

# Chromosome Formulae of North American Fishes<sup>1</sup>

J.R. Gold, W.J. Karel, and M.R. Strand

*Genetics Section, Texas A&M University  
College Station, Texas 77843*

**ABSTRACT:** Chromosome formulae (diploid chromosome and chromosome arm number) are listed for 309 North American fish species, including representatives from 145 genera in 54 families. This updates earlier lists by more than 130 entries. In addition the list displays the presence of microelements or sex chromosomes in the complements of several species. The source of taxa was the Third Edition (1970) of the list of common and scientific names of fishes prepared by the American Fisheries Society's Committee on Names of Fishes.

Within the last decade, there has been a renewed and vigorous interest in studying the chromosome complements or karyotypes of organisms. This has been due in large part to technological advances which facilitate chromosome preparation and which often provide resolution of individual chromosomes within a complement (German 1973; Hsu 1973). Equally important have been the findings that karyotypic comparisons among and within various taxa are often crucial in assessing phenetic and phylogenetic relationships (Chiarelli and Capanna 1973b).

The study of karyotypes of fishes has lagged far behind that of most vertebrates. There are more than 20,000 living species of fishes, but chromosome numbers are known for only 700-750 species; complete karyotypes are published for less than 600 species. In contrast, more than 40% of the living species of eutherian mammals have been karyotyped, in some cases extensively.

The difficulty in studying fish chromosomes stems from their small size and large number in most complements. Fish chromosomes generally average between 2 and 5  $\mu\text{m}$  in length, although many species possess numerous chromosomes of 2  $\mu\text{m}$  or less. Reported diploid chromosome numbers in fishes range from 16 to 168, but the distribution is strongly leptokurtic, with almost 70% of the assayed species falling in the range  $2n = 44-52$  (Gold 1979). A further difficulty is that many fish karyotypes are highly asymmetric (*sensu* Stebbins 1958); not only are differences in chromosome size apparent, but also differences are evident in centromere position, even within groups of chromosomes of approximately equal size.

In the following, the chromosome formulae (diploid

chromosome and chromosome arm numbers) of 309 North American fish species are presented; this list updates earlier lists (Chiarelli and Capanna 1973a; Denton 1973; Park 1974) by more than 130 North American entries. We chose to restrict the list to North American fishes since there already exists a critical reference (see below) of currently recognized and valid North American fish taxa. This restriction circumvents problems of taxonomic revisions that may occur after publication of an original work, which may confuse non-taxonomists or ichthyologists attempting to use the list. This list should also serve as a strong base for future lists.

The source of taxa was the Third Edition of the list of common and scientific names of fishes prepared by the American Fisheries Society's (AFS) Committee on Names of Fishes (AFS 1970). This includes all species known from the fresh waters of the continental United States and Canada, and those marine species inhabiting contiguous shore waters on or above the continental shelf. Pelagic fishes that enter waters over the continental shelf are included; the Indo-Pacific fish fauna of Hawaii are not. The sequence of orders and families of fishes is essentially natural or phyletic, and generally follows Greenwood et al. (1966), with the species of each family alphabetized to generic and specific names.

The list includes 343 separate entries covering 309 named species from 145 genera in 54 families. All but 11 entries were checked from the cited reference. A few species are included in the list which are not recognized by the Committee on Names of Fishes; these are indicated by quotation marks around the specific name. Multiple entries per species occur according to the following criteria: (1) subspecific rank listed by the Committee on Names of Fishes, (2) documentation of intraspecific chromosomal polymorphism, or (3) documentation of sex chromosomes. The choice of literature references was based on the general availability of the reference, the chromosome preparation technique, and the

<sup>1</sup> A closely similar version of this paper, with the same title, appeared as report MP-1411 of the Texas A&M Agricultural Experiment Station. The desirability of wider dissemination of this information is the basis for its appearance in *The Progressive Fish-Culturist*.

number of species reported in the reference. Where possible, references from hard-to-obtain journals were excluded, as were studies which employed other than modern techniques of chromosome preparation. A few papers that presented karyotypes for a number of species were cited in preference to an original work to condense the reference section.

The list displays diploid chromosome and chromosome arm numbers. If not stated specifically in the reference, we estimated chromosome arm numbers after Levan et al. (1964); if no mention was made as to chromosome type (metacentric, acrocentric, etc.), chromosome arm numbers are not shown. An asterisk (\*) following the chromosome number indicates the presence of microelements in the complement. In some species (e.g.,

*Polyodon spathula*) there is clear separation between macro- and micro-elements in the karyotype; this is noted where appropriate. A dagger (†) preceding the generic name indicates an "exotic" or introduced species that was listed by the Committee on Names of Fishes. Parentheses that enclose sex chromosome symbols following the specific name indicate sexual heterogamety. By convention, XX:XY and XX:XO indicate male heterogamety; WZ:ZZ indicates female heterogamety. The WY:YY designation in *Xiphophorus maculatus* refers to populations with female heterogamety (see Gold 1979). Superscripts 1 and 2 following the parentheses indicating sex chromosomes indicate whether the sex chromosomes were identified cytologically (= 1), or inferred from genetic or other evidence (= 2).

Table 1. Chromosome formulae of North American fishes. Asterisks (\*) indicate the presence of microelements in the complement; daggers (†) denote exotic or introduced species. Parentheses enclosing sex chromosomes symbols indicate sexual heterogamety; superscripts to the parentheses indicate whether the sex chromosomes were identified cytologically (1) or inferred from genetic or other evidence (2).

Taxon	Chromosome number	Chromosome arm number	Source
CLASS AGNATHA — JAWLESS FISHES			
ORDER MYXINIFORMES			
Myxinidae — hagfishes			
<i>Eptatretus stouti</i>	48*	48	Taylor (1967)
<i>Myxine glutinosa</i>	42*	—	Nygren and Jahnke (1972)
ORDER PETROMYZONTIFORMES			
Petromyzontidae — lampreys			
<i>Ichthyomyzon fossor</i>	164-166*	—	Robinson et al. (1974)
<i>Ichthyomyzon gagei</i>	164*	≥164	Howell and Duckett (1971)
<i>Lampetra aepyptera</i>	164*	—	Howell and Denton (1969)
<i>Lampetra lamottei</i>	164-166*	—	Robinson et al. (1974)
<i>Petromyzon marinus</i>	164-168*	—	Potter and Rothwell (1970)
CLASS CHONDRICHTHYES — CARTILAGINOUS FISHES			
ORDER SQUALIFORMES			
Squalidae — dogfish sharks			
<i>Squalus acanthias</i>	62*	—	Nygren et al. (1971c)
ORDER RAJIFORMES			
Torpedinidae — electric rays			
<i>Narcine brasiliensis</i>	28	50	Donahue (1974)
Rajidae — skates			
<i>Raja radiata</i>	98*	104	Nygren et al. (1971c)
Dasyatidae — stingrays			
<i>Dasyatis sabina</i>	68	96	Donahue (1974)
<i>Dasyatis sayi</i>	68	102	Donahue (1974)

