have described a specimen of Therapon plumbeus 16.5 mm long and given the figure of a 10 mm long one from Philippines. From description and figure given, it is obvious that the stages described by the above authors are in more advanced developmental condition than the longest postlarva of T. jarbua dealt with in the present account. However, the 12 mm stage of an unidentified species of Therapon described by them shows some similarities to 11.36 mm postlarva of T. jarbua. No mention is made by them in the text about number of myotomes present in the specimen; but from the figure given, about 35 myotomes appear to be present; and hence, it should belong to a species having a vertebral number of about 35.

(I) Family Mullidae

Family Mullidae comprising "Goat fishes" or "Red mullets" is represented in Indian waters by the genera Upeneus, Mulloidichthyes, Parupeneus and Upeneichthyes. They are all valuable food fishes, including species such as Upeneus (Upeneus) vittatus, U.(U.) sulphureus, U.(Pennon) bensasi, U.(P.) tragula, etc, found along both coasts of India.

3. 2. 21 Upeneus (Pennon) bensasi (Temminck & Schlegel)

Upeneus (Pennon) bensasi has a wide distribution from east coast of Africa through seas of India, Indonesia, Philippines and further northwards to Taiwan, eastern China and southern Japan. It appears in fairly good numbers in trawl catches off Porto Novo. Apart from the account given by Thomas (1969) on systematics of this species, little is known on its fishery and biology from Indian waters. Shojima (1958 a) has given an account of larvae and juveniles of Upeneus bensasi from Japan. In the present section, one larval stage and two postlarvae, all collected on 3 -11 -1978 are described.

(a) Larva (Pl IX, Fig 128)

The stage measuring 2.29 mm was in an early larval condition, with a prominent finfold, unpigmented eyes and without mouth. Caudal region showed indications of a few rays in the form of striations. Alimentary canal did not appear to have been fully established, as could be seen from absence of anus. An oilglobule was present at anterior aspect of visceral region. Pigmentation consisted of two series of black spots one along dorsal and another along ventral aspects of body proper, the former extending from postcephalic region till hinder region of trunk and the latter from postvisceral aspect till region infront of tail region. In the absence of anus the myotomes could be classified only as trunk myotomes for denoting those present before level of hind end of visceral mass and postvisceral myotomes for denoting those behind visceral region. The former were 6 and latter 18 in number.

(b) Postlarvae (Figs 129, 130)

3.74 mm (Fig 129):- In this stage larval finfold has become reduced in width, mouth has developed as a small gape, eyes were pigmented black and alimentary canal has become established.

Head has become prominent, although the greatest depth of the postlarva was at its middle region and hinder part of body tapered gradually towards caudal end. Snout was rather flat and lower jaw was slightly longer than upper. Postlarval opercular cleft has formed and pectoral fin was membraneous and flap like. Pigmentation has become slightly changed and intensified. Dorsal series of black pigment spots has extended further anteriorly till middle region of head. Ventral series of pigments also has become extended anteriorly in the form of a few prominent spots above viscera till auditory region. In postanal area three pigment spots were present ventrally and along ventral aspect of hindgut another three pigments have appeared. Preanal part of the body was 70 % of total length; and there were 18 preanal and 6 postanal myotomes.

<u>5.3 mm</u> (Fig 130):- In this stage body has become considerably elongated and streamlined with head forming the most prominent part, its greatest depth at postopercular region. Maxillary bone has become defined and distinct. Larval finfold has become confined to postvisceral region; and at caudal region it has assumed a somewhat truncated shape with indications of a few rays at lower caudal region. Pigmentation has increased considerably, two spots

above maxillary region, a small patch at nasal, a few pigments on dorsal side of head, much more along midlateral aspect of head and a few in ventral region below eye. Pigmentation along side of body was much diffused from postopercular region till near end of caudal. At the base of pectoral fin a pigment patch was present and another one midventrally below pectoral region. At posterio-dorsal aspect of pectoral fin an oblique patch of partly sunken pigments was present; and pigment spots along dorsal aspect of postanal region have extended to finfold also. In middle and lower regions of caudal fin a group of pigments was observed. Preanal length has become reduced to 64 % of total; and number of preanal myotomes has decreased to 16 and that of postanal myotomes increased to 8.

(c) Systematics

Number of myotomes in the postlarvae and larvae correspond with the adult vertebral number, namely 24. Disposition of vertebrae in adults of this species is 10 preanal and 14 postanal, while in postlarvae the disposition is different, 18 preanal + 6 postanal in 3.74 mm and 16 preanal + 8 postanal in 5.3 mm. Forward shifting in position of anus from 3.74 mm to 5.3 mm accompanied by a reduction in preanal length from 70 % in the former to 64 % in the latter indicates that in further development anus would further shift forwards reaching adult vertebral condition of 10 preanal + 14 postanal.

Shojima (1958 a) has given an account of postlarval stages of U.bensasi from Japan, measuring 5.5 and 7.2 mm; but these are in more advanced stages of development than the present material. However, between 5.5 mm specimen of Japan and 5.3 mm in the present account, development of dorsal and anal fins, increase and localization of pigmentation, etc in the former become apparent. Besides, preanal length in the former is only 37 % of total, showing a marked reduction from the developmental condition observed in present material. It appears quite probable that in further sequences of development in the Indian material also the anus would shift forwards and pass through the 5.5 mm postlarval condition from Japan. Shojima (op.cit) has also given an account of 3.7 mm and 5 mm postlarvae of an unidentified mullid from Japan. In these cases also, apart from progressive developmental features, the principal difference noticed from the present material is the forward position of anus.

(J) Family Centropomidae

This Family consisting of "Snooks" includes the genera Ambassis, Lates and Psammoperca, usually found in sea and brackish water. Lates calcarifer and Psammoperca waigiensis found in India are economically important.

3. 2. 22 Lates calcarifer (Bloch)

Lates calcarifer, poularly called "cock - up" or "sea bass" is a highly valued food fish found mostly in tropical areas of Indo-Pacific. It is essentially marine but also ascends estuaries, backwaters and even freshwaters. It is of great value in brackish water fish culture and is known to grow to a length of about 30 cm weighing upto 500 gm in the first year itself of its life; and is also known to attain length of about 1.5 m. It is highly predatory, voracious and piscivorus. At Porto Novo it forms a good fishery in Vellar Estuary where it is caught by a process of spearing from canoes to which black clothes are attached under water surface and kept in a state of movement in water. The fish, mistaking that the moving black cloth is a fish on which it can feed, makes an effort to capture the cloth during which process it is quickly speared from the canoe and caught. Earlier work on this fish from India includes aspects on its fishery in West Bengal by Hora and Nair, K.K. (1944) availability of its fry by Nayudu (1942) and Gopalakrishnan (1968), notes on its systematics and biology by Gopalakrishnan (1972), description of postlarvae and juveniles by Ghosh (1973) and Mukhopadhyay and Verghese (1979) and maturation and spawning by Patnaik and Jena (1978).

(a) Postlarvae (Figs 131, 132)

2.13 mm (Fig 131):- Date of collection: 21 -10 -'77.

Larval finfold was almost non-existent and body was somewhat streamlined with hinder region tapering gradually and ending in an expanded caudal region provided with a few rays. Head was comparatively large with greatest depth in region of midbrain. Pigmentation was in the form of two prominent patches with branches along ventral side of body above hindgut and postanal region, a large patch posterio-dorsal to pectoral fin, a small patch above pectoral base, a series of pigments along ventral region of viscera and a ventral spot below level of hind end of eye. Preanal length was 45 % of total; and there were 8 preanal and 15 postanal myotomes.

4.94 mm (Pl X, Fig 132):- Date of collection: 12 -9 - '77. Body has become streamlined, deeper and more elongated. Dorsal and anal fins have been formed although number of rays in them were not well discernible. Caudal region has become somewhat oval shaped with developing rays, many of which in middle region were three segmented. Minute conical teeth have appeared in upper jaw and two short triangular spines in preopercular region. Pigmentation was characteristic. Along dorsal aspect of body there was a large, black, downwardly branching pigment patch above level of midgut, followed by five similar patches in postanal region infront of caudal peduncle. Along midlateral region of body, a series of branching chromatophores was present between caudal peduncle and pectoral region. Anterior to this, partly sunken pigment till hind margin of eye were present and in snout region there were three pigment patches. In postanal region of body ventrally there was a series and above visceral region an expanded patch of downwardly branching pigments was observed. In preanal region ventrally a few pigment streaks were found and in lower region of operculum a sunken pigment above and a branching chromatophore below were noticed.

