A KARYOTYPE STUDY OF SOME TELEOSTS FROM PORTONOVO WATERS*

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ABSTRACT

1. The present report embodies the results of a study on the karyotypes of 16 teleost species belonging to 15 families and 7 orders, viz., Anguilliformes (1 sp.), Cypriniformes (1 sp.), Siluriformes (1 sp.), Synbranchiformes (1 sp.), Scorpaeniformes (2 spp.), Perciformes (9 spp.) and Tetradontiformes (1 sp.).

2. The diploid chromosome numbers in the 16 species presently studied ranges from 40 to 62.

3. The size of the chromosomes ranges from 0.83 to 5.30 μ.

4. No heteromorphic pair or pairs of chromosomes are discernible in any of them: further, a study of the karyotypes in both the sexes of Mystus gulio, Etroplus suratensis, E. maculatus, Mugil cephalus and Anabas testudineus failed to reveal the occurrence of heteromorphism, if any, in them.

5. Based on the available morphological and cytological information, the systematic position and species interrelationships have also been discussed.

INTRODUCTION

The usefulness of the study of chromosomes in fish systematics, especially as an invaluable tool in understanding their phylogenetic relations (Roberts, 1967) has now been fully realised. Teleostei is the largest (60 %) vertebrate group comprising nearly 40,000 species (Lagler et al., 1963) and the heterogeneous nature of the group is revealed amply in the complex classification (Greenwood et al., 1966). This most interesting group, however, has not been well understood cytologically: of the 32 orders containing more than

* Dedicated to our teacher, late Prof. R. V. Seshaiya in fond memory and great appreciation.
400 families, the chromosome numbers of only 57 families falling under 13 orders are at present known. Thus, the total number of cytotologically known species constitutes 0.7% of the total number of living bony fishes.

Studies on fish chromosomes have been few and spotty, most of the early observations being related to spermatogenesis or development (Turner, 1919; Geiser, 1924; Hann, 1927; Vaupel, 1929; Ralston, 1934; Bennington, 1936; Svärdsong, 1939; Svärdsong and Wickbom, 1942). Mitotic inhibitors such as colchicine (Roberts, 1964; Olmo et al., 1965; McPhail and Jones, 1966; Natarajan and Subrahmanyam, 1968), rotenone (Subrahmanyam, 1970) or velban (present study) are a boon to the fish cytologists. Several investigators also employed culture techniques in fish chromosome studies (Roberts, 1966; Lueken and Foerster, 1969; Chen, 1970; Heckman and Brubaker, 1970; Ojima et al., 1970). Extensive cytological studies on the fish chromosomes are very few; Nogusa (1960) reported on the chromosome complements of 60 species and Post (1965) recorded the haploid chromosome numbers of 106 teleost species. Roberts (1964) studied 20 species of centrarchids, Nayyar (1962, 1964, 1965, 1966) 22 freshwater fishes from India, Setzer (1968) 12 species of Fundulus and Chen 25 deep sea fishes (1969) and 20 species of the genus Fundulus (1971).

In India, excepting for the reports of Nayyar (op. cit.) and Kaur and Srivastava (1965), both of them on freshwater fishes, studies on the chromosomes of marine fishes have never been attempted excepting in this laboratory (Subrahmanyam, 1969; Subrahmanyam and Natarajan, 1970). The present study, a continuation of that programme, reports on the karyotype analyses of 16 bony fishes (15 families) from Portonovo waters. All the species, except Lepidocephalichthys berdmorei, Anabas testudineus and Macrornathus aculeatum are marine. The chromosome numbers in seven families, viz., Ophichthidae, Synbranchidae, Scorpaenidae, Platycephalidae, Centropomidae, Scatophagidae and Tetradontidae are reported only now for the first time.

Material and Methods

Specimens were collected from the Vellar estuary and connected backwater except Lepidocephalichthys berdmorei, Anabas testudineus and Macrornathus aculeatum which were secured from the freshwater canals and tanks from the nearby localities. 0.2% of rotenone (Scatophagus argus, Mystus gulio and Macrornathus aculeatum) (Subrahmanyam, 1970), 0.01% of velban (Platycephalus indicus) and 0.1% of colchicine (all the remaining species) administrations were given 2 to 3 hours before dissecting out the gills, kidney and gonads and the method followed has already been described.
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in detail in an earlier report (Natarajan and Subrahmanyam, 1968). Intraperitoneal injections of calcium chloride were given (except in L. berdmori) in order to increase the mitotic index (Subrahmanyam, 1969). The camera lucida drawings were made after carefully determining the diploid chromosome number and their morphology from several well spread and intact metaphase plates in each species. The classification followed in the present study is that of Greenwood et al. (1966).

RESULTS AND DISCUSSION

The chemical injected, the tissues studied and the sex and diploid numbers of chromosomes of the species investigated presently are listed in Table I.

Order: ANGUILLIFORMES
Suborder: ANGUILLOIDEI
Family: Ophichthidae

1. Pisodonophis boro (Hamilton Buchanan) (Figs. 1, 2, 48)

The diploid chromosome number of this species as revealed from a study of the somatic chromosomes from the gills of the male is 40 (Fig. 1). The karyotype drawn from this complement is shown in Fig. 2. The mitotic chromosomes range from 1·50 µ to 4·50 µ in size (Fig. 48); the chromosomes pairs 3,5 to 7,16 and 20 have median centromeres with the rest showing submedian centromeres. No heteromorphic pair or pairs could be noticed in the somatic male complement studied presently.