Taxon	Chromosome number	Chromosome arm number	Source
ORDER CHAMAERIFORMES			
Chimaeridae — chimaeras			
<i>Hydrolagus collicii</i>	58* (24 macro-) (34 micro-)	-	Ohno et al. (1969)
CLASS OSTEICHTHYES — BONY FISHES			
ORDER ACIPENSERIFORMES			
Acipenseridae — sturgeons			
<i>Scaphirhynchus platyrhynchus</i>	112* (64 macro-) (48 micro-)	-	Ohno et al. (1969)
Polyodontidae — paddlefishes			
<i>Polyodon spathula</i>	120* (48 macro-) (72 micro-)	-	Dingerkus and Howell (1976)
ORDER SEMIONOTIFORMES			
Lepisosteidae — gars			
<i>Lepisosteus oculatus</i>	68* (42 macro-) (26 micro-)	-	Ohno et al. (1969)
ORDER AMMIIFORMES			
Ammiidae — bowfins			
<i>Amia calva</i>	46	-	Ohno et al. (1969)
ORDER ANGUILLIFORMES			
Anguillidae — freshwater eels			
<i>Anguilla rostrata</i>	38	-	Sick et al. (1962)
ORDER CLUPEIFORMES			
Clupeidae — herrings			
<i>Alosa pseudoharengus</i>	48	48	Mayers and Roberts (1969)
<i>Clupea harengus harengus</i>	52	-	Roberts (1966)
<i>Clupea harengus pallasii</i>	52	60	Ohno et al. (1968)
Engraulidae — anchovies			
<i>Engraulis mordax</i>	48	48	Klose et al. (1968)
ORDER OSTEOGLOSSIFORMES			
Hiodontidae — mooneyes			
<i>Hiodon alosoides</i>	50	90	Uyeno (1973)
ORDER SALMONIFORMES			
Salmonidae — trouts			
<i>Coregonus artedii</i>	80	106	Booke (1968)
<i>Coregonus clupeaformis</i>	80	108	Booke (1968)
<i>Coregonus hoyi</i>	80	98	Booke (1968)
<i>Coregonus nasus</i>	80	92	Nygren et al. (1971a)
<i>Coregonus pidschian</i>	80	-	Nygren et al. (1971a)

Taxon	Chromosome number	Chromosome arm number	Source
<i>Coregonus reighardi</i>	80	104	Booke (1968)
<i>Coregonus zenithicus</i>	80	98	Booke (1968)
<i>Oncorhynchus gorbuscha</i>	52	104	Simon (1963)
<i>Oncorhynchus keta</i>	74	106	Sasaki et al. (1968)
<i>Oncorhynchus kisutch</i>	60	104	Simon (1963)
<i>Oncorhynchus nerka</i>	58	104	Sasaki et al. (1968)
<i>Oncorhynchus nerka</i> (XX:XY-A) <sup>1</sup>	57(♂), 58(♀)	104	Thorgaard (1978)
<i>Oncorhynchus tshawytscha</i>	68	104	Simon (1963)
<i>Prosopium abyssicola</i>	72	100	Booke (1974)
<i>Prosopium coulteri</i>	82	100	Booke (1968)
<i>Prosopium cylindraceum</i>	78	100	Booke (1968)
<i>Prosopium gemmiferum</i>	64	100	Booke (1974)
<i>Prosopium sponnotus</i>	74	100	Booke (1974)
<i>Prosopium williamsoni</i>	78	100	Booke (1970)
<i>Salmo aguabonita</i>	58	104	Gold and Gall (1975)
<i>Salmo apache</i>	56	106	Miller (1972)
<i>Salmo clarki bouvieri</i>	64	104	Loudenslager and Thorgaard (1979)
<i>Salmo clarki clarki</i>	70	106	Simon (1964)
<i>Salmo clarki clarki</i>	68	104	Gold et al. (1977)
<i>Salmo clarki henshawi</i>	64	104	Gold et al. (1977)
<i>Salmo clarki lewisi</i>	64	106	Simon and Dollar (1963)
<i>Salmo clarki lewisi</i>	66	104	Loudenslager and Thorgaard (1979)
<i>Salmo gairdneri</i>	58-60	104	Thorgaard (1976)
<i>Salmo gairdneri</i> (XX:XY) <sup>1</sup>	58	104	Thorgaard (1977)
<i>Salmo gairdneri</i>	60	104	Simon and Dollar (1963)
<i>Salmo gairdneri</i>	62	104	Vasil'yev (1975)
<i>Salmo gilae</i>	56	105	Beamish and Miller (1977)
<i>Salmo</i> sp. (Redband)	58	104	Gold (1977)
<i>Salmo salar</i> (European)	58	74	Rees (1967)
<i>Salmo salar</i> (European)	60	72	Prokofieva (1934)
<i>Salmo salar</i> (North American)	54-57	72	Roberts (1968, 1970)
† <i>Salmo trutta</i>	80	100	Nygren et al. (1971b)
<i>Salvelinus alpinus</i>	80	96	Svårdson (1945)
<i>Salvelinus fontinalis</i>	84	100	Davisson et al. (1973)
<i>Salvelinus malma</i>	82	102	Abe and Muramoto (1974)
<i>Salvelinus namaycush</i>	84	100	Davisson et al. (1973)
<i>Stenodus leucichthys</i>	74	108	Booke (1975)
Osmeridae — smelts			
<i>Hypomesus pretiosus</i>	50	60	Ohno (1974)
<i>Spirinchus starksi</i>	50	60	Klose et al. (1968)
Argentinidae — argentines			
<i>Argentina silus</i>	44	61(♂)	Ebeling et al. (1971)
Bathylagidae — deepsea smelts			
<i>Bathylagus stilbius</i> (XX:XY) <sup>1</sup>	64	-	Chen (1969)
Umbridae — mudminnows			
<i>Dallia pectoralis</i>	78	118	Beamish et al. (1971)
<i>Novumbra hubbsi</i>	48	74	Beamish et al. (1971)
<i>Umbra limi</i>	22	44	Beamish et al. (1971)
<i>Umbra pygmaea</i>	22	44	Beamish et al. (1971)