In lower jaw, a series of five pigment patches was noticed and at hind end of upper jaw a single patch. Preanal length has decreased to 41.8 % of total length; and predorsal length was 46.1 %. Number of preanal myotomes has increased to 10 and that of postanal myotomes has decreased to 13, the number and disposition of myotomes thus corresponding to adult vertebral condition.

(b) Systematics

L.calcarifer is believed to spawn during cold seasons of the year and at the mouth of estuaries in southern India (Gopalakrishnan, 1972). During 1977 - '79, mature and spent specimens of this species were observed in fish catches at Porto Novo, during September - November period. Eggs of this species are said to be heavy and to sink to the bottom (Gopalakrishnan, 1972). Occurrence of present postlarvae in plankton and spawning stock in Porto Novo simultaneously as well as the identical number and disposition of postlarval myotomes and adult vertebral number serve to identify the former as those of *L.calcarifer*. Ghosh (1973) described some postlarvae of this species from Hooghly - Matlah estuarine system. The stages dealt with by him are larger than present ones, above 6 mm long. In 6 mm

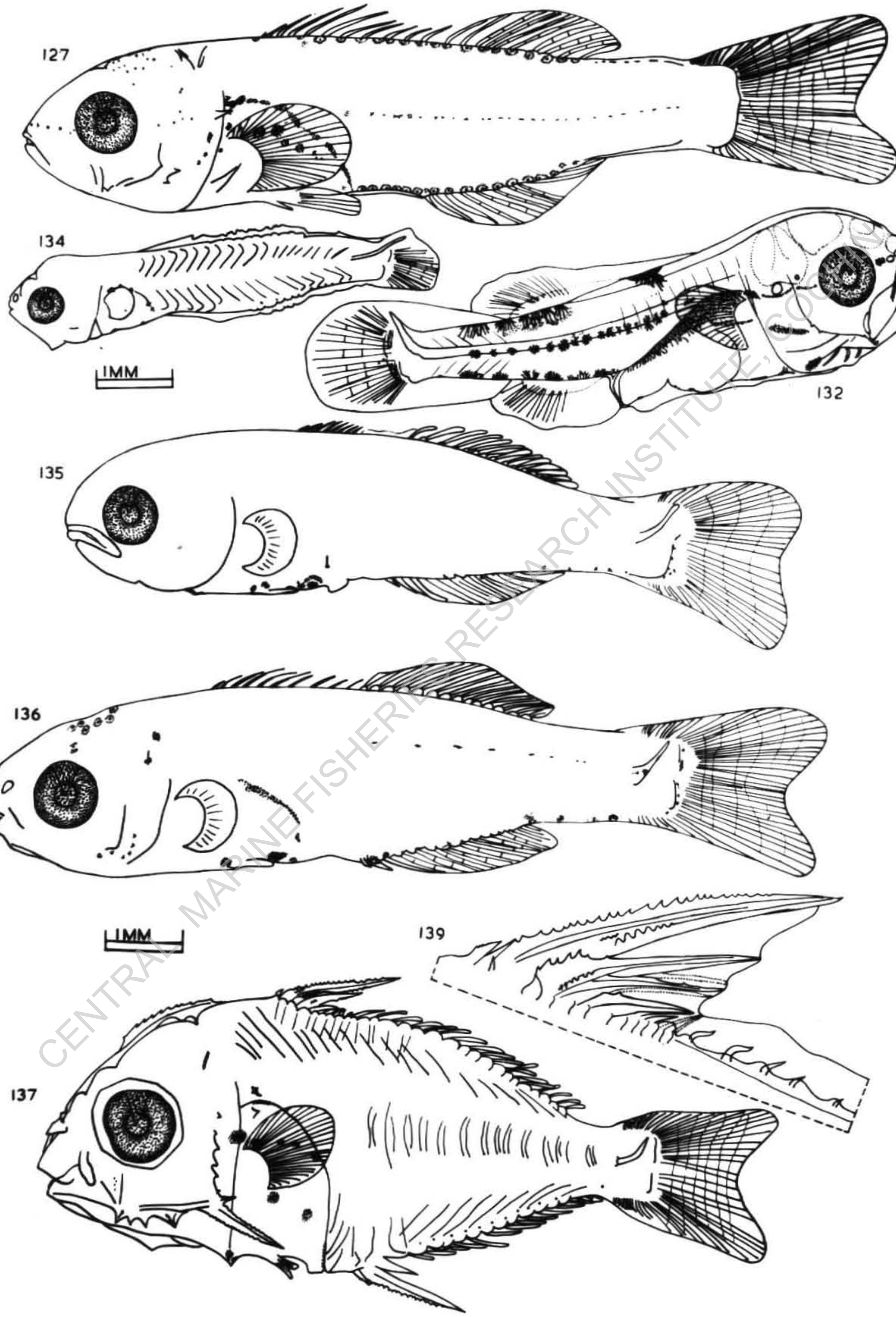
PLATE X

Figure 127. 11.36 mm postlarval stage of Therapon jarbua.

Figure 132. 4.94 mm postlarva of Lates calcarifer.

Figures 134 - 137. Postlarvae and juveniles of Siganus javus: Figs 134 - 136. Postlarvae, Fig 134. 5.63 mm; Fig 135. 9.7 mm; Fig 136. 10.81 mm; Fig 137. Juvenile of 9.56 mm.

Figure 139. Showing the first dorsal fin region of a 15 mm juvenile Siganus javus.


127
134
1MM
132
135
136
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139
137

specimen Ghosh (op.cit) has found "8 countable" preanal and 12 postanal myotomes, which is somewhat similar to the condition in 4.94 mm postlarva in the present account, with 10 preanal and 13 postanal myotomes.

Recently, Mukhopadhyay and Verghese (1979) have described a postlarva of 4.24 mm size from Hooghly Estuary. Although the above stage and 4.94 mm postlarva in the present account bear a number of similarities to each other, some differences are seen in pigmentation. Two large, branching chromatophores are present behind eye and three large ones along lateral side of body diagonally in middle region in the former but absent in the latter. The dense patch of pigments on dorsal aspect of gut and the single large chromatophore in middorsal region at anterior aspect of dorsal fin base are absent in the material described from Hooghly Estuary. Apart from these differences in pigmentation, number of preanal myotomes in the two cases is identical.

(K) Family Siganidae

The "Rabbit fishes" constituting Family Siganidae and composed of the genera Siganus and Lo are one of the little known groups, found in sea, estuaries, lagoons, backwaters, reefs, etc. They are distributed in both tropical and subtropical areas of Indo-Pacific region and are known to be of capture fishery value in Philippines (Calvelo and Ginon, 1974). The growth of fry of Siganus sp in the above country was investigated by Rosario (1974). In India, knowledge on systematics, fishery and biology of this Family remains practically unknown at present. Two species, Siganus javus and S.canaliculatus are commonly reported from the country.

3. 2. 23 Siganus javus (Linnaeus)

In the course of present studies at Porto Novo, Siganus javus was found to contribute to a seasonal fishery in Vellar Estuary. A study of its stomach contents has shown it to be a herbivore, feeding mostly on algae, diatoms, detritus, etc. Previous work on early development of a Siganid is that of

S.fuscescens by Senta, Ueno and Fujita (1958) from Japan. The present account deals with a few postlarvae and juveniles collected from plankton and fry net catches at Porto Novo during December, 1977. Early postlarvae were somewhat transparent and later stages were transluscent in fresh condition, but turned whitish in formalin.

(a) Postlarvae (Figs 133 - 136)

4.81 mm (Pl IX, Fig 133):- This stage as well as the following one were collected from plankton on 19 -12 -'77. Larval finfold was still present, although in a highly reduced form. Fin rays have appeared in lower caudal region but their precise number could not be ascertained. Indications of dorsal and anal fin could be seen as middorsal and midventral thickenings of larval finfold. Pectoral fin was membraneous and semicircular. Head was the most prominent part of the postlarva, with greatest depth at region of midbrain. Lower jaw was longer than upper and the latter showed a few minute conical teeth. Larval opercular cleft has developed and anus was situated well infront of middle region of postlarva, with preanal length forming 36 % of total length. Pigmentation was rather sparse, in the form of two patches at upper region of viscera, a small patch a little above hinder part of anus and another larger patch infront of anus ventrally. Behind middle of postanal part of body, also ventrally, a series of ten pigment spots was present. There were 23 myotomes, of which 5 were preanal and 18 postanal.