Previously, the chromosome numbers of seven species of eels belonging to four families have been reported. 2n = 50 in Echelidae and 2n = 40, 42 in Muraenidae (Nogusa, 1960), 2n = 38 in Anguillidae (Sick et al., 1962; Chiarelli et al., 1969) and 2n = 50 in Moringuidae (Subrahmanyam and Ramamoorthi, 1971). The present study adds information on one species of Ophichthidae (2n = 40). Diploid chromosome numbers of 38 to 50 have so far been reported in eels. Chiarelli et al. (1969) reported the occurrence of a heteromorphic pair of chromosomes in Anguilla anguilla. However, in Moringuidae as well as Ophichthidae studied by the authors, no such heteromorphic pair or pairs could be found.

The family Ophichthidae is said to be closely related to Myridae and Nemichthyidae (Weber and Beaufort, 1916), to Cyenidae and Neenchelyidae (Jordan, 1923), to Congridae and Dysommidae (Berg, 1940: as quoted by Lagler et al., 1963), to Congridae and Todaridae
### Table I

*Chromosome numbers of fishes investigated presently with other details*

<table>
<thead>
<tr>
<th>Species</th>
<th>Environment</th>
<th>Chemical</th>
<th>Tissues studied</th>
<th>Sex, $2n(n)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Pisodonophis bore</em></td>
<td>Estuary</td>
<td>Rotenone</td>
<td>Gills</td>
<td>Male 40</td>
</tr>
<tr>
<td>2. <em>Lepidocephalichthys berdmori</em></td>
<td>Freshwater</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Male 62</td>
</tr>
<tr>
<td>3. <em>Mystus gulio</em></td>
<td>Estuary</td>
<td>Rotenone &amp;</td>
<td>Gills, kidney &amp; gonads</td>
<td>Male 58, Female (29)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colchicine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. <em>Synbranchus bengalensis</em></td>
<td>Estuary</td>
<td>Rotenone</td>
<td>Gills &amp; ovary</td>
<td>Female 46</td>
</tr>
<tr>
<td>5. <em>Tetrarogoniger</em></td>
<td>Backwaters</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Male 50 (25)</td>
</tr>
<tr>
<td>6. <em>Platycephalus indicus</em></td>
<td>Estuary</td>
<td>Velban</td>
<td>Gills</td>
<td>Immature 48</td>
</tr>
<tr>
<td>7. <em>Lates calcarifer</em></td>
<td>Estuary</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Immature 48</td>
</tr>
<tr>
<td>8. <em>Epinephelus diacanthus</em></td>
<td>Estuary</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Immature 48</td>
</tr>
<tr>
<td>9. <em>Monodactylus argenteus</em></td>
<td>Estuary</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Immature 48</td>
</tr>
<tr>
<td>10. <em>Scatophagus argus</em></td>
<td>Estuary</td>
<td>Rotenone</td>
<td>Gills</td>
<td>Male 46, Female (23)</td>
</tr>
<tr>
<td>11. <em>Etroplus maculatus</em></td>
<td>Estuary</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Male, Female 48</td>
</tr>
<tr>
<td>12. <em>E. suratensis</em></td>
<td>Estuary</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Male, Female 48</td>
</tr>
<tr>
<td>13. <em>Mugil cephalus</em></td>
<td>Estuary</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Male, Female 48</td>
</tr>
<tr>
<td>14. <em>Anabas testudineus</em></td>
<td>Freshwater</td>
<td>Colchicine &amp; Rotenone</td>
<td>Gills, kidney &amp; gonads</td>
<td>Male 48, Female (24)</td>
</tr>
<tr>
<td>15. <em>Macrognathus aculeatum</em></td>
<td>Freshwater</td>
<td>Rotenone</td>
<td>Gills</td>
<td>Female 48</td>
</tr>
<tr>
<td>16. <em>Arothron hispids</em></td>
<td>Estuary</td>
<td>Colchicine</td>
<td>Gills</td>
<td>Immature 42</td>
</tr>
</tbody>
</table>
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(Greenwood et al., 1966), to Nettastomidae and Dysommiidae (McAllister, 1968) and to Anguillidae and Echeilidae (Munro, 1967). Of these the chromosome numbers of only Echeilidae (2n = 50) and Anguillidae (2n = 38) are known. The karyotype of Pisodonophis boro (Ophichthidae) studied presently seems to be closer to Anguillidae (2n = 38) than to Echeilidae (2n = 50).

**Order**: CYPRINIFORMES

**Suborder**: CYPRINOIDEI

**Family**: Cobitidae

2. *Lepidocephalichthys bredmori* (Blyth) (Figs. 3, 4, 49)

The diploid chromosome number, studied from the gill tissues (Fig. 3) of two male specimens, was found to be 62. The karyotype (Fig. 4) consists of metacentrics with median centromeres except for pairs 23 and 24 which show submedian centromeres. The karyogram (Fig. 49) reveals a gradual decrease in the size of the chromosomes. The chromosome lengths range from 0.83 μ to 3.30 μ. The karyotype did not include any heteromorphic pair or pairs.