Taxon	Chromosome number	Chromosome arm number	Source
Esocidae — pikes			
<i>Esox americanus americanus</i>	50	50	Beamish et al. (1971)
<i>Esox americanus vermiculatus</i>	50	50	Beamish et al. (1971)
<i>Esox lucius</i>	50	50	Nygren et al. (1968)
<i>Esox masquinongy</i>	50	50	McGregor (1970)
<i>Esox niger</i>	50	50	Beamish et al. (1971)
ORDER MYCTOPHIFORMES			
Synodontidae — lizardfishes			
<i>Synodus lucioceps</i>	48	76(♀)	Ebeling et al. (1971)
Myctophidae — lanternfishes			
<i>Ceratoscopelus townsendi</i>	48	48	Chen and Ebeling (1974)
<i>Diaphus theta</i>	48	—	Chen and Ebeling (1974)
<i>Lampanyctus regalis</i>	48	48	Chen and Ebeling (1974)
<i>Notoscopelus resplendens</i>	48	—	Post (1972)
<i>Protomyctophum crockeri</i>	48	48	Chen and Ebeling (1974)
<i>Stenobranchius leucopsarus</i>	48	48	Chen and Ebeling (1974)
<i>Triphoturus mexicanus</i>	48	48(♂)	Ebeling et al. (1971)
ORDER CYPRINIFORMES			
Characidae — characins			
<i>Astyanax mexicanus</i>	50	90	Kirby et al. (1977)
Cyprinidae — minnows and carps			
<i>Campostoma anomalum</i>	50	96	Gold et al. (1978)
† <i>Carassius auratus</i>	100	148	Ojima et al. (1966)
† <i>Carassius auratus</i>	100	160	Kobayasi et al. (1970)
† <i>Carassius auratus</i>	104	124	Chiarelli et al. (1969)
† <i>Carassius auratus</i> (XX:XY) <sup>2</sup>			Yamamoto and Kajishima (1968)
<i>Couesius plumbeus</i> (= <i>Hybopsis plumbea</i> )	50	—	Legendre and Steven (1969)
† <i>Cyprinus carpio</i>	104	168	Ohno et al. (1968)
<i>Dionda episcopa</i>	50	—	Gold et al. (1980)
<i>Ericymba buccata</i>	50	—	Gold et al. (1980)
<i>Exoglossum maxillingua</i>	48	—	Legendre and Steven (1969)
<i>Gila bicolor</i>	50	94	Gold and Avise (1977)
<i>Gila orcutti</i>	50	88	Greenfield and Greenfield (1972)
<i>Hesperoleucus symmetricus</i>	50	92	Gold and Avise (1977)
<i>Hybognathus hayi</i>	50	96	Gold et al. (1978)
<i>Hybognathus nuchalis</i>	50	—	Gold et al. (1980)
<i>Hybopsis aestivalis</i>	50	94	Gold et al. (1978)
<i>Hybopsis amblops</i>	50	96	Gold et al. (1980)
<i>Lavinia exilicauda</i>	50	92	Gold and Avise (1977)
<i>Lepidomeda albivallis</i>	50	94	Uyeno and Miller (1973)
<i>Lepidomeda mollispinis</i>	50	92	Uyeno and Miller (1973)
<i>Lepidomeda vittata</i>	50	96	Uyeno and Miller (1973)
† <i>Leuciscus idus</i>	50	—	Hinegardner and Rosen (1972)
<i>Meda fulgida</i>	50	92	Uyeno and Miller (1973)
<i>Mylopharodon conocephalus</i>	50	94	Gold and Avise (1977)
<i>Nocomis leptcephalus</i>	50	92	Gold et al. (1980)

Taxon	Chromosome number	Chromosome arm number	Source
<i>Notemigonus crysoleucas</i>	50	94	Gold and Avise (1977)
<i>Notropis amabilis</i>	50	98	Gold et al. (1980)
<i>Notropis atherinoides</i>	50	98	Gold et al. (1980)
<i>Notropis atrocaudalis</i>	50	96	Gold et al. (1980)
<i>Notropis callistius</i>	50	—	Denton and Howell (1969)
<i>Notropis camurus</i>	50	96	Gold et al. (1980)
<i>Notropis chrysocephalus</i>	50	98	Gold et al. (1979b)
<i>Notropis cornutus</i>	50	96	Greenfield et al. (1973)
<i>Notropis fumeus</i>	50	98	Gold et al. (1979b)
<i>Notropis longirostris</i>	50	94	Gold et al. (1979b)
<i>Notropis lutrensis</i>	50	100	Gold et al. (1979b)
<i>Notropis oxyrhynchus</i>	50	98	Gold et al. (1979b)
<i>Notropis potteri</i>	50	98	Gold et al. (1980)
<i>Notropis roseipinnis</i>	50	98	Gold et al. (1979b)
<i>Notropis sabiniae</i>	50	100	Gold et al. (1979b)
<i>Notropis shumardi</i>	50	98	Gold et al. (1979b)
<i>Notropis signipinnis</i>	50	98	Gold et al. (1979b)
<i>Notropis stilbius</i>	50	—	Denton and Howell (1969)
<i>Notropis stramineus</i>	50	100	Gold et al. (1980)
<i>Notropis texanus</i>	50	98	Gold et al. (1979b)
<i>Notropis umbratilis</i>	50	100	Gold et al. (1979b)
<i>Notropis venustus</i>	50	98	Gold et al. (1979b)
<i>Notropis volucellus</i>	50	96	Gold et al. (1979b)
<i>Opsopoeodus (=Notropis) emiliae</i>	48	80	Campos and Hubbs (1973)
<i>Orthodon microlepidotus</i>	50	94	Gold and Avise (1977)
<i>Phenacobius mirabilis</i>	50	96	Gold et al. (1978)
<i>Phoxinus eos</i>	50	—	Legendre and Steven (1969)
<i>Phoxinus erythrogaster</i>	50	96	Greenfield et al. (1973)
<i>Pimephales notatus</i>	52	—	Legendre and Steven (1969)
<i>Pimephales promelas</i>	50	98	Gold et al. (1980)
<i>Pimephales vigilax</i>	50	98	Gold et al. (1978)
<i>Plagopterus argentissimus</i>	50	94	Uyeno and Miller (1973)
<i>Pogonichthys macrolepidotus</i>	50	94	Gold and Avise (1977)
<i>Ptychocheilus grandis</i>	50	92	Gold and Avise (1977)
<i>Ptychocheilus lucius</i>	50	—	Uyeno and Smith (1972)
<i>Rhinichthys atratulus</i>	50	94	Howell and Villa (1976)
<i>Rhinichthys cataractae</i>	50	94	Howell and Villa (1976)
<i>Rhinichthys evermanni</i>	50	—	McPhail and Jones (1966)
<i>Richardsonius egregius</i>	50	86	Gold and Avise (1977)
† <i>Scardinius erythrophthalmus</i>	48	—	Chiarelli et al. (1969)
<i>Semotilus atromaculatus</i>	52	—	Legendre and Steven (1969)
<i>Semotilus atromaculatus</i>	50	96	Gold et al. (1980)
<i>Semotilus corporalis</i>	52	—	Legendre and Steven (1969)
<i>Semotilus margarita</i>	50	—	Legendre and Steven (1969)
† <i>Tinca tinca</i>	48	80±	Wolf et al. (1969)
Catostomidae — suckers			
<i>Carpiodes carpio</i>	96-100	—	Uyeno and Smith (1972)
<i>Catostomus catostomus</i>	98	—	Beamish and Tsuyuki (1971)
<i>Catostomus clarki</i>	96-100	—	Uyeno and Smith (1972)
<i>Catostomus commersoni</i>	98	—	Beamish and Tsuyuki (1971)
<i>Catostomus commersoni</i>	100	124	Chromosome Atlas, Vol. 2 (1973)
<i>Catostomus discobolus</i>	96-100	—	Uyeno and Smith (1972)
<i>Catostomus latipinnis</i>	96-100	—	Uyeno and Smith (1972)