5.63 mm (Pl X, Fig 134):- Important changes noticed in this stage over previous one were development of dorsal and anal fin ray buds and a slight increase in visceral pigmentation, particularly in appearance of an additional pigment behind larval opercular cleft. Caudal region still showed a truncated appearance and a few caudal rays had two segmented condition. Preanal length has become reduced, forming 34.5 % of total. Disposition in number of myotomes has changed to 7 preanal and 16 postanal.

9.7 mm (Fig 135):- Date of collection: 23 -12 -'77. Many developmental processes appeared to have taken place before attaining this stage. Body has become considerably enlarged and elongated, with head still forming the most prominent region. Mouth was well developed with jaws covered by lip like formations. All postlarval fins have developed, with first dorsal showing about 10 soft spines, second dorsal about 14 rays, caudal fin about 26 rays most of which were four segmented and anal fin with 2 spines and 10 rays. Pelvic fin has developed below level of pectoral fin; and precise number of rays in both these fins could not be ascertained. Bifurcation of caudal fin appeared to be in progress. Pigmentation consisted of a series of black pigments at ventral aspect of body, one behind region of isthumus, two infront of base of pelvic fin, another two behind it, a partly sunken pigment above anus, a series of 10 pigments at base of anal fin and behind it till caudal peduncle and a vertical group at the base of caudal fin in its middle and lower aspects. Preanal length has increased in proportion, forming 39.8 % of total; and percentages of pre-first dorsal and pre-second dorsal fins were 31.4 and 44.8 of total length. Number of preanal myotomes has increased to 10 and postanal myotomes decreased to 13.

<u>10.81 mm</u> (Fig 136):- The principal changes recorded in this stage collected on the same day as previous, were an increase in pigmentation, more marked bifurcation of caudal fin and appearance of minute spines in opercular region, marking beginning of future spines. Above eye region dorsolaterally, some black branching chromatophores and a little above midlateral region behind origin of second dorsal fin,

a series of about 10 chromatophores have appeared, the last one of latter series occupying urostylar region. Besides, at base of preopercular region a partly sunken pigment and at base of second and third anal spines two chromatophores could be seen. Caudal fin rays have increased in number to about 30 and anal fin rays to about 17. A group of five minute, somewhat conical spines were observed behind angle of preopercular region, one infront and four behind. Preanal length appeared to have increased a little more, forming 41.5 % of total; and pre-first and pre-second dorsal proportions have decreased to 27.3 % and 42.1 % of total length respectively. Preanal myotomes have further increased to 11 and postanals decreased to 12. Snout region showed a slight projection, marking the beginning of a more prominent snout in older stages.

(b) Juveniles (Figs 137 - 141)

The following juvenile stages were collected in fry net catches at the mouth of Vellar Estuary on 28 -12 -'77. They were pale whitish in fresh condition but turned much more whitish in formalin.

9.56 mm (Fig 137):- Many differences could be seen in general characters of this stage over previous postlarval condition. One principal feature observed was dorsoventral expansion of body and a reduction in length, probably accompanying the former change undergone. From more than 1 mm reduction in length over previous postlarval condition, it appeared as though after attaining a particular stage the postlarva did not undergo significant linear increase, but a dorsoventral expansion attaining the present juvenile condition and perhaps even registering a decrease in length in the process. Beginning of this process could be seen in the previous postlarval stage as indication of dorsoventral expansion in head region.

The juvenile has become somewhat oval in shape as in adult condition and greatest depth of body was at level of first dorsal fin. Head region has become somewhat triangular in shape and gape of mouth was well below level of lower margin of eye. Minute conical teeth were present in lower jaw; and both upper and lower jaws have become somewhat short and pointed. Above upper jaw a short, stout, spine like formation was present, directed downwards. Over the eye, on middorsal aspect of head, a crest of serrations has developed commencing from a level parallel to anterior margin of eye and extending till level of operculum. Below eye region there were four short, stout spines facing ventrally; and behind this, a long, stout, pointed spine serrated on its upper and lower margins and directed posterio-ventrally and reaching upto level of pelvic fin was present. At dorsal base of the long spine, a short one serrated dorsally and above it a vertical row of six partly curved, short, pointed spines were present, forming preopercular edge. Behind dorsal end of operculum, a short spine was present, directed backwards; and, at lower end of operculum, another one directed downwards.

The spines of dorsal and anal fins in the juvenile were not the same unserrated, slender ones, as in previous postlarval stage. In first dorsal region seven strong, stout spines have appeared. Of these, the first one was short, truncated and nonserrated; second was longest, serrated in its anterior and posterior edges; third was a little shorter than second and partly serrated; and fourth to seventh spines were nonserrated, much shorter and pointed. In anal fin also, there were three strong, stout spines, directed posterio-ventrally, the first one somewhat short and partly serrated on its anterior aspect; the second one the longest and stoutest, serrated anteriorly; and the third one shorter than the second and nonserrated. These spines in dorsal and anal fins represented newly developing spines which have taken the place of postlarval spines and rays. In fact, under larger magnifications in a subsequent stage (vide infra), the former postlarval spines and rays in the process of atrophy or resorption could be seen side by side with development of new spines. Behind dorsal spines about 16 rays most of which were 2 to 3 segmented were present; as well as behind anal spines 15 rays, 3 to 4 segmented. There were 30 caudal rays, most of which 7 to 9 segmented. Pectoral fin has become more prominent; and about 15 rays could be counted in it. Pelvic fin has also developed further, with about 6 rays.

Pigmentation of the juvenile consisted of a patch at the base of first infraorbital spine, a group of partly sunken pigments and branching chromatophores in visceral region dorsolaterally, a narrow patch below anterior part of hind brain, a prominent chromatophore and a patch of pigment at the base of ventral spine below opercular margin, a narrow black pigment patch at hinder margin of rectum and a series of twelve pigments along anal fin base. There were 8 preanal and 15 postanal myotomes in this stage. Preanal length has become reduced to about 40 % of total.

<u>15, 20 and 24 mm</u> (Figs 138 - 141):- Head region in 15 mm juvenile,

collected on 30 -12 -'77 from fry net catches, has become much more triangular and snout more acute (Pl XI, Fig 138). When compared to the previous juvenile stage, a shifting up of the region below eye anterio-dorsally, thus resulting in a more upward position of mouth occupying a level above the lower margin of eye has taken place. Due to this change, the upper jaw appeared to have been placed in conjunction with the spine on the snout in this stage, the spine itself forming a hook like structure above upper jaw. Besides, the crest of serrations found along dorsal region of head in the previous stage has shifted backwards, the origin of which at this stage occupying a level parallel to posterior third of eye and extending posteriorly till front end of first dorsal region. Vertical row of short spines infront of opercular margin observed in previous stage was absent in the present one. There was an increase in pigmentation due to appearance of a few chromatophores in hind region of head dorsolaterally. Also, a few pigment spots were present above angle of operculum, a few scattered spots below eye, two branching chromatophores infront of pectoral fin base, one infront of dorsal origin and a group of light brown branching chromatophores along side of viscera. Pelvic fin has developed a strong stout spine with a few serrations at its ventral base and about 6 rays.

First dorsal fin in 15 mm stage showed a total of ten newly developing spines (Pl X, Fig 139), of which the first six were stronger than others. Apart from first three spines which were serrated variously recalling almost the same condition as in previous stage, the others were not serrated. Hinder five spines were partly curved and somewhat tubercular. In addition to these newly developing spines, remnants of slender spines of postlarval condition could be seen clearly, one in between the second and third newly developing spines, another in between the third and fourth new spines and two in between the sixth and seventh ones. These were in various stages of atrophy or resorption accompanied by progressive development of juvenile spines. In anal fin also (Pl XI, Fig 140), followed by the first three newly formed juvenile spines, there were four small spines developing at the bases of postlarval anal fin rays undergoing gradual atrophy. Preanal length has become further reduced to 36 % of total, the proportion almost similar to adult condition. On the other hand, pre-first dorsal length was 36 % of total, which is different from adult condition of about 21 %. Further development of the new set of juvenile dorsal spines was in progress in a specimen of 20 mm (Fig 141), in which dorsal fin rays behind anal level also could be seen getting atrophied or resorbed. From these facts, it was obvious that most of the first dorsal and anal spines and/or rays present in postlarval stage would be replaced by a new set of juvenile spines, developing in the course of early juvenile growth.