The chromosome numbers of 9 species of this family are known. In seven species (Nogusa, 1960; Post, 1965; Kobayasi, 1965; Muramoto et al., 1968; Hitotsumachi et al., 1969), diploid chromosome numbers of 48, 50 and 52 have been reported while in the other two it has been found that 2n = 96 and 98 (Nogusa, 1960; Muramoto et al., 1968; Ojima and Hitotsumachi, 1969; Hitotsumachi et al., 1969). In one of the latter, *Cobitis biwae* (2n = 96), Ojima and Hitotsumachi (1969) reported the occurrence of twice the amount of DNA than that in *C. delicata* (2n = 52) and thus, *C. biwae* is reported to be a tetraploid. Whether the occurrence of 2n = 98 (Muramoto et al., 1968) may also be taken as indicative of tetraploidy in Botia macracantha remains to be seen.

The diploid chromosome number of 62 in *Lepidocephalichthys bredmori* is quite high compared to 50 and 52 reported in other seven species so far and thus, raises some very interesting questions. It has been known that polyploidy plays a definite role in the evolution of fishes (Ohno et al., 1968) as evidenced in Salmoniformes (Ohno et al., 1969), Cypriniformes (Ohno et al., 1967) and Cyprinodontiformes (Schultz, 1967; Cimino and Schultz, 1970; Rasch et al., 1970). In the family Cobitidae, wherein diploid chromosome numbers of 48, 50, 52, 62, 96 and 98 have been recorded and the occurrence of a tetraploid species has also been reported (Ojima and Hitotsumachi, 1969), it is
Figs. 1-23
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imperative that more detailed cytological investigations of the members of
the family must be undertaken in order to understand the species interrela-
tionships and to know the role of polyploidy, if any, in their evolution.

Order : SILURIFORMES
Family : Bagridae

3. *Mystus gulio* (Hamilton Buchanan) (Figs. 5–9, 50)

The karyotype of this species has been studied presently from the gills,
kidney and gonads in both the sexes. \(2n = 58\) (Figs. 5, 7) and \(n = 29\)
(Fig. 9) in this species and all the elements are metacentrics with median
centromeres excepting pairs 4 to 9 and 14 to 18 which possess submedian
centromeres (Figs. 6, 8). The chromosomes range in size between 1·10 \(\mu\)
and 3·00 \(\mu\) (Fig. 50). No dissimilar pair or pairs could be noticed in the
karyotype of either sex.

The diploid chromosome number 58 in *Mystus gulio* is the highest
recorded so far in this family. Previously, the karyotypes of five species, *i.e.*, *Pelteobagrus nudiceps* (\(2n = 56, n = 28\)) from Japan (Nogusa, 1960) and
*Rita rita, Mystus tengara* (\(2n = 54\); Nayyar, 1966), *M. seenghala* and
*M. vittatus* (\(2n = 50, n = 25\); Srivastava and Das, 1969) from Indian waters
have been studied. The chromosome number in the genus *Mystus* shows
variations between 50 and 58 in the four species cytologically known so far.
Interestingly, the meristic characters of the different species of *Mystus* show
only slight variations (Table II) while cytologically the karyotypes appear
to be quite distinct.

<table>
<thead>
<tr>
<th>Table II</th>
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</table>

*A comparison of the meristic characters between three species of the genus Mystus*

<table>
<thead>
<tr>
<th>M. seenghala</th>
<th>M. vittatus</th>
<th>M. gulio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsal fin I, 7</td>
<td>I, 7</td>
<td>I, 7</td>
</tr>
<tr>
<td>Anal fin III, 8–9</td>
<td>II–III, 7–9</td>
<td>III·IV, 9–11</td>
</tr>
<tr>
<td>Pectoral fin I, 9</td>
<td>I, 9</td>
<td>I, 8–9</td>
</tr>
<tr>
<td>Caudal fin 19–21</td>
<td>17</td>
<td>17</td>
</tr>
</tbody>
</table>
In the two other cytologically known families of the order, Ictaluridae (2n = 56) and Siluridae (2n = 40 to 86), the chromosome numbers show a wider range.

Order : SYNBRANCHIFORMES  
Suborder : SYNBRANCHOIDEI  
Family : Synbranchidae  

4. *Synbranchus bengalensis* (Mc Clelland) (Figs. 10–12, 51)

The chromosome complement of *Synbranchus bengalensis* has been studied from the gills (Fig. 10) and ovary (Fig. 12) of the female specimens only. The chromosome number of this species is 2n = 46 and all the elements are metacentrics with median centromeres except pairs 19 and 20 which have submedian centromeres (Fig. 11). There is a gradation in the size of the chromosomes and their length ranges between 1·50 μ and 4·00 μ (Fig. 51). The female karyotype does not reveal the occurrence of any heteromorphic pair or pairs.

Synbranchiformes is a cytologically unknown group hitherto and the karyotype of *S. bengalensis* (2n = 46) seems to resemble more the percoid pattern, in accordance with the suggestions given by Berg (1940), Munro (1955, 1967) and Greenwood *et al.* (1966) based on the morphological grounds. It is worth while to study cytologically the family Amphipnoidae and other species of Synbranchoidei so as to throw more light on the true relationships of this family.