Taxon	Chromosome number	Chromosome arm number	Source
<i>Cycleptus elongatus</i>	96-100	-	Uyeno and Smith (1972)
<i>Erimyzon sucetta</i>	96-100	-	Uyeno and Smith (1972)
<i>Hypentelium nigricans</i>	96-100	-	Uyeno and Smith (1972)
<i>Ictiobus</i> sp.	96-100	-	Uyeno and Smith (1972)
<i>Moxostoma duquesnei</i>	96-100	-	Uyeno and Smith (1972)
<i>Moxostoma erythrurum</i>	96-100	-	Uyeno and Smith (1972)
<i>Moxostoma macrolepidotum</i>	96-100	-	Uyeno and Smith (1972)
Cobitidae — loaches			
† <i>Misgurnus anguillicaudatus</i>	50	64	Hitotsumachi et al. (1969)
ORDER SILURIFORMES			
Ictaluridae — freshwater catfishes			
<i>Ictalurus melas</i>	60	76	LeGrande (1978)
<i>Ictalurus natalis</i>	62	84	LeGrande (1978)
<i>Ictalurus nebulosus</i>	60	76	LeGrande (1978)
<i>Ictalurus punctatus</i>	56	94	Muramoto et al. (1968)
<i>Ictalurus punctatus</i>	58	92	LeGrande (1978)
<i>Ictalurus serracanthus</i>	52	90	LeGrande (1978)
<i>Noturus albater</i>	66-72	82	LeGrande (1978)
<i>Noturus elegans</i>	46	82	LeGrande (1978)
<i>Noturus eleutherus</i>	42	66	LeGrande (1978)
<i>Noturus exilis</i>	54	68	LeGrande (1978)
<i>Noturus flavater</i>	44	62	LeGrande (1978)
<i>Noturus flavipinnis</i>	52	82	LeGrande (1978)
<i>Noturus flavus</i>	50	70	LeGrande (1978)
<i>Noturus flavus</i>	48	70	LeGrande (1978)
<i>Noturus funebris</i>	44	68	LeGrande (1978)
<i>Noturus gilberti</i>	54	82	LeGrande (1978)
<i>Noturus gyrinus</i>	42	64	Chromosome Atlas, Vol. 2 (1973)
<i>Noturus gyrinus</i>	42	72	LeGrande (1978)
<i>Noturus hildebrandi</i>	46	80	LeGrande (1978)
<i>Noturus insignis</i>	54	74	LeGrande (1978)
<i>Noturus lachneri</i>	42	72	LeGrande (1978)
<i>Noturus leptacanthus</i>	46	74	LeGrande (1978)
<i>Noturus miurus</i>	50	74	LeGrande (1978)
<i>Noturus munitus</i>	42	62	LeGrande (1978)
<i>Noturus nocturnus</i>	48	72	LeGrande (1978)
<i>Noturus phaeus</i>	42	68	LeGrande (1978)
<i>Noturus stigmosus</i>	42	62	LeGrande (1978)
<i>Noturus "taylori"</i>	40	61-62	LeGrande (1978)
<i>Pylodictis olivaris</i>	56	82	LeGrande (1978)
Clariidae — airbreathing catfishes			
† <i>Clarias batrachus</i>	52	58	Srivastava and Das (1968)
† <i>Clarias batrachus</i>	50	74	Rishi (1978)
ORDER BATRACHOIDIFORMES			
Batrachoididae — toadfishes			
<i>Porichthys notatus</i>	48	-	Chen (1967)
ORDER GADIFORMES			
Gadidae — codfishes			
<i>Gadus morhua</i>	46	-	Nygren et al. (1974)