20 mm juvenile was still whitish, but intensity of pigmentation in visceral and postvisceral areas has increased; in fact in the latter area it was in the form of a triangular group of brownish black branching chromatophores. Along the base of dorsal fin three patches of pigments were present and at anal base 15 pigment spots and at caudal base a vertical patch. Standard length was 14 mm; body depth at dorsal origin 8 mm; and preanal length 7.5 mm. About 7 prominent dorsal spines were seen, followed by about 16 rays. In anal fin 3 spines were prominent followed by about 18 rays. In a specimen of 24 mm total length (20 mm standard length), body colouration has changed to light brownish. As may be seen from morphometric features, it appeared as though there was linear increase at the expense of body depth, since the latter was almost the same as in previous stage. Preanal length was

10 mm, dorsal spines have increased to 12 with 10 rays and anal fin spines have increased to 8 with 8 rays. There was an edge of brown pigment at base of hinder dorsal and hinder ventral regions; and a patch of vertical pigments was present at the base of caudal fin. Number of vertebrae in this stage was 9 preanal and 14 postanal, corresponding to adult condition.

(c) Systematics

In the present postlarvae, the disposition of vertebrae are: 6 preanal + 17 postanal in 4.81 mm, 7 preanal + 16 postanal in 5.63mm, 10 preanal + 13 postanal in 9.7 mm and 11 preanal + 12 postanal in 10.81 mm. In later postlarval as well as early juvenile phase of development however there appears to be a gradual reduction in preanal myotome number and a corresponding increase in postanal number, as in 9.56 mm juvenile there are 8 preanal and 15 postanal myotomes. Subsequent to this there appears to be a slight change because in 24 mm juvenile there are 9 preanal and 14 postanal myotomes, corresponding to adult condition.

Our knowledge on early life history of Siganids till now is chiefly based on the work of Senta, Ueno and Fujita (1958) on *Siganus fuscescens* from

Japan. Eggs of this species are demersal; and in early larval stages a distinct reduction in preanal length is noticed from about 42.8 % in 2.60 mm to 32.9 % in 3 mm.* In 3 and 3.3 mm stages described by them, preanal length has increased, forming about 43 %; and in still later stages it has further increased, forming about 44.7 % in 5.4 mm and 46.6 % in 8.3 mm. In the present case however, a reduction is observed in the beginning followed by an increase in later postlarvae, forming 41.5 % of total length as in S.fuscescens; but in the juveniles there is a secondary reduction resulting in 40 % in 9.56 mm, 36 % in 15 mm and 37 % in 20 mm. This is again followed by a secondary increase, resulting in 41 % in 24 mm. It may be noted in this connection that in adults of S.javus preanal length is only about 34 % of total length, thus indicating that preanal length should still become shorter in further development.

Another significant feature of difference recorded in the development of these two species is related to the sequence of formation of dorsal and anal fins. In S.javus the second dorsal and anal rays originate in 4.81 mm stage itself followed by development of postlarval first dorsal fin in the form of a few soft rays in 9.7 mm stage. But, in S.fuscescens, first dorsal spines are indicated in 3.30 mm itself and

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* Percentages based only on the figures given by the above authors and not based on any description.

development of second dorsal fin rays is delayed till 5.4 mm stage. However, in 9.56 mm juvenile of S.javus, some of the serrated spines of first dorsal and anal fins have already developed; and, as seen earlier, development of other spines of juveniles takes place side by side with atrophy or resorbtion of postlarval spines and/or rays. This process appears to be in progress even in 24 mm stage, by which time all spines of dorsal and anal fins are not yet formed. In 5.4 mm postlarva of S.fuscescens juvenile spines of anal fin have not yet developed although a few dorsal spines are well formed. In S.javus the postlarval set of dorsal and anal spines and rays is atleast partly replaced by a new set of juvenile spines; but from the account given by the above authors it is not quite clear as to whether in S.fuscescens also such a condition is present or not.

Nair,R.V.(1952 c) has given the figure of a postlarva believed to be of Leiognathus ruconius (Secutor ruconius). From appearance of the figure, it seems that the material actually belongs to Siganus and not to Secutor. Postlarvae of the latter should have a much more convex belly, a depression behind snout and much smaller dorsal and anal spines. Presence and shape of dorsal and anal spines are characteristic of the postlarvae of Siganus spp.

(L) Family Scombridae

Commercially one of the most important groups, this Family is composed of mackerels, tunas, billfishes and seerfishes in Indian waters. The Indian mackerel Rastrelliger kanagurta supports one of the most valuable coastal pelagic fisheries in India, particularly along south-west coast, amounting to annual landings ranging from 1,00,000 to 2,00,000 tonnes. Along east coast also this species is commonly found, although not contributing to a regular and localized fishery of so much magnitude as in west coast. The oceanic skipjack Katsuwonus pelamis and yellowfin tuna Thunnus albacares are fished in considerable quantities in Lakshadweep Islands, off south-west coast of mainland; and total tuna production in the country in recent years amounts to about 20,000 tonnes per annum.

The frigate mackerels Auxis thazard, A. rochei, the bonito Sarda orientalis, the little tunny Euthynnus affinis and northern bluefin Thunnus tonggol are the other species commonly caught from coastal waters, particularly along south-west and south-east areas. Also, seerfishes Scomberomorus commerson, S. guttatus and S.lineolatus account for an average annual production of about 15,000 tonnes from the country.

3. 2. 24 Rastrelliger kanagurta (Cuvier)

Rastrelliger kanagurta is known to spawn along both west and east coasts, in the latter region during October - November to April - May (Venkataraman, 1970). Delsman (1926 e) first reported certain eggs as belonging to this species, from Java coast. Subsequently, Devanesan and John (1940) and Balakrishnan, V.(1957) assigned certain eggs to this species, but detailed descriptions and figures are not given by them. Peter (1967; 1970 a) and Silas (1974) gave descriptions of some larval stages identified as of this species, collected from off west coast. Recently, Natarajan,R. and Bensam (1978) identified its planktonic eggs from Porto Novo and gave a brief account of eggs and early larvae, reared in the laboratory. A few more eggs and a postlarva identified as of this species were isolated from plankton collected during March 1978 and are figured and described in the present section.

(a) Eggs (Figs 142 - 147)

Preserved eggs identified as of R.kanagurta ranged in diameters from 0.66 mm to 0.78 mm, with oilglobules in diameter range of 0.20 mm to 0.25 mm. Perivitelline space was rather narrow. Pigmentation on embryo, yolksac and oilglobule in preserved eggs, although conforming to the basic pattern described for fresh and/or newly preserved eggs in weak formalin as reported by Natarajan,R. and Bensam (1978), was not so distinct. Six views of formalin preserved eggs are given in figures 142 - 147, to facilitate identification of preserved eggs in ichthyoplankton collections.

(b) Postlarva (Fig 148)

The only postlarva collected from plankton was on 14 -3 -'78. It measured 3.34 mm long and larval finfold was still present. Body was elongated with head forming most prominent part and tapering gradually behind. Postlarval opercular cleft has developed and pectoral fin was membraneous and semicircular, without clear indications of rays. Body length was 95.8, head 22.3, eye 8.6, preanal length 40 and depth of body at vent 17 percent of total length. Pigmentation consisted of a patch of pigments at dorsal aspect of viscera followed by two smaller patches behind, two patches on ventral aspect of viscera and a series of 15 pigments along ventral aspect of body from 6th postanal myotome till 20th. There were 6 preanal and about 24 postanal myotomes.

(c) Systematics

As discussed in an earlier publication on eggs and early larvae of Indian mackerel collected at Porto Novo (Natarajan,R. and Bensam, 1978) along with present eggs, identification of the eggs is based on coincident occurrences of eggs and postlarva in plankton and spawners in local catches; and confirmed by number of myotomes in larvae hatching out corresponding to adult vertebral number. It may be noted in this connection that position of vent during early development of mackerels undergoes a forward shifting followed by a backward movement (Uchida, 1958c; Russell, 1976), as pointed out by Natarajan,R. and Bensam (op.cit). Beginning of forward shifting of vent in larvae of Indian mackerel is observed in 73 hrs old stage. Backward shifting in position of vent in Indian mackerel in later stages is reported by Balakrishnan,V. and Rao, K.V.N.(1971) and Silas (1974).