Order : SCORPAENIFORMES  

Two species belonging to this order have been studied presently.

Suborder : SCORPAENOIDEI  
Family : Scorpaeidae  

5. *Tetraroge niger* (Cuvier and Valenciennes) (Figs. 13–15, 52)

The chromosome complement of *Tetraroge niger* has been studied from the gill epithelium of the males only. The diploid chromosome number of this species is 50 (Fig. 13). The karyotype (Fig. 14) shows that pairs 1 to 13, 15 to 18 and 22 to 25 have median centromeres, the remaining pairs being submedians. The karyogram (Fig. 55) shows a gradual decrease in the size of the elements. The length of the chromosomes ranges between 1·50 μ and 4·00 μ. The last four pairs (22 to 25) are the smallest elements in the complement.
measuring about 1·50 μ. No heteromorphic pair or pairs are discernible in the karyotype of the male. The meiotic bivalents \((n = 25)\) from the testis are shown in Fig. 15.

Suborder : **PLATYCEPHALOIDEI**

Family : **Platycephalidae**

6. *Platycephalus indicus* (Linnaeus) Figs. 16, 17, 53)

As the specimens injected were immature, the specimens could not be sexed. The diploid chromosome number (Fig. 16) of *Platycephalus indicus* is 48 as revealed in the gill epithelial cells after velban injections. All the elements in the karyotype (Fig. 17) are medians except for five submedian pairs (13 to 17). The karyogram shows a slight gradation in the size of the elements and the chromosome lengths range from 1·10 μ to 3·00 μ (Fig. 53). The karyotype does not reveal any heteromorphism in any of the chromosomes.

Chromosome numbers of seven species belonging to three families, *viz.*, Cottidae (Hann, 1927; Nogusa, 1960; Starmach, 1967), Hexagrammidae (Makino, 1937, quoted from Makino, 1951; Nogusa, 1960) and Synanceiidae (Nogusa, 1960) show a wide range from 36 to 52. The chromosome-numbers for the families Scorpaenidae \((2n = 50)\) and Platycephalidae \((2n = 48)\) are reported here for the first time.

The systematic position of this family is also unsettled. It has been treated as a suborder under Perciformes by Berg (1940), Munro (1955, 1967) and McAllister (1968) while Jordan (1923), DeBeaufort (1962) and Greenwood et al. (1966) accorded it an ordinal status. The chromosome size, morphology and number in the two species studied now and those reported by others seem to show similarities to the Perciformes karyotypes, in general. Both from cytological and morphological points of view, they do not appear to be widely diverged from the Perciformes. Accordingly, a separate ordinal status to these members may obscure their phylogenetic relationship with Perciformes. It must however be borne in mind here that the karyotypes of only eight species are known and more information on this group is needed, to know whether a separate ordinal status is warranted for the members of this group.

Munro (1955, 1967) and McAllister (1968) included the families Scorpenidae and Platycephalidae under Cottoidei but Greenwood et al. (1966) treated them under two separate suborders, Scorpaenoidae and Platycephaloidae. Their diploid chromosome numbers are 50 and 48 and morpho-
Figs. 24–47
logically, the two differ only in body form and dorsal spines. It may therefore be justified to include them under one suborder, Cottoidei. All the five families of the order Scorpaeniformes, studied so far cytologically, show diploid chromosome numbers of 48, 50 and 52 and thus seem to be quite closely related.

Order : PERCIFORMES

Presently, the chromosomes of nine species of Perciformes belonging to four different suborders and eight families have been studied. The chromosomes of six species belonging to the suborder Percoidei and to the families Centropomidae, Serranidae, Monodactylidae, Scatophagidae and Cichlidae, of one species under the suborder Mugiloidae and family Mugilidae, of another species under Anabantoidei and family Anabantidae and of one species belonging to Mastacembelodei and family Mastacembelididae have been studied. $2n=48$ in all of them except in *Etroplus maculatus* where $2n=46$.

Suborder : PERCOIDEI

Family : Centropomidae

7. *Lates calcarifer* (Block) (Figs. 18, 19, 54)

A large number of well spread metaphase plates were obtained from the gills of a single immature specimen. The diploid chromosome number is 48 (Fig. 18). All the chromosomes in the karyotype (Fig. 19) are metacentrics with median centromeres except pair 20 which has submedian centromeres. The size of the chromosomes is much smaller and the length is seen to range from $1.00 \mu$ to $2.67 \mu$ (Fig. 54). The karyotype analysis did not reveal any heteromorphism.

Cytological information on two species is only available. Post (1965) reported $n=22$ for *Chanda ranga* and Nayyar (1966) recorded that $2n=50$ for *Ambassis nama*.