Taxon	Chromosome number	Chromosome arm number	Source
<i>Pollachius virens</i>	40	50	Nygren et al. (1974)
ORDER ATHERINIFORMES			
Cyprinodontidae — killifishes			
<i>Adinia xenica</i>	32	—	Uyeno and Miller (1971)
<i>Cyprinodon "atrorus"</i>	48	50	Stevenson (1975)
<i>Cyprinodon "beltrani"</i>	48	50	Stevenson (1975)
<i>Cyprinodon "bifasciatus"</i>	48	50	Stevenson (1975)
<i>Cyprinodon bovinus</i>	48	50	Stevenson (1975)
<i>Cyprinodon elegans</i>	48	50	Stevenson (1975)
<i>Cyprinodon eximius</i>	48	50	Stevenson (1975)
<i>Cyprinodon hubbsi</i>	48	50	Stevenson (1975)
<i>Cyprinodon macularius</i>	48	50	Turner (1974)
<i>Cyprinodon nevadensis</i>	48	50	Turner (1974)
<i>Cyprinodon radiosus</i>	48	50	Turner (1974)
<i>Cyprinodon rubrofluviatilis</i>	48	50	Stevenson (1975)
<i>Cyprinodon salinus</i>	48	50	Turner (1974)
<i>Cyprinodon</i> sp. (= "pecosensis")	48	50	Stevenson (1975)
<i>Cyprinodon variegatus</i>	48	50	Stevenson (1975)
<i>Fundulus chrysotus</i>	34	48	Chen (1971)
<i>Fundulus cingulatus</i>	46	48	Chen (1971)
<i>Fundulus confluentus</i>	48	48	Chen (1971)
<i>Fundulus diaphanus</i> (XX:XY) <sup>1</sup>	48	52	Chen and Ruddle (1970)
<i>Fundulus grandis</i>	48	50	Chen (1971)
<i>Fundulus heteroclitus</i>	48	48	Chen and Ruddle (1970)
<i>Fundulus kansae</i>	48	48	Chen (1971)
<i>Fundulus lineolatus</i>	46	48	Chen (1971)
<i>Fundulus luciae</i>	32	52	Chen (1971)
<i>Fundulus majalis</i>	48	50	Chen and Ruddle (1970)
<i>Fundulus notatus</i>	40	50	Black and Howell (1978)
<i>Fundulus notatus</i>	44	50	Black and Howell (1978)
<i>Fundulus notti</i>	46	48	Chen (1971)
<i>Fundulus olivaceus</i>	48	50	Black and Howell (1978)
<i>Fundulus parvipinnis</i> (XX:XY) <sup>1</sup>	48	49(♂), 50(♀) <sup>1</sup>	Chen and Ruddle (1970)
<i>Fundulus pulvereus</i>	48	50	Chen (1971)
<i>Fundulus rathbuni</i>	48	50	Chen (1971)
<i>Fundulus sciadicus</i>	44	50	Chen (1971)
<i>Fundulus seminolis</i>	48	48	Chen (1971)
<i>Fundulus similis</i>	48	50	Chen (1971)
<i>Fundulus stellifer</i>	48	48	Denton and Howell (1969)
<i>Fundulus waccamensis</i>	48	52	Chen (1971)
<i>Jordanella floridae</i>	48	—	Post (1965)
<i>Lucania parva</i>	46	—	Uyeno and Miller (1971)
<i>Rivulus marmoratus</i>	48	—	Scheel (1972)
Poeciliidae — livebearers			
† <i>Belonesox belizanus</i>	48	—	Post (1965)
<i>Gambusia affinis</i> (U.S.) (WZ:ZZ) <sup>1</sup>	48	50(♂), 51(♀) <sup>1</sup>	Chen and Ebeling (1968)
<i>Gambusia affinis</i> (Italy)	48	48	Cataudella and Sola (1977)
<i>Gambusia affinis</i> (U.S.)	48	50	Black and Howell (1979)
<i>Gambusia gaigei</i> (WZ:ZZ) <sup>1</sup>	48	48(♂), 49(♀)	Campos and Hubbs (1971)
<i>Gambusia nobilis</i> (WZ:ZZ) <sup>1</sup>	48	48(♂), 49(♀)	Campos and Hubbs (1971)
<i>Heterandria formosa</i>	48	—	Post (1965)
<i>Poecilia formosa</i> (diploid)	46	46	Prehn and Rasch (1969)
<i>Poecilia formosa</i> (triploid)	69	69	Prehn and Rasch (1969)



Taxon	Chromosome number	Chromosome arm number	Source
<i>Poecilia latipinna</i>	46	46	Prehn and Rasch (1969)
† <i>Poecilia mexicana</i>	46	—	Prehn and Rasch (1969)
† <i>Poecilia reticulata</i>	46	—	Post (1965)
† <i>Poecilia reticulata</i> (XX:XY) <sup>2</sup>			Winge (1922)
<i>Poeciliopsis occidentalis</i>	48	—	Schultz (1961)
† <i>Xiphophorus helleri</i>	48	48	Ohno and Atkin (1966)
† <i>Xiphophorus maculatus</i>	48	—	Scheel (1972)
† <i>Xiphophorus maculatus</i> (XX:XY) <sup>1</sup>			Förster (1969)
† <i>Xiphophorus maculatus</i> (XX:XY) <sup>2</sup>			Gordon (1947)
† <i>Xiphophorus maculatus</i> (WY:YY) <sup>2</sup>			Gordon (1951)
† <i>Xiphophorus variatus</i>	50	—	Friedman and Gordon (1934)
† <i>Xiphophorus variatus</i> (XX:XY) <sup>2</sup>			Bellamy (1936)
Atherinidae — silversides			
<i>Menidia menidia</i> (=notata)	ca. 36	—	Moenkhaus (1904)
ORDER GASTEROSTEIFORMES			
Gasterosteidae — sticklebacks			
<i>Apeltes quadracus</i> (WZ:ZZ) <sup>1</sup>	46	77(♀), 78(♂)	Chen and Reisman (1970)
<i>Culaea inconstans</i>	46	54	Chen and Reisman (1970)
<i>Gasterosteus aculeatus</i>	42	54	Chen and Reisman (1970)
<i>Gasterosteus wheatlandi</i> (XX:XY) <sup>1</sup>	42	52	Chen and Reisman (1970)
<i>Pungitius pungitius</i>	42	70	Chen and Reisman (1970)
ORDER PERCIFORMES			
Percichthyidae — temperate basses			
<i>Morone americana</i>	48	48	Chromosome Atlas Vol. 2 (1973)
<i>Morone saxatilis</i>	48	50	Rachlin et al. (1978)
Centrarchidae — sunfishes			
<i>Acantharchus pomotis</i>	48	48	Roberts (1964)
<i>Ambloplites rupestris</i>	48	48	Roberts (1964)
<i>Centrarchus macropterus</i>	48	48	Roberts (1964)
<i>Elassoma evergladei</i>	48	—	Post (1965)
<i>Elassoma zonatum</i>	48	50	Roberts (1964)
<i>Enneacanthus chaetodon</i>	48	48	Roberts (1964)
<i>Enneacanthus gloriosus</i>	48	48	Roberts (1964)
<i>Enneacanthus obesus</i>	48	48	Roberts (1964)
<i>Lepomis auritus</i>	48	48	Roberts (1964)
<i>Lepomis cyanellus</i>	46	48	Roberts (1964)
<i>Lepomis cyanellus</i>	48	48	Roberts (1964)
<i>Lepomis gibbosus</i>	46	56	Fontana et al. (1970)
<i>Lepomis gibbosus</i>	48	48	Roberts (1964)
<i>Lepomis gulosus</i>	48	48	Roberts (1964)
<i>Lepomis humilis</i>	46	48	Roberts (1964)
<i>Lepomis macrochirus</i>	48	48	Roberts (1964)
<i>Lepomis marginatus</i>	48	48	Roberts (1964)
<i>Lepomis megalotis</i>	48	48	Roberts (1964)
<i>Lepomis microlophus</i>	48	48	Roberts (1964)
<i>Micropterus dolomieu</i>	46	48	Roberts (1964)
<i>Micropterus punctulatus</i>	46	48	Thompson et al. (1978)
<i>Micropterus salmoides</i>	46	48	Roberts (1964)
<i>Micropterus treculi</i>	46	48	Thompson et al. (1978)
<i>Pomoxis annularis</i>	48	48	Roberts (1964)