The 3.34 mm postlarva of Indian mackerel described in the present section bears a close similarity to 3.38 mm stage described by Silas (1974) in such essential features as percentages of body length, head, eye, preanal length, etc in relation to total length. Basic pattern of pigmentation in the two cases also

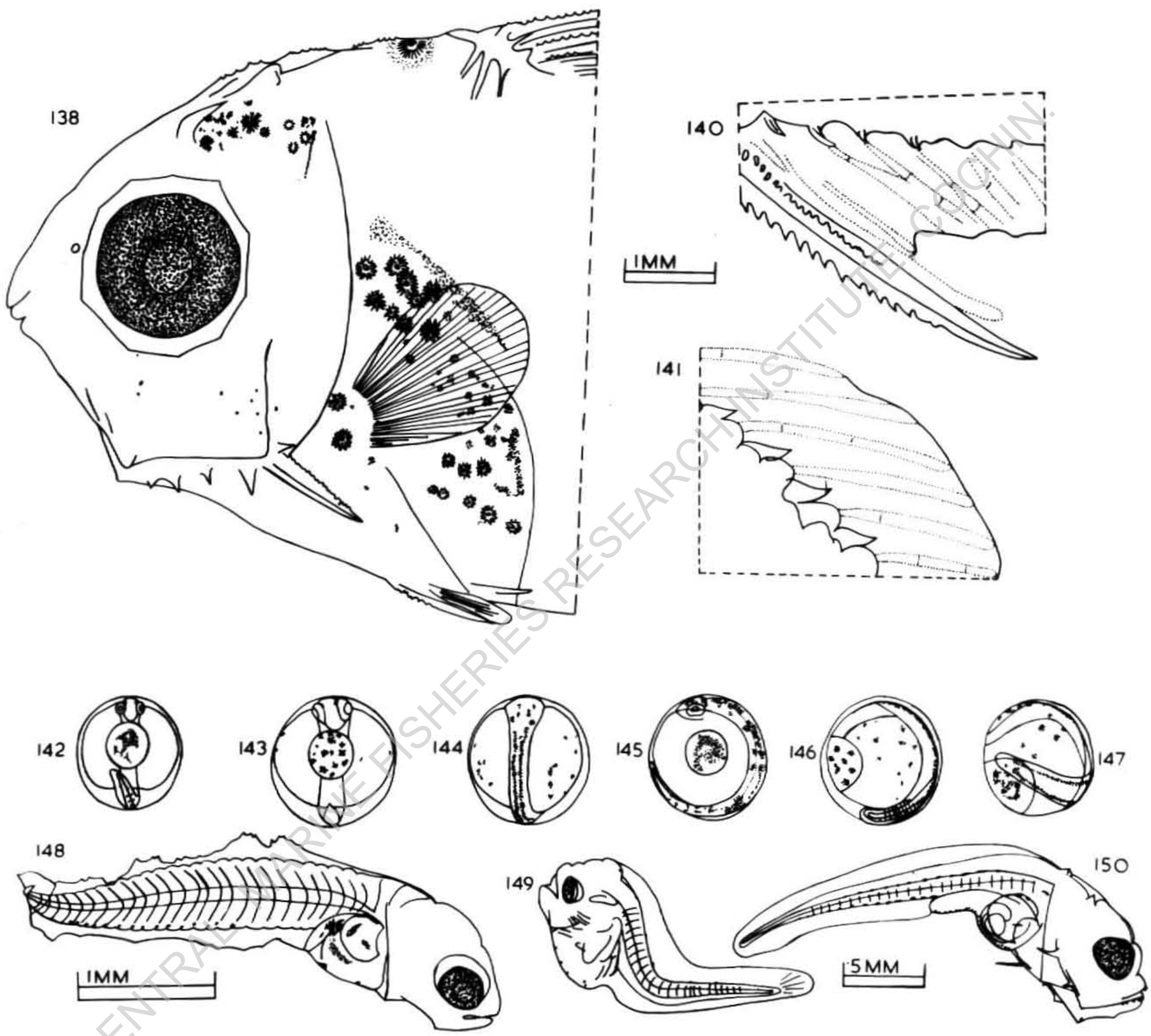
PLATE XI

Figures 138 and 140. Sketches showing head region and anterior part of anal fin respectively of a juvenile Siganus javus of 15 mm.

Figure 141. Hind region of dorsal fin in ajuvenile Siganus javus of 20 mm.

Figures 142 - 148. Eggs and a postlarva of Rastrelliger kanagurta: Figs 142 - 147. Sketches of formalin preserved eggs showing six views; Fig 148. 3.34 mm postlarva.

Figures 149 and 150. 1.95 mm and 2.9 mm postlarval stages respectively of Platycephalus indicus.


138
140
141
1MM
142
143
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147
148
149
150
1MM
5MM

appears to be the same, except for presence of pigment in lower caudal region in the material described by Silas (*op.cit*). Apart from this, the only marked difference appears to be in disposition of myotomes which is 10 preanal and 20 postanal in the specimen reported by Silas (*op.cit*) but only 6 preanal and about 24 postanal in the present one, showing a difference of four myotomes in disposition. Silas (*op.cit*) comments that number of myosepta in larvae of mackerel from west coast of India are variable, implying similar variation in disposition of myotomes also. However, in 3.6 mm stage of the Japanese mackerel described by Uchida (1958 c) only 8 preanal myotomes are seen and in 4.3 mm stage of the Atlantic mackerel *Scomber scombrus* (the adults of which have an almost similar number of total vertebrae as in the Indian mackerel, namely 30 - 31), described by Berrien (1975) only 7 preanal myotomes are shown. The above dispositions of preanal myotomes in Japanese and Atlantic mackerel are closest to the condition in the material described in the present section, but different from the material reported from west coast of India.

(M) Family Platycepahlidae

Family Platycephalidae is composed of "Flatheads", mostly marine, sometime brackish water. Mainly distributed in Indo-Pacific, the genus Platycepahlus is the common one. These fishes are not much relished as food fishes, although eaten by poor section of people. They are usually benthic.

3. 2. 25 Platycephalus indicus (Linnaeus)

Platycephalus indicus, popularly called Indian Flathead, is commonly found along both coasts of India, caught mostly in demersal fishing gears. Nothing substantial is published on biology of this fish from India. In the present section, two postlarvae collected from plankton on 10 -8 -'77 are described.

(a) Postlarvae (Figs 149, 150)

1.95 mm (Fig 149):- This was an early postlarval stage in which larval finfold was still present. Head and viscera constituted the most prominent part with greatest depth in middle region of viscera; postanal region gradually tapering behind; caudal region showing striations indicating future rays; mouth cleft small and somewhat oblique; and eyes were small but pigmented black. Pigmentation consisted of a series of spots on dorsal side of body commencing from above hind end of brain. On ventral aspect of viscera a series of pigment spots was present. Preanal length was 38 % of total; and there were about 9 preanal and 19 postanal myotomes.

2.9 mm (Fig 150):- Body has become considerably elongated and streamlined and head region continued to be prominent. Head has assumed the characteristic shape somewhat similar to adult condition, with a prominent chin and partially upturned jaws. A few minute conical teeth were present on distal part of upper jaw; and above it two minute spiny processes were present. Two short, triangular, tubercular processes have appeared dorsally, one in midbrain region and another above opercular end. In preoperculum two spines have developed, upper one longer than lower. Pectoral fin was membraneous and semicircular; and caudal region showed more prominent rays. Pigmentation has increased much more than in previous stage. There was a dorsal series of pigments, a postanal ventral series developed anew, two pigment patches at dorsal aspect of viscera, minute pigment spots from vent to opercular region ventrally and a pigment patch at chin. Preanal length has increased considerably more, forming about 50 % of total length. There were 11 preanal and 16 postanal myotomes, their disposition corresponding to adult vertebral condition.

(b) Systematics

Mature and spent specimens of **P. indicus** were collected at Porto Novo during August and September 1977, coinciding with appearance of postlarvae in the plankton. Identification of the present postlarvae is based on this fact and confirmed by number and disposition of myotomes corresponding to adult vertebral condition of 11 preanal and 16 postanal.

Ueno and Fujita (1958) have described eggs, larvae, postlarva and juveniles from Japan, of which 2.71 mm larva may be compared to 1.95 mm stage in present account. Major differences between them are: lack of development of mouth, unpigmented condition of eyes and more diffuse pigmentation in former and opposite conditions in latter. These features may very well be associated with earlier stage of development in the Japanese material. Infact, the present 1.95 mm may be treated as a stage in between 2.71 and 2.84 mm stages reported from Japan. On the other hand, the 2.9 mm stage in the present study is more advanced than 2.84 mm stage described from Japan.