The families Moronidae (Jordan, 1923), Priacanthidae (Weber and Beaufort, 1929), Theraponidae (Berg, 1940), Ambassidae (Munro, 1955), Serranidae (Weber and Beaufort, 1929; Berg, 1940, Greenwood *et al.*, 1966), Chandidae and Kuliidae (Munro, 1967) are suggested to be related to Centropomidae. Of these, the chromosome numbers of the families Ambassidae ($2n=50$: Nayyar, 1966), Theraponidae ($2n=48$: Subrahmanyam and Natarajan, 1970) and Serranidae ($2n=48$: Nogusa, 1960; present study) are
only known. Theraponidae and Serranidae appear to be close to Centropomidae cytologically. Greenwood et al. (1966) have lumped the families Chandidae ($n=22$) and Ambassidae ($2n=50$) with Centropomidae ($2n=48$); more cytological information is however needed to confirm the above opinion of treating these families together.

Family : Serranidae

8. *Epinephelus diacanthus* (Valenciennes) (Figs. 20, 21, 55)

The diploid chromosome number was found to be 48 (Fig. 20) in this species as revealed from the gill epithelium of immature specimens. The karyotype (Fig. 21) consists of metacentrics with median centromeres except for pair 24 which has submedian centromeres. A gradual decrease in the length of the chromosomes is also evident from the karyogram. The chromosome length ranged between 1.67 $\mu$ and 4.33 $\mu$ (Fig. 55). The karyotype revealed no heteromorphism.

The diploid number of *Epinephelus diacanthus* is 48 and the same number has also been found in *Coreoperca kawamebari* studied from Japan (Nogusa, 1960). The family Epinephelidae treated separately by Jordan (1923) and Munro (1967) was included under the family Serranidae by Weber and Beaufort (1931), Greenwood et al. (1966) and McAllister (1968). The families Plesiopidae (Jordan, 1923), Centropomidae, Theraponidae (Weber and Beaufort, 1931), Kuhliidae (Berg, 1940), Ambassidae and Pseudochromidae (Munro, 1955), Grammistidae (Greenwood et al., 1966) and Scombropsidae and Trichodentidae (McAllister, 1968) have been reported to be related to the serranids. Of them, the families Centropomidae ($2n=48$) (Post, 1965; present study) Theraponidae ($2n=48$) (Subrahamanyam and Natarajan, 1970), Ambassidae ($2n=50$) (Nayyar, 1966) are only known cytologically. The family Ambassidae has been merged with Centropomidae (Greenwood et al., 1966) and thus, from the available information, the families Centropomidae, Theraponidae and Serranidae may be considered to be very closely related.

Family : Monodactylidae (Psettidae)

9. *Monodactylus argenteus* (Linnaeus) (Figs. 22, 23, 56)

The specimens were immature. The chromosome complement was studied from the gill epithelium and the diploid number was found to be 48 (Fig. 22). All the elements in the karyotype are metacentrics with median centromeres (Fig. 23). A slight gradation in the karyotype is evident and
the chromosome length is seen to range from 1.00 μ to 2.67 μ (Fig. 56). The chromosomes apparently are smaller in size. No dissimilar pair or pairs are discernible in the karyotype.

The diploid number of 48 reported presently for Monodactylus argenteus is in agreement with the earlier report for this species from Germany by Post (1965).

Family : Scatophagidae

10. Scatophagus argus (Linnaeus) (Figs. 24, 25, 57)

The chromosome complement of Scatophagus argus was studied from the gill epithelium (sex undetermined) and the diploid number was found to be 48 (Fig. 24). The karyotype (Fig. 25) shows the pairs 2 and 24 to be submedians while the remaining elements (pairs 1 and 3 to 23) are metacentrics with median centromeres. The karyogram (Fig. 57) reveals a gradual decrease in the length of the chromosomes and the size range is from 1.50 μ to 4.00 μ. No heteromorphic elements could be seen in the karyotype of S. argus.

No other member of Scatophagidae has been studied cytologically so far and the present report of 2n=48 in Scatophagus argus is the only one available for this family. The affinities of this family with others could not therefore be discussed in the absence of cytological information on any other species of this family.

Family : Cichlidae

11. Etroplus suratensis (Bloch) (Figs. 26–29, 58)

The diploid chromosome complement of this species as studied from the gills is 48 in both the sexes (Figs. 26, 28). The karyotype (Figs. 27, 29) consists of metacentrics with median centromeres (pairs 1 to 22 and 24) except for one pair (23) which is subterminal in nature. The chromosome length ranges between 1.83 μ and 3.00 μ (Fig. 58). None of the pairs in the karyotypes of both the sexes has been found to be dissimilar either in size or shape.

12. Etroplus maculatus (Bloch) (Figs. 30–34, 59)

The chromosome number of this species was studied using gill tissues and the diploid number was found to be 46 in both the sexes (Figs. 30, 32).
The karyograms (Figs. 31, 33) reveal three distinct size groups. Two pairs (1 and 2) (4·30μ to 5·30μ) are large; pairs 3 to 16 (2·00μ to 3·00μ) are intermediate in size and the remaining pairs, i.e., 17 to 23 (0·83μ to 1·50μ) are small. The last pair (23) is the smallest measuring about 0·833μ (Fig. 59). Pairs 8 and 16 are submedians while the remaining elements have median centromeres. No heteromorphism could be noticed in the male and female karyotypes. Haploid chromosome number of 23 has been observed from testis (Fig. 34).

The family Cichlidae is considered as the most advanced among Perciformes (Greenwood et al., 1966) and is said to contain 92 species. The members of this family exhibit territoriality, courtship and parental care (Sterba, 1967). Diploid chromosome numbers of 44, 46, 48 and 60 have been reported in 16 species of Cichlidae studied so far inclusive of the present study.