Taxon	Chromosome number	Chromosome arm number	Source
<i>Pomoxis nigromaculatus</i>	48	48	Roberts (1964)
Percidae — perches			
<i>Ammocrypta vivax</i>	48	92	Gold et al. (1979a)
<i>Etheostoma blennioides</i>	48	50	Ross (1973)
<i>Etheostoma caeruleum</i>	48	54	Ross (1973)
<i>Etheostoma camurum</i>	48	52	Ross (1973)
<i>Etheostoma ditrema</i>	48	52	Remy (1977)
<i>Etheostoma flabellare</i>	48	52	Ross (1973)
<i>Etheostoma nigrum</i>	48	52	Ross (1973)
<i>Etheostoma swaini</i>	48	52	Remy (1977)
<i>Perca flavescens</i>	48	48	Chromosome Atlas, Vol. 2 (1973)
<i>Percina caprodes</i>	48	92	Gold et al. (1979a)
<i>Percina nigrofasciata</i>	48	94	Gold et al. (1979a)
<i>Percina sciera</i>	48	92	Gold et al. (1979a)
Echeneidae — remoras			
<i>Remora remora</i>	42	42	Rishi (1973)
Pomadasyidae — grunts			
<i>Haemulon sciurus</i>	46	48	Regan et al. (1968)
<i>Haemulon sciurus</i>	48	48	Regan et al. (1968)
Sparidae — porgies			
<i>Archosargus probatocephalus</i>	48	53	Law et al. (1978)
Sciaenidae — drums			
<i>Bairdiella chrysura</i>	48	48	Black et al. (unpubl.) <sup>a</sup>
Cichlidae — cichlids			
† <i>Astronotus ocellatus</i>	48	54	Thompson (1976)
<i>Cichlasoma cyanoguttatum</i>	48	54	Thompson (1976)
† <i>Cichlasoma nigrofasciatum</i>	48	52	Thompson (1976)
† <i>Cichlasoma severum</i>	48	52	Thompson (1976)
† <i>Hemichromis bimaculatus</i>	44	—	Post (1965)
† <i>Tilapia mossambica</i>	44	44	Thompson (1976)
Embiotocidae — surfperches			
<i>Embiotoca jacksoni</i>	48	—	Chen (1967)
Labridae — wrasses			
<i>Tautoglabrus (=Ctenolabrus) adpersus</i>	38-48	—	Pinney (1918)
Mugilidae — mullets			
<i>Mugil cephalus</i>	48	48	LeGrande and Fitzsimons (1976)
<i>Mugil curema</i>	28	48	LeGrande and Fitzsimons (1976)
Bathymasteridae — ronquils			
<i>Ronquilus jordani</i>	26	—	McPhail and Jones (1966)
Gobiidae — gobies			
† <i>Acanthogobius flavimanus</i>	44	44	Arai and Kobayasi (1973)
<i>Gillichthys mirabilis</i>	44	56	Chen and Ebeling (1971)
† <i>Tridentiger trigonocephalus</i>	44	—	Arai and Kobayasi (1973)

Taxon	Chromosome number	Chromosome arm number	Source
Hexagrammidae — greenlings			
<i>Hexagrammos octogrammus</i>	48	—	Makino (1937)
Cottidae — sculpins			
<i>Clinocottus analis</i>	48	—	Chen (1967)
<i>Cottus bairdi</i>	36-38	—	Hann (1927)
<i>Cottus pygmaeus</i>	48	48	Black and Howell (unpubl.) <sup>b</sup>
ORDER PLEURONECTIFORMES			
Bothidae — lefteye flounders			
<i>Citharichthys spilopterus</i>	28	48	LeGrande (1975)
<i>Etropus crossotus</i>	38	≥56	LeGrande (1975)
<i>Paralichthys lethostigma</i>	48	48	LeGrande (1975)
<i>Xystreureys liolepis</i>	48	48	Ohno and Atkin (1966)
Pleuronectidae — righteye flounders			
<i>Pleuronichthys verticalis</i>	48	48	Ohno and Atkin (1966)
Soleidae — soles			
<i>Achirus lineatus</i>	40	≥48	LeGrande (1975)
<i>Trinectes maculatus</i>	48	48	LeGrande (1975)
Cynoglossidae — tonguefishes			
<i>Symphurus plagiusa</i> (XX:XO) <sup>1</sup>	45(♂), 46(♀)	68(♂), 70(♀)	LeGrande (1975)

<sup>a</sup> Black, D.A., W.M. Howell, R.D. Ellender, and B.L. Middlebrooks. 1979. Alterations involving nucleolus organizer chromosomes in a cell line of the silver perch, *Bairdiella chrysura* (Lacépède). Unpublished manuscript.

<sup>b</sup> Black, D.A., and W.M. Howell. Unpublished data. Department of Biology, Samford University, Birmingham, Alabama.

## Acknowledgments

This work was supported by funds administered through the Dean's Office of the College of Agriculture of Texas A&M University and through the Texas Agricultural Experiment Station. We thank D.A. Black for providing several references and L.E. Musick for editorial assistance.

## References

- Abe, S., and J. Muramoto. 1974. Differential staining of chromosomes of two salmonoid species, *Salvelinus leucomaenis* (Pallas) and *Salvelinus malma* (Walbaum). Proc. Jpn. Acad. 50:507-511.
- American Fisheries Society. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd Ed. Am. Fish. Soc. Spec. Publ. 6, Washington, D.C., 150 pp.
- Anders, A., F. Anders, and S. Rase. 1969. XY females caused by X-irradiation. Experientia 25:871.
- Arai, R., and H. Kobayasi. 1973. A chromosome study on thirteen species of Japanese Gobiid fishes. Jpn. J. Ichthyol. 20(1):1-6.
- Beamish, R.J., M.J. Merrilees, and E.J. Crossman. 1971. Karyotypes and DNA values for members of the suborder Esocoidei (Osteichthyes: Salmoniformes). Chromosoma 34:436-447.
- \_\_\_\_\_, and R.R. Miller. 1977. Cytotaxonomic study of gila trout, *Salmo gilae*. J. Fish. Res. Board Can. 34:1041-1045.
- \_\_\_\_\_, and H. Tsuyuki. 1971. A biochemical and cytological study of the longnose sucker (*Catostomus catostomus*) and large and dwarf forms of the white sucker (*Catostomus commersoni*). J. Fish. Res. Board Can. 28:1745-1748.
- Bellamy, A.W. 1936. Inter-specific hybrids in *Platylocichthys*: one species ZZ:WZ; the other XY:XX. Proc. Natl. Acad. Sci. (U.S.) 22:531-536.
- Black, A., and W.M. Howell. 1978. A distinctive chromosomal race of the cyprinodontid fish, *Fundulus notatus*, from the Upper Tombigbee River system of Alabama and Mississippi. Copeia 1978(2):280-288.
- \_\_\_\_\_, and \_\_\_\_\_. 1979. The North American mosquitofish, *Gambusia affinis*: a unique case in sex chromosome evolution. Copeia 1979: (3): 509-513.
- Booke, H. 1968. Cytotaxonomic studies of the Coregonine fishes of the Great Lakes, USA: DNA and karyotype analysis. J. Fish. Res. Board Can. 25:1667-1687.
- \_\_\_\_\_. 1970. Speciation parameters in coregonine fishes: I. Egg-size. II. Karyotype. Pages 61-66 in C.C. Lindsey and C.S. Woods, eds. Biology of coregonid fishes. University of Manitoba Press, Winnipeg, Canada.
- \_\_\_\_\_. 1974. A cytotaxonomic study of round whitefishes, genus *Prosopium*. Copeia 1974(1):115-119.
- \_\_\_\_\_. 1975. Cytotaxonomy of the salmonid fish *Stenodus leucichthys*. J. Fish. Res. Board Can. 32:295-296.