3. 3 GENERAL REMARKS

Among about six hundred species of fishes available in the sea off Porto Novo and in the Vellar Estuary, the early life history stages of about fiftyfive species have been reported from late fifties to late seventies (Rangarajan and Jacob, 1960; Rao, K.S.P.B., 1963; Ramaiyan and Rao, T.V.S., 1972; Vijayaraghavan, 1973 a; b; 1974; Venkataramanujam, 1975 a; b; Venkataramanujam and Ramamoorthi, 1976; Ramanathan, 1977; Natarajan and Bensam, 1978; Ramanathan and Natarajan, 1979). In the present thesis, based on studies undertaken from August 1977 till June 1979, the eggs, larvae, postlarvae and/or juveniles of fifteen additional species are reported, viz., *Nematalosa nasus*, *Sardinella clupeoides*, *S.sirm*, *S.albella*, *Ilisha melastoma*, *I.megaloptera*, *Thryssa dussumieri*, *T.mystax*, *Liza dussumieri*, *L.tade*, *Polynemus sextarius*, *Gerres oblongus*, *G.setiferus*, *Therapon jarbua* and *Siganus javus*.

Although mere mention on occurrence of eggs, fry, etc of the Milkfish *Chanos chanos* in Indian waters abound in literature (Chacko, 1950; Tampi, 1968), no comprehensive account dealing with development and systematics of early life history stages of this commercially valuable culturable fish is as yet available. Similarly, early life history stages of the commercially important sardine <u>Sardinella fimbriata</u>, from Indian waters is also not described adequately. Aspects on development and systematics of these species given in the present thesis, including taxonomic differences between developmental stages of allied species, may be of help in the separation of such stages in ichthyoplankton collections.

Development and systematics of early life history stages of the commercially important fishes <u>Sillago sihama</u>, <u>Upeneus (Pennon) bensasi</u> and <u>Platycephalus indicus</u> are dealt with for the first time from Indian seas. A postlarval stage of the Indian mackerel, <u>Rastrelliger kanagurta</u> is also described from Porto Novo, in continuation of the earlier report of its eggs (Natarajan and Bensam, 1978), for the first time from the east coast of India.

(2) From the occurrence of eggs and larvae of estuarine and marine fishes at Porto Novo, as reported previously as well as presently, it is obvious that many species of these fishes do spawn in and around this locality. Also, based on the occurrence of postlarvae and juveniles of many a species, it may be

stated that Porto Novo and its environs serve not only as breeding grounds but also as nursery grounds for these fishes. Occurrences of eggs and postlarva of the mackerel, Rastrelliger kanagurta and of eggs, postlarvae and juveniles of the Milkfish Chanos chanos, although in small numbers, indicates that breeding grounds of these economically valuable species may be available off Porto Novo coast. In this regard, much more intensive collections, pelagic, midwater and demersal, and studies are needed in order to elucidate the development and early systematics of much more species from this area; as well as to assess their distribution and abundance in space and time.

It may be noted in this connection that the eggs of many species occurring in this region, such as perches, rabbitfishes, etc should be demersal; and hence, demersal collections from the locality are very much needed for more detailed investigations. Adequate plans should be drawn up and implemented, in order to take up work on these lines in future.

(3) From the fact that some species of value in commercial culture such as Chanos chanos, Liza dussumieri, L.macrolepis, Gerres oblongus, G.setiferus, Lates calcarifer and Siganus javus do

breed in Porto Novo coastal areas, it appears that seed resources of these fishes could be located in the area. An intensive seed resources survey in this region, including backwaters and mangrove swamps, should be planned and undertaken, in order to locate such centres and to plan for their rational exploitation in commercial stocking operations. Since the area is also known to be a breeding and nursery ground for many fishes, it is essential to protect the stocks there from indescriminate fishing, particularly during spawning seasons, by declaring "closed" periods and regulating the maturity condition of the fish to be captured, based on length.

In view of the presence of extensive backwaters at Porto Novo, affording required ecological niches for life and growth of culturable species, steps should be initiated for induced breeding, propagation and stocking of species useful in commercial culture. Fishes such as Liza dussumieri, L.macrolepis, Lates calcarifer, Siganus javus, etc appear to be quite suitable in this regard.

(4) With regard to identification of planktonic eggs, apart from major differences such as size, shape, presence or absence of oilglobule,

vacuolation, pigmentation, etc, certain subtle differences in the structure of eggs proved to be of crucial value. One such feature is the size of vitelline area of the developing egg. The vitelline area (or yolk) in the eggs of Sardinella fimbriata is markedly smaller than in closely allied S.longiceps, although overall size ranges of the eggs of both the species are almost similar. The diameter of the eggs of Liza dussumieri is different from that of the eggs of L.macrolepis and L.tade. The latter two species have overlapping ranges of egg diameters. But, in the newly hatched larvae of L.tade the oilglobule is situated at the front of the yolksac whereas in the newly hatched larvae of L.macrolepis, it occupies the hinder part of the yolksac. Eggs of Therapon jarbua, as also the oilglobule in them, present a dark, glistening appearance, which is characteristic.

(5) In larvae and postlarvae of closely allied fishes, particularly those which have overlapping ranges in myotomes, differences in their dispositions as preanal and postanal have proved to be of value. For instance, larvae of Nematalosa nasus have 30 to 35 preanal myotomes; but, in the larvae of most species of Sardinella there are as many as 34 to 40 preanal

myotomes. Similarly, although larvae and postlarvae of Ilisha megaloptera and Opisthopterus tardoore (Bensam, 1968 b) have the same range of myotome numbers, the preanal complement is 30 in a very early postlarval stage in the latter species, whereas it remains as 37 to 39 even in an advanced postlarval stage in the former.

Among the larvae of mullets which exhibit the same number of myotomes, the early larvae of Liza dussumieri and L.tade have only 6 to 7 preanal myotomes, while in the early larvae of L.macrolepis there are 11 preanal myotomes. Similarly, in the postlarvae of Gerres oblongus, there are 7 preanal and 17 postanal myotomes in an early size of 2.91 mm; but, in the postlarvae of G.setiferus, the above disposition of myotomes is attained only after 7.65 mm size.

(6) Differences in patterns of pigmentation are of value in separating the larvae and/or postlarvae of certain species which show the same range in the number of preanal and/or postanal myotomes. Thus, although the postlarvae of Nematalosa nasus and Sardinella gibbosa on the one hand and those of S.albella and Hilsa kelee (Rao,K.S., 1973) on the other, have the same number of preanal and postanal

myotomes, differences in the pattern of pigmentation are useful in separating them from each other. Similarly, this character is useful for differentiating between early postlarvae of the mullets, Liza tade and L.dussumieri as well as between the early postlarvae of the silver biddies, Gerres oblongus and G.setiferus.

In the early life history stages of mullets in the present studies, a gradual decrease of pigmentation is recorded during larval phase of development, leading to sparse condition in postlarvae. In Liza dussumieri, only advanced postlarvae show pigmentation again, resulting in subsequent increase. This is different from the presence of fairly good pigmentation throughout the larval and postlarval development of Mugil cephalus, as recounted by Martin and Drewry (1978). It appears quite probable that sparse pigmentation in the postlarvae of Liza dussumieri and fairly good pigmentation in the postlarvae of Mugil cephalus are related to generic differences.

(7) Variations in the structure and development of one or the other part of the body is also found to be of importance in distinguishing the postlarvae of certain species which exhibit similar ranges in number of myotomes. Thus, in the postlarvae

of *Ilisha melastoma* and *Sardinella clupeoides*, which have the same number of myotomes, the elongated nature of developing anal fin base in the former, foreshadowing the condition in adults, proved to be a useful diagnostic character for their separation. Higher number of first dorsal spines in the late postlarvae and juveniles of *Gerres setiferus* is useful in identifying them from similar stages of *G.oblongus*.

(8) Differences in the development of general body form as well as certain other parts of the body have been observed in a few related species. Postlarvae of *Sardinella dayi* (Bensam, 1973) shows a quicker pace of development in certain characters than those of *Sardinella fimbriata*, where, only in the juveniles that the ventral fin is indicated. But, in *S.dayi*, the ventral fin develops much earlier than the attainment of juvenile condition. In *S.fimbriata*, juvenile condition is reached by the size of 21.5 mm; but in *S.dayi*, even at a size of 20.25 mm, the postlarval condition persists, comparable to 11.43 and 12.3 mm stages of *S.fimbriata*.

During the postlarval development of *Thryssa mystax*, ventral scutes are seen to develop by 26.5 mm stage itself, while in *Setipinna phasa* (Nair,K.K.,1940;

Jones, S. and Menon, 1951 c) scutes begin to develop only at 30 - 32 mm stage. In the postlarvae of *Sardinella sirm*, the forward movement of the vent takes place earlier than in the postlarvae of *S. clupeoides* and *Ilisha melastoma*.