The two species of *Etroplus*, studied presently, differ from each other as follows:

**Table III**

A comparison of the meristic characters between two species of *Etroplus*

<table>
<thead>
<tr>
<th>Character</th>
<th><em>E. suratensis</em></th>
<th><em>E. maculatus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat</td>
<td>Marine &amp; brackish-waters</td>
<td>Brackish &amp; fresh-waters</td>
</tr>
<tr>
<td>Dorsal fins</td>
<td>XVIII–XIX 14–15</td>
<td>XVII–XX 8–10</td>
</tr>
<tr>
<td>Anal fin</td>
<td>XII–XIII 11–12</td>
<td>XII–XV 8–9</td>
</tr>
<tr>
<td>Pectoral fin</td>
<td>17</td>
<td>14–16</td>
</tr>
<tr>
<td>L. 1.</td>
<td>35–40</td>
<td>35–37</td>
</tr>
</tbody>
</table>

Cytologically the two species appear to be distinct: not only the chromosome numbers are different (48 and 46) but the karyotypes also show differences. Cytologically, therefore, the two species may be considered as quite distinct and well separated from each other.

It is very interesting to note here that varying diploid chromosome numbers of 44 to 60, reported in Cichlidae, has also been recorded in Gobioidae the members of which show sexual dimorphism, territoriality, courtship behaviour and parental care as do the members of Cichlidae.
There thus appears to be a striking parallelism between these two highly advanced groups.

The chromosome numbers in 48 species of Percoidei have so far been reported and most of them (38 species) have $2n = 48$. It is tempting to suggest therefore that probably, the basic chromosome number for members of this suborder is 48. It may be interesting to trace the evolution of different families of this suborder when more cytological information is available for all the families. Of the 71 families included under the suborder Percoidei (Greenwood et al., 1966), cytological information is available only for 11 families at the present.

Suborder: Mugiloidae
Family: Mugilidae

13. Mugil cephalus Linnaeus (Figs. 35–38, 60)

The chromosome complements from the gill epithelial cells showed that diploid chromosome number of *Mugil cephalus* is 48 (Figs. 35, 37) in both the sexes. The karyotype (Figs. 36, 38) of this species consists of metacentrics with median centromeres. Homologous elements lie side by side. The chromosome length (Fig. 60) ranges between $1.40 \mu$ and $3.30 \mu$. The gradual decrease in the size of the chromosomes, seen previously in other species, is not apparent in *Mugil cephalus*, particularly in the last 13 pairs (12 to 24), all of which measure almost $1.40 \mu$ in length. The first pair is the longest ($3.30 \mu$) and the pairs 2 to 11 are $2.30 \mu$ in length.

The karyotype of *Mugil cephalus* does not reveal the occurrence of any heteromorphic elements in either sex.

Information on the chromosome numbers in the family Mugilidae is limited to one freshwater species, *Mugil corsula* ($2n = 48$) from Indian waters (Nayyar, 1966). The species *Mugil corsula* Hamilton, 1822 has been moved to the genus *Rhinomugil* Gill, 1863 by Misra (1962). But the close resemblance between *M. corsula* and *M. cephalus* studied presently, both in morphology (Table IV) and karyology, seem to justify *corsula*'s inclusion in the genus *Mugil* Linnaeus, 1758.

Some authors (Day, 1878; Munro, 1955, 1967) accorded to this group of fishes a separate ordinal status, Mugiliformes. Several others (Regan, 1929 as quoted by Sterba, 1967; Berg, 1940; Greenwood et al., 1966; McAlister, 1968) treated them under the order Perciformes (suborder: Mugiloidae). Based on a study of plasma proteins Gunter and Hall (1965) suggested that Mugiliformes may be considered as primitive percomorphs.
A Karyotype Study of Some Teleosts from Portonovo Waters

TABLE IV
Comparison of meristic characters of two species of Mugilidae

<table>
<thead>
<tr>
<th></th>
<th>Mugil corsula (2n=48)</th>
<th>M. cephalus (2n=48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsal fins</td>
<td>4/1/7-8</td>
<td>4/1/8</td>
</tr>
<tr>
<td>Anal fin</td>
<td>3/9</td>
<td>3/8</td>
</tr>
<tr>
<td>Caudal fin</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>L. L.</td>
<td>48–52</td>
<td>42–44</td>
</tr>
<tr>
<td>L. tr.</td>
<td>15</td>
<td>14</td>
</tr>
</tbody>
</table>

The karyotypes of M. cephalus and M. corsula contain 48 elements which resemble the typical Perciformes pattern (Nogusa, 1960; Kaur and Srivastava, 1965; Post, 1965; Nayyar, 1966; Subrahmanyan and Natarajan, 1970; present study). The cytological information so far available seem to justify the inclusion of the members of Mugilidae in the order Perciformes, as suggested by Gunter and Hall (1965), Greenwood et al. (1966) and Mc Allister (1968).