- Campos, H.H., and C. Hubbs. 1971. Cytomorphology of six species of gambusiine fishes. *Copeia* 1971(3):566-569.
- \_\_\_\_\_, and \_\_\_\_\_. 1973. Taxonomic implications of the karyotype of *Opsopoeodus emiliae*. *Copeia* 1973(1):161-163.
- Cataudella, S., and L. Sola. 1977. Sex chromosomes of the mosquitofish (*Gambusia affinis*): An interesting problem for American ichthyologists. *Copeia* 1977(2):382-384.
- Chen, T.R. 1967. Comparative karyology of selected deep-sea and shallow water Teleost fishes. Ph.D. thesis. Yale University, New Haven, Conn. (Cited from Hinegardner and Rosen 1972).
- \_\_\_\_\_. 1969. Karyological heterogamety of deep-sea fishes. *Postilla* 130:1-29.
- \_\_\_\_\_. 1971. A comparative chromosome study of twenty killifish species of genus *Fundulus* (Teleostei: Cyprinodontidae). *Chromosoma* 32:436-453.
- \_\_\_\_\_, and A.W. Ebeling. 1968. Karyological evidence of female heterogamety in the mosquitofish, *Gambusia affinis*. *Copeia* 1968(1):70-75.
- \_\_\_\_\_, and \_\_\_\_\_. 1971. Chromosomes of the goby fishes in the genus *Gillichthys*. *Copeia* 1971(1):171-174.
- \_\_\_\_\_, and \_\_\_\_\_. 1974. Cytotaxonomy of Californian Myctophoid fishes. *Copeia* 1974(4):839-848.
- \_\_\_\_\_, and H.M. Reisman. 1970. A comparative chromosome study of the North American species of sticklebacks (Teleostei: Gasterosteidae). *Cytogenetics* 9:321-332.
- \_\_\_\_\_, and F.H. Ruddle. 1970. A chromosome study of four species and a hybrid of the killifish genus *Fundulus* (Cyprinodontidae). *Chromosoma* 29:255-267.
- Chiarelli, A.B., and E. Capanna. 1973a. Checklist of fish chromosomes. Pages 206-232 in A.B. Chiarelli and E. Capanna, eds. *Cytotaxonomy and vertebrate evolution*. Academic Press, New York and London.
- \_\_\_\_\_, and \_\_\_\_\_, editors. 1973b. *Cytotaxonomy and vertebrate evolution*. Academic Press, New York and London. 783 pp.
- \_\_\_\_\_, O. Ferrantelli and C. Cucchi. 1969. The caryotype of some Teleostea[n] fish obtained by tissue culture *in vitro*. *Experientia* 25:426-427.
- Chromosome Atlas: Fish, amphibians, reptiles and birds. 1973. Vol. 2. K. Benirschke and T.C. Hsu, eds. Springer-Verlag, Berlin.
- Davissson, M.T., J.E. Wright, and L.M. Atherton. 1973. Cytogenetic analysis of pseudolinkage of LDH loci in the teleost genus *Salvelinus*. *Genetics* 73:645-658.
- Denton, T.E. 1973. Fish chromosome methodology. Charles C. Thomas, Publ. Springfield, Ill.
- \_\_\_\_\_, and W.M. Howell. 1969. A technique for obtaining chromosomes from the scale epithelium of teleost fishes. *Copeia* 1969(2):392-393.
- Dingerkus, G., and W.M. Howell. 1976. Karyotypic analysis and evidence of tetraploidy in the North American paddlefish, *Polyodon spathula*. *Science* 194:842-844.
- Donahue, W.H. 1974. A karyotypic study of three species of Rajiformes (Chondrichthyes, Pisces). *Can. J. Genet. Cytol.* 16:203-211.
- Ebeling, A.W., N.B. Atkin, and P.Y. Setzer. 1971. Genome sizes of teleostean fishes: Increases in some deep-sea species. *Am. Nat.* 105:549-561.
- Fontana, F., B. Chiarelli, and A.C. Rossi. 1970. Il cariotipo di alcune specie di Cyprinidae, Centrarchidae, Characidae studiate mediante coltura "in vitro." *Caryologia* 23(4):549-564.
- Förster, W. 1969. Dissertation Giessen. (Cited from Anders et al. 1969).
- Friedman, B., and M. Gordon. 1934. Chromosome numbers in Xiphophorin fishes. *Am. Nat.* 68:446-455.
- German, J. 1973. Studying human chromosomes today. *Am. Sci.* 58:1-20.
- Gold, J.R. 1977. Systematics of western North American trout (*Salmo*), with notes on the redband trout of Sheepheaven Creek, California. *Can. J. Zool.* 55(11):1858-1873.
- \_\_\_\_\_. 1979. *Cytogenetics*. Pages 353-405 in W.S. Hoar, D.J. Randall, and J.R. Brett, eds. *Fish physiology* Vol. VIII. Academic Press, New York and London.
- \_\_\_\_\_, and J.C. Avise. 1977. Cytogenetic studies in North American minnows (Cyprinidae). I. Karyology of nine California genera. *Copeia* 1977(3):541-549.
- \_\_\_\_\_, \_\_\_\_\_, and G.A.E. Gall. 1977. Chromosome cytology in the cutthroat trout series, *Salmo clarki* (Salmonidae). *Cytologia* 42:377-382.
- \_\_\_\_\_, and G.A.E. Gall. 1975. Chromosome cytology and polymorphism in the California High Sierra golden trout (*Salmo aguabonita*). *Can. J. Genet. Cytol.* 17:41-53.
- \_\_\_\_\_, B.J. Janak, and J.A. Barlow, Jr. 1979a. Karyology of four North American percids (Perciformes: Percidae). *Can. J. Genet. Cytol.* 21: 187-191.
- \_\_\_\_\_, C.W. Whitlock, W.J. Karel, and J.A. Barlow, Jr. 1979b. Cytogenetic studies in North American minnows (Cyprinidae). VI. Karyotypes of thirteen species in the genus *Notropis*. *Cytologia* 44: 457-466.
- \_\_\_\_\_, W.D. Womac, F.H. Deal, and J.A. Barlow, Jr. 1978. Gross karyotypic change and evolution in North American cyprinid fishes. *Genet. Res.* 32:37-46.
- \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_. 1980. Cytogenetic studies in North American minnows (Cyprinidae): VII. Karyotypes of 13 species from the southern United States. *Cytologia* (in press).
- Gordon, M. 1947. Genetics of *Platypoecilus maculatus*. IV. The sex determining mechanisms in two wild populations of the Mexican platyfish. *Genetics* 32:8-17.
- \_\_\_\_\_. 1951. Genetics of *Platypoecilus maculatus*. V. Heterogametic sex-determining mechanisms in a female of a domesticated stock originally from British Honduras. *Zoologica* 36:127-134.
- Greenfield, D.W., and T. Greenfield. 1972. Introgressive hybridization between *Gila orcutti* and *Hesperoleucus symmetricus* (Pisces: Cyprinidae) in the Cuyama River basin, California. I. Meristics, morphometrics and breeding. *Copeia* 1972(4):849-859.
- \_\_\_\_\_, F. Abdel-Hameed, G.D. Deckert, and R.R. Flinn. 1973. Hybridization between *Chrosomus erythrogaster* and *Notropis cornutus* (Pisces: Cyprinidae). *Copeia* 1973(1):54-60.
- Greenwood, P.H., D.E. Rosen, S.H. Weitzman, and G.S. Myers. 1966. Phyletic studies of teleostean fishes with provisional classification of living forms. *Bull. Am. Mus. Nat. Hist.* 131:339-456.
- Hann, H.W. 1927. The history of the germ cells of *Cottus bairdii* Girard. *J. Morphol. Physiol.* 43:427-480.
- Hinegardner, R., and D.E. Rosen. 1972. Cellular DNA content and the evolution of Teleostean fishes. *Am. Nat.* 106:621-644.
- Hitotsumachi, S., M. Sasaki, and Y. Ojima. 1969. A comparative karyotype study in several species of Japanese loaches (Pisces, Cobitidae). *Jpn. J. Genet.* 44:157-161.
- Howell, W.M., and T.E. Denton. 1969. Chromosomes of am-