A more pronounced forked caudal fin in an early postlarva than in later stages is seen in *Liza dussumieri*, the adult of which has fairly well forked caudal fin. Similar changes from a markedly forked caudal fin in an early stage to a less marked condition in a later one are seen in some fishes reported from mid Atlantic Bight, such as *Tetragonurus atlanticus* and *Sphyraena borealis* (Martin and Drewry, 1978). And, among mullets themselves (Martin and Drewry, *op.cit*), 24 mm *Mugil cephalus* shows a longer lower caudal lobe than upper, 25 and 32 mm juveniles show more or less symmetrical caudal lobes, 39 mm stage shows longer lower caudal lobe, but *vice-versa* in 63 mm. From these facts, it appears that the shape of caudal fin in mullets undergoes changes in the course of development.

(9) Inferior location of mouth as in adult condition has not been observed in early postlarval stages of all species such as *Thryssa* spp, *Chanos chanos* and *Polynemus sextarius*. The mouth is terminal in

position first, with lower jaw longer than the upper. However, as development progresses the snout grows longer than the lower jaw and in postlarvae or juveniles, the mouth becomes inferior in position.

(10) A significant fact observed during early juvenile development of Siganus javus is the formation of a secondary set of spines and rays in dorsal and anal fins. The postlarval sets of spines and rays undergo atrophy or resorption in 9.56 mm stage, giving place to the new sets. Thus, it is obvious that unlike in vast majority of fishes, in S. javus the adult complement of spines and rays in unpaired fins do not represent the postlarval components but are subsequent replacements.

(11) Differences are observed in forward and backward movement of vent in the course of development of larvae, postlarvae or juveniles, thus altering the disposition of preanal and postanal composition, till reaching the adult condition. While in Clupeiformes and many other fishes like Therapon jarbua, Upeneus (Pennon) bensasi, Lates calcarifer, etc, the movement is always forward, in many mullets, mackerel, etc the initial shifting is forward in larval stages, followed by a

backward movement in postlarvae. However, in *Mugil cephalus*, as recounted by Martin and Drewry (1978), the initial movement is backward and the subsequent one is forward. In *Sillago sihama* from Japan, Ueno, Senta and Fujita (1958) have shown in the figures an initial forward and a subsequent backward movement in postlarvae and juveniles respectively. But, in the present material of the same species from India, there is a backward movement of anus in late postlarvae followed by a forward movement in early juvenile phase and a tertiary backward shift in late juveniles. It is quite possible that such differences in the same species from two geographical areas such as Japan and India are related to species or stock variations. More intensive studies on material from the two countries are needed to clarify this aspect.

Apart from the above, within the same genus, two species are observed to exhibit differences in forward and backward movements of the vent. Thus, in *Gerres oblongus*, a gradual increase in preanal proportion is seen in postlarvae while in those of *G.setiferus*, an initial decrease and a subsequent increase could be recorded presently. A similar difference in the location of vent could be noted in the figures of larvae and/or postlarvae of *Mugil curema* and *M.cephalus*, recounted by Martin and Drewry (1978). In *Siganus javus* also there was a initial decrease and a subsequent increase, whereas in Platycephalus indicus an increase in preanal proportion could be seen during early postlarval development.

(12) The disposition of myotomes during larval, postlarval and juvenile phases of development undergoes changes followed by shifting in position of the anus, in most of the cases studied. But, in some instances, accompanied by changes in preanal and postanal proportions, there is no corresponding change in the location of vent with reference to the number of myotomes. For instance, in the 24 hrs old larva of Liza dussumieri (2.03 mm), a significant decrease in preanal proportion could be recorded from the newly hatched larva(1.31 mm), without any change in the position of anus. In 3.6 mm postlarva of Polynemus sextarius, the preanal proportion was 51.3% of total length but only 41.5% in 6.52 mm stage, without any change in the disposition of myotomes. This was inspite of the fact that more than 10% of total length of the specimen was involved by the movement of anus. Similar conditions could be pointed out to a lesser extent during early postlarval development of Sillago sihama, Gerres oblongus, etc. It appears as though these conditions of growth are differential rates,

without involving the position of vent.

(13) In most cases, the proportion of predorsal to total length registered a gradual decrease during development. The same was true in species provided with two dorsal fins. In the juveniles of *Liza dussumieri*, the proportion of predorsal registered a sharp increase from 26.4% in 10.8 mm stage to 42.7% in 12.45 mm stage.

(14) In the newly hatched larvae of *Liza macrolepis* and *L.tade*, the vent did not open to the outside, but did so only later during development. Such a condition was observed in the early larval stage of *Sardinella gibbosa* also (Bensam, 1970) and in a 2.4 mm larval stage of *Mugil cephalus* recounted by Martin and Drewry (1978). It is not known whether the above condition depicts a normal or abnormal one. More observations on newly hatched larvae are needed in this regard.

(15) Variations in the intensity of pigmentation and in the length of lower jaw were noticed between postlarvae of *Chanos chanos* bred artificially in Philippines (Liao, Juario, *et al*, 1979) and studied presently from plankton. Similarly, Senta and Kumagai

(1977) found lowest mean number of vertebrae in Indian specimens, but higher counts in Philippine specimens, implying differences in the two stocks. The ontogenic differences presently found could also be due to differences in the two stocks.

(16) Some authors have reported on the distribution and/or occurrence of early life history stages of marine fishes from Indian coasts, without descriptions, figures or justification for their identification (Basheeruddin and Nayar, 1962; Chandra, 1964; Rao, K.V., 1964; Rao, N.G.S., 1967; UNDP/FAO, 1974; 1975 b, to mention a few). Such reports appear to be based on incomplete information and hence are of limited value.

On the development and systematics of early life history stages of the vast majority of marine and estuarine fishes of India, lacunae still exist. Hence, it is essential to undertake long-term research programmes for intensive studies in a critical manner in the lines indicated.

RÉSUMÉ

Adequate knowledge on development and systematics of early life history stages of marine and estuarine fishes is an important prerequisite for estimating adult biomass, monitoring changes in stocks, forecasting trends of production, collecting seeds of target species for commercial stocking, clarifying taxonomic features based on ontogenetic aspects, etc, etc. In India, among about 1,800 marine and estuarine fish species available, development and systematics of early life history stages in not even 10% of them are known in sufficient detail. And, in Porto Novo itself, along south-east coast of India, among about 600 species of fishes present, the early life history stages of only about 55 are identified and documented till 1977. Hence, in order to expand our knowledge further, a study on development and systematics of early life history stages of the common fishes in the locality was undertaken during 1977 -'79, based on material collected mostly from plankton; and the results are recorded in the present thesis.

Among twentyfive species dealt with in the present work, one or more early life history stages of fifteen cases are reported for the first time, namely: Nematalosa nasus, Sardinella clupeoides, S.sirm, S.albella, Ilisha melastoma, I.megaloptera, Thryssa

dussumieri, T.mystax, Liza dussumieri, L.tade, Polynemus sextarius, Gerres oblongus, G.setiferus, Therapon jarbua and Siganus javus. Developmental stages of five other species are described for the first time in India, viz, those of Chanos chanos, Sardinella fimbriata, Sillago sihama, Upeneus (Pennon) bensasi and Platycephalus indicus. Also, eggs, larvae, etc of another five species are recorded for the first time from Porto Novo, namely Thryssa hamiltonii, Stolephorus tri, Liza macrolepis, Lates calcarifer and Rastrelliger kanagurta. Discussion on systematics of the early life history stages is included to highlight their salient features and diagnostic characters.

Larvae of Nematalosa nasus have 45 myotomes, as against 41 in the closely allied Anodontostoma chacunda. Differences in number and disposition of myotomes, sequence of development of caudal fin and pigmentation pattern have aided in identification of the postlarvae of this species for the first time from plankton.

Size of egg, diameter of yolk and absence of oilglobule are characteristic of the eggs of Sardinella clupeoides. Early larvae of this species could be distinguished by the absence of oilglobule. Postlarvae of S.clupeoides, inspite of their larger size, showed a lesser pace of development and hinder position of vent compared to postlarvae of closely related S.gibbosa. Also, the former could be distinguished from the postlarvae of S.dayi by variations in number and disposition of myotomes, inspite of similar developmental sequences. Postlarvae of Sardinella sirm, when compared to those of S.clupeoides, presented a lesser number of preanal myotomes and difference in pigmentation pattern.