The available cytological information does not seem to indicate any close relationship between the Ophicephalidae (2n = 34 and 40; Nayyar, 1966) and Mugilidae. Though the family Atherinidae (n = 24: Post, 1965) may appear to be cytologically close to Mugilidae, it has been separated from the Mugiloidae and placed under the order Atheriniformes by Greenwood et al. (1966). Extensive and detailed cytological information on these families would be of great help in unveiling their true relationships.

Suborder: Anabantoidei
Family: Anabantidae

14. Anabas testudineus (Bloch) (Figs. 39–44, 61)

Several karyotypes were studied from gills (Fig. 39), gonads (Fig. 43) and kidney (Fig. 43) after colchicine and rotenone injections. The diploid chromosome number was found to be 48 in both the sexes. Pairs 1 to 4, 6 to 13, 16, 17 and 19 to 24 are metacentrics with median centromeres while the remaining pairs (5, 14, 15 and 18) are submedians (Figs. 40, 42). The karyogram (Fig. 61) showed a gradual decrease in length of the elements and
the chromosome length ranged from 1.17 $\mu$ to 4.00 $\mu$. The karyotype was not found to contain any heteromorphic pair or pairs of elements in either of the sexes.

The first meiotic metaphase plate from the testis showed 24 bivalents (Fig. 44).

The diploid chromosome number of 48 observed presently in *A. testudineus* corroborates the previous observations made by Kaur and Srivastava (1965) and Nayyar (1966) from India on *A. testudineus* and *C. fasciatus* ($2n = 48$). The chromosomes of *Betta splendens* ($2n = 42$, $n = 21$) have been studied by Bennington (1936) and Svärdson and Wickbom (1942) and the haploid chromosome numbers of *Ctenopoma ansorgei* ($n = 24$), *Trichogaster trichopterus* ($n = 24$; 23?) by Post (1965) and *Macropodus opercularis* ($n = 21$) by Svärdson and Wickbom (1942) and Post (1965).

*Anabas* is an interesting fish which possesses an accessory respiratory organ. Anabantidae was treated as a separate order Labyrinthici by Weber and Beaufort (1922) but the latter authors treated it under the orders Perciformes (Berg, 1940; Munro, 1955; Greenwood *et al.*, 1966) and Ophi- cephaliformes (McAllister, 1968) (suborder: Anabantoidi).

The family Anabantidae is said to be close to Stromatoidei (Berg, 1940; Munro, 1955; Greenwood *et al.*, 1966) and McAllister (1968) placed it between Belontiidae and Luciocephalidae (Luciocephaloidei); none of these groups are known cytologically. From a consideration of the chromosome numbers it is obvious that the anabantids are closer to Perciformes.

**Suborder** : **MASTACEMBELOIDEI**

**Family** : **Mastacembelidae** (*Rhynchobdelidae*)

15. *Macrognathus aculeatum* (Bloch) (Figs. 45, 62)

The chromosome number of *Macrognathus aculeatum* has been studied, after rotenone injections, from the gill epithelial cells and the karyotype consists of 48 elements; all are metacentric elements with median centromeres except for one pair (9) which is submedian in nature (Fig. 45). A gradation is seen in the size of the chromosomes and the chromosome length ranges between 1.33 $\mu$ and 2.33 $\mu$ (Fig. 62). No heteromorphic pair or pairs of chromosomes could be seen in the karyotype of this spiny eel.

The diploid chromosome number of 48 observed now in *Macrognathus aculeatum* is in agreement with the previous report from India (Kaur and
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Srivastava, 1965). The family Chaudhuridae (Greenwood et al., 1966; McAllister, 1968) has been suggested to be close to Mastacembelidae but the cytological information on this family is not available.

The karyotype of *M. aculeatum* (2n = 48) resembles the karyotypes of the Perciformes families like Nandidae (Kaur and Srivastava, 1965; Post, 1965), Centropomidae, Serranidae, Scatophagidae, Mugilidae (present study), and Theraponidae (Subrahmanyam and Natarajan, 1970) both in number and morphology. Job (1941) while studying the life-history and bionomics of *Mastacembelus pancalus* (Hamilton) pointed out its close affinity to the Perciformes fishes (Nandidae).

The members of the family Mastacembelidae have been treated under a separate order (Ophisthomi) by Jordan (1923) and under Mastacemeliformes by Berg (1940), Munro (1955) and McAllister (1968). However Greenwood et al. (1966) included these fishes under Perciformes (suborder: Mastacembeloidei), which seems to be supported by the cytological information so far available.

Order : TETRAODONTIFORMES
Suborder : TETRAODONTOIDEI
Family : Tetraodontidae

16. *Arothron hispidus* (Linnaeus) (Figs. 46, 47, 63)

Only immature specimens of *Arothron hispidus* were injected and the gills yielded good number of well spread metaphase plates. The diploid chromosome number of this species was found to be 42 (Fig. 46). The chromosome complement is characterised by the presence of few elements which are small to moderate in size. The karyotype is formed of median and submedian elements. Pairs 2 to 5 and 9 to 16 are with median centromeres and the remaining elements (pairs 1, 6 to 8 and 17 to 21) have submedian centromeres (Fig. 47). The chromosome length ranged between 1.00 μ and 2.33 μ (Fig. 63). The karyotype failed to reveal the presence of any heteromorphism.