Eggs of Sardinella fimbriata could be distinguished from those of allied species having similar egg diameter by a smaller size of yolk. Among allied species which have overlapping range of myotomes, postlarvae of S.fimbriata could be separated from those of S.gibbosa, S.dayi and S.longiceps through variations in number and disposition of myotomes, in developmental sequences and in pattern of pigmentation. Postlarvae and juveniles of Sardinella albella could be isolated from those of S.sirm and S.clupeoides, all of which have the same range of total myotomes, by dissimilarities in their disposition.

Advanced postlarvae of Ilisha melastoma showed indication of a longer anal fin base under development than those of other clupeids having a short anal fin in adult condition. Also, a rapid forward movement of vent was noticed during postlarval development in this species than in certain sardines. Distinctly low number of total myotomes in I.melastoma when compared to the allied I.megaloptera could be used with advantage for separating the postlarvae of these two species.

Postlarvae and juveniles of Chanos chanos collected at Porto Novo showed some variations in pigmentation from those artificially bred and reared in Philippines. Recent finding that four subpopulations of this species are present in Indo-Pacific region seems to be supported by this observation.

Eggs of Thryssa dussumieri were smaller than those of T.hamiltonii. Their larvae also showed differences in number and disposition of myotomes. Number of myotomes was useful in the identification of a postlarva of Stolephorus tri also.

Eggs of the mullet Liza dussumieri were smaller than those of Liza macrolepis and L.tade. Larvae hatching out from the eggs of L.tade had oilglobules at front aspect of yolksac whereas in those of L.macrolepis the oilglobules occupied a hinder position. Differences in pattern of pigmentation were helpful to separate early postlarvae of the above three species of mullets.

Postlarvae of the threadfin *Polynemus sextarius* could be distinguished from those of other polynemids in the number and disposition of their myotomes. Its juveniles showed six free pectoral fin rays. In the postlarvae and juveniles of *Sillago sihama*, described from Indian waters here, differences were observed in forward and backward movement of anus with resultant variations in preanal and postanal proportions of the body, as compared to material reported earlier from Japan. This points out to the existence of differences in the species, based on geographical variations.

Eggs of the silver biddy, *Gerres oblongus* had a vacuolated yolk and a pigmented oilglobule. Postlarvae of this species could be separated from those of the allied species *G.setiferus* chiefly by the presence of a characteristic midlateral series of pigmentation in the latter and its absence in the former. Late postlarvae and juveniles of these two species could be distinguished in that in *G.setiferus* ten developing spines could be made out in the first dorsal fin, but only nine in those of the other species. Also, between these two species, a difference in forward and backward movement of anus could be observed during postlarval development.

The eggs of Therapon jarbua, with a prominent oilglobule, present a dark, glistening appearance. Postlarvae of the goatfish, Upeneus (Pennon) bensasi, differ from those of the same species reported from Japan, in the position of vent. Post-larval and juvenile development of the rabbitfish Siganus javus suggested a lateral flattening of the body at the end of postlarval phase, accompanied by a reduction in length. A significant observation with regard to this species was replacement of the postlarval dorsal and anal fin spines during development, by a new juvenile set, accompanied by atrophy or resorption of the postlarval set.

A single postlarval form of the Indian mackerel Rastrelliger kanagurta, reported for the first time from the east coast of India, resembled similar stages of Japanese and Atlantic mackerels closely, in the low number of preanal myotomes.

Salient features of taxonomic value in respect of the developmental stages are commented upon, including those for comparison and contrast to equivalent stages of related species described by previous authors. Differences in such subtle aspects as position of oilglobule in larvae, pattern of pigmentation, sequence of development of certain parts of the body, etc, etc, **which were found to be of value** in the separation of developmental stages with overlapping meristic characters, are highlighted in the concluding section on general remarks.

It is obvious that extensive and intensive collections, pelagic, midwater and demersel, should be undertaken at Porto Novo and nearby neritic waters, in order to study the systematics of early life history stages of this locality and to add to our knowledge on the developmental stages of much more species. Also, from the occurrence of the early life history stages of many culturable fishes at Porto Novo, such as Chanos chanos, Liza dussumieri, L.macrolepis, Sillago sihama, Gerres spp, Siganus javus, etc, seed resources of these species appear to be available in this area for exploitation and stocking in commercial Coastal Aquaculture operations. Since Porto Novo and its environs appear to be a breeding and nursery ground for a good number of fishes, including commercially important ones, it is imperative to protect the spawning stocks through controlled fishing. The concluding section draws attention to these aspects also and points out to the need for planned programmes in the above regards.

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APPENDIX

List of Papers Published by the Author

(A) Research Papers and Scientific Articles:-

(1) Bensam, P. 1964 On certain gonadial abnormalities met with in the Indian Oilsardine *Sardinella longiceps* Val. *J. mar. biol. Ass. India*, 6 (1): 135 - 142.

(2) Bensam, P. 1964 Regeneration of the caudal fin in the Indian Oilsardine *Sardinella longiceps* Valencienns. *J. mar. biol. Ass. India*, 7 (1): 102 - 107.

(3) Bensam, P. 1965 On a freak embryo of the grey shark *Carcharinus limbatus* Muller and Henle. *J. mar. biol. Ass. India*, 7 (1): 206 - 208.

(4) Bensam, P. 1967 The pharyngeal pockets in the Indian Oilsardine *Sardinella longiceps* Valenciennes and a few other Clupeiformes from Indian Waters. *Indian J. Fish.*, 11 A (1): 175 - 180.

(5) Bensam, P. 1967 Differences in the food and feeding adaptations between juveniles and adults of the Indian Oilsardine *Sardinella longiceps* Valenciennes. *Indian J. Fish.*, 11 A (1): 377 - 390.

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(10) Bensam, P. 1968 Growth variations in the Indian Oilsardine _Sardinella longiceps_ Valenciennes. _Indian J_. _Fish_., 11 A (2): 699 - 708.

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(13) Bensam, P. and P.K.M. Pillai 1970 Regeneration in the flat fish Cynoglossus macrolepidotus Bleeker. J. mar. biol. Ass. India, 10 (2): 403 - 406.

(14) Bensam, P. 1970 Notes on the eggs, larvae and juveniles of the Indian sprat Sardinella jussieu (Lacepede). Indian J. Fish., 13 (1 & 2): 219 - 231.

(15) Bensam, P. 1971 Notes on postlarval stages of the White sardine Kowala coval (Cuvier). J. mar. biol. Ass. India, 11 (1 & 2): 251 - 254.

(16) Bensam, P. 1971 On a few postlarval stages of Anodontostoma chacunda Hamilton. Indian J. Fish., 14 (1 & 2): 48 - 53.

(17) Bensam, P. 1972 A preliminary review of our knowledge on the early lifehistories of Clupeiformes from Indian Waters with provisional keys for identifying the eggs and early larvae. La mer, 9 (3): 158 - 167.

(18) Bensam, P. 1972 On the fluctuations in the Oilsardine fishery at Cannanore during 1961 - 1964. Indian J. Fish., 17: 132 - 148.

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(26) Tampi, P.R.S. and P.Bensam 1976 Review of work programs on the biology of the Milkfish carried out in India. *Proc. internat. Milkfish Workshop Conf.*, Working Pap 15 (I R D C & S E A F D E C).

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(30) Bensam, P., K. Ramadoss and N. Sundaram 1974 Methods of Mariculture. Seafood Exp. J., 6 (11): 23 - 32.

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(33) Bensam, P. 1980 On judicious exploitation of marine fisheries resources. Seafood Exp. J., 12 (3): 9 - 12.

(C) Research Abstracts:-

(34) Bensam, P., N. Sundaram and R. Gurusamy 1972

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(35) Bensam, P., M.E. Rajapandian and R. Gurusamy 1972 Proc. Symp. pelag. fish. resour., Abstracts: 25 (C M F R I).

(36) Bensam, P. 1973 Techniques of identifying fish eggs and larvae in tropical waters. Proc. internat. Symp. early lifehist. Fish., Abstracts: 5 (F A O, I A B O, I C E S, I C N A F & S C O R).

(37) Natarajan, R. and P. Bensam 1980 Prospects of Coastal Aquaculture at Porto Novo. Proc. Symp. coast. Aquacult., Abstracts: 5 - 6 (M B A I).

(38) Bensam, P. and S. Shanmugam 1980 On commercial culture of marine fin fish in India. Proc. Symp. coast. Aquacult., Abstracts: 63 - 64 (M B A I).

(39) Bensam, P. 1980 Some problems in commercial culture of marine prawns in India. Proc. Symp. coast. Aquacult., Abstracts: 75 (M B A I).

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