The diploid chromosome complements of three species, viz., *Stephanolepis cirrhifer* (2n = 34, n = 17), *Rudarius ercodes* (2n = 36, n = 18) and *Novodon modestus* (2n = 40, n = 20) of the family Aluteridae (= Balistidae, Greenwood et al., 1966) are only known previously (Nogusa, 1960). The diploid numbers reported for three species of Balistidae range between 34 and 40 (Nogusa, 1960) and 2n = 42 in *A. hispidus* of the family Tetra-
odontidae. All these fishes possess low chromosome numbers, and the size of the chromosomes also is very small. In the absence of detailed cytological information, the affinities of this family could not be discussed at present.

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——— . . Ibid., 1922, 4, 1-410.

——— . . Ibid., 1929, 5, 1-458.

——— . . Ibid., 1931, 6, 1-448.

EXPLANATION OF FIGURES

Figs. 1-47. Karyotypes

Figs. 1, 2. Phisodonophis boro, 2 n = 40, gill, male.

Figs. 3, 4. Lepidocephalichthys berdmori, 2 n = 62, gill.

Figs. 5-9. Mystus gulio, 2 n = 58, gill: Figs. 5, 6, female; Figs. 7, 8, male; Fig. 9, testis, meiotic bivalents (n = 25).

Figs. 10-12. Synbranchus bengalensis, 2 n = 46: Figs. 10, 11, gill, female; Fig. 12, ovary.

Figs. 13-15. Tetrarogine niger, 2 n = 50, male: Figs. 13, 14, gill; Figs. 15, testis, meiotic bivalents (n = 25).

Figs. 16, 17. Platypocephalus indicus, 2 n = 48, gill.

Figs. 18, 19. Lates calcarifer, 2n = 48, gill.

Figs. 20, 21. Epinephelus diacanthus, 2 n = 48, gill.

Figs. 22, 23. Monodactylus argenteus, 2 n = 48, gill.

Figs. 24, 25. Scatophagus argus, 2 n = 48, gill.

Figs. 26-29. Etroplus suratensis, 2 n = 48, gill: Figs. 26, 27, male; Figs. 28, 29, female.
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Figs. 30–34. *E. maculatus*, 2 n = 46, gill; Figs. 30, 31, female; Figs. 32, 33, male; Fig. 34, testis, meiotic bivalents (n = 23).

Figs. 35–38. *Mugil cephalus*, 2 n = 48, gill; Figs. 35, 36, female; Figs. 37, 38, male.

Figs. 39–44. *Anabas testudineus*, 2 n = 48; Figs. 39, 40, female, gill; Figs. 41, 42, male, kidney; Fig. 43, ovary; Fig. 44, testis, meiotic bivalents (n = 24).

Fig. 45. *Macrignathus aculeatum*, 2 n = 48, gill, female.

Figs. 46, 47. *Arothron hispidus*, 2 n = 42, gill.

Figs. 48–63. Karyograms (A–J represent chromosome pairs)

Fig. 48. *P. boro* (A, 1; B, 2, 4; C, 3; D, 5–7; E, 8–11; F, 12; G, 13–15; H, 16; I, 17–19; J, 20).

Fig. 49. *L. berdmorei* (A, 1; B, 2–4; C, 5–16; D, 17–22, 24; E, 23; F, 25–30; G, 31).

Fig. 50. *M. gilus* (A, 1–3; B, 4–9; C, 10–13; D, 14–18; E, 19–22; F, 23–29).

Fig. 51. *S. bengalensis* (A, 1, 2; B, 3–7; C, 8–14; D, 15–17; E, 18; F, 19, 20; G, 21–23).

Fig. 52. *T. niger* (A, 1–3; B, 4–13; C, 14; D, 15; E, 16–18; F, 19; G, 20, 21; H, 22–25).

Fig. 53. *P. indicus* (A, 1–8; B, 9–12; C, 13, 14; D, 15–17; E, 18; F, 19–24).

Fig. 54. *L. calcarifer* (A, 1; B, 2–9; C, 10–19; D, 20; E, 22–24).

Fig. 55. *E. diacanthus* (A, 1–7; B, 8–19; C, 20–23; D, 24).

Fig. 56. *M. argenteus* (A, 1–7; B, 8–16; C, 17–23; D, 24).

Fig. 57. *S. argus* (A, 1; B, 2; C, 3–7; D, 8–12; E, 13–18; F, 19, 20; G, 21–23; H, 24).

Fig. 58. *E. suratensis* (A, 1–9; B, 10; C, 11–23; D, 24).

Fig. 59. *E. maculatus* (A, 1; B, 2; C, 3; D, 4, 5; E, 6, 7; F, 8; G, 9, 10; H, 11–16; I, 17–22; J, 23).

Fig. 60. *M. cephalus* (A, 1; B, 2–11; C, 12–24).

Fig. 61. *A. testudineus* (A, 1–4; B, 5; C, 6–8; D, 9–13; E, 14, 15; F, 16, 17; G, 18; H, 19–22; I, 23–24).

Fig. 62. *M. aculeatum* (A, 1; B, 2–8; C, 9; D, 10–15; E, 16–24).

Fig. 63. *A. hispidus* (A, 1; B, 2, 3; C, 4; D, 5; E, 6–8; F, 9–16; G, 17–21).