- mocoetes of the Ohio brook lamprey, *Lampetra aepyptera*. Copeia 1969(2):393-395.
- \_\_\_\_\_, and C.R. Duckett. 1971. Somatic chromosomes of the lamprey, *Ichthyomyzon gagei* (Agnatha; Petromyzontidae). Experimentia 27:222-223.
- \_\_\_\_\_, and J. Villa. 1976. Chromosomal homogeneity in two sympatric cyprinid fishes of the genus *Rhinichthys*. Copeia 1976(1):112-116.
- Hsu, T.C. 1973. Longitudinal differentiation of chromosomes. Annu. Rev. Genet. 7:153-176.
- Kirby, R.F., K.W. Thompson, and C. Hubbs. 1977. Karyotypic similarities between the Mexican and blind tetras. Copeia 1977(3):578-580.
- Klose, J., U. Wolf, H. Hitzeroth, and H. Ritter. 1968. Duplication of the LDH gene loci by polyploidization in the fish order Clupeiformes. Humangenetik 5:190-196.
- Kobayasi, H., Y. Kawashima, and N. Takeuchi. 1970. Comparative chromosome studies in the genus *Carrasius* especially with a finding of polyploidy in the ginbuna (*C. auratus langsdorffii*). Jpn. J. Ichthyol. 17(4):153-160.
- Law, W.M., R.D. Ellender, J.H. Wharton, and B.L. Middlebrooks. 1978. Fish cell culture: properties of a cell line from the Sheepshead, *Archosargus probatocephalus*. J. Fish. Res. Board Can. 23:767-768.
- Legendre, P., and D.M. Steven. 1969. Denombrement des chromosomes chez quelques cyprins. Nat. Can. (Que.) 96:913-918.
- LeGrande, W.H. 1975. Karyology of six species of Louisiana flatfishes (Pleuronectiformes: Osteichthyes). Copeia 1975(3):516-522.
- \_\_\_\_\_. 1978. Cytotaxonomy and chromosomal evolution in North American catfishes (Siluriformes, Ictaluridae) with emphasis on *Noturus*. Ph.D. thesis. Ohio State University, Columbus.
- \_\_\_\_\_, and J.M. Fitzsimons. 1976. Karyology of the mullets *Mugil curema* and *M. cephalus* (Perciformes: Mugilidae) from Louisiana. Copeia 1976(2):388-391.
- Levan, A., K. Fredga, and A.A. Sandberg. 1964. Nomenclature for centromeric position on chromosomes. Hereditas 52:201-220.
- Loudenslager, E.J., and G.H. Thorgaard. 1979. Karyotypic and evolutionary relationships of the Yellowstone (*Salmo clarki bouvieri*) and west-slope (*S.c. lewisi*) cutthroat trout. J. Fish. Res. Board Can. 36(6):630-635.
- McGregor, J.F. 1970. The chromosomes of the maskinonge (*Esox masquinongy*). Can. J. Genet. Cytol. 12:224-229.
- McPhail, J.D., and R.L. Jones. 1966. A simple technique for obtaining chromosomes from teleost fishes. J. Fish. Res. Board Can. 23:767-768.
- Makino, S. 1937. Notes on the chromosomes of some teleost fishes. Zool. Mag. (Tokyo) 49. (Cited from Chiarelli and Capanna 1973a).
- Mayers, L.J., and F.L. Roberts. 1969. Chromosomal homogeneity of five populations of alewives, *Alosa pseudoharengus*. Copeia 1969(2):313-317.
- Miller, R.R. 1972. Classification of the native trouts of Arizona with the description of a new species, *Salmo apache*. Copeia 1972(3):401-422.
- Moenkhaus, W.J. 1904. The development of the hybrids between *Fundulus heteroclitus* and *Menidia notata*, with especial reference to the behavior of the maternal and paternal chromatin. Am. J. Anat. 3:29-65.
- Muramoto, J., S. Ohno, and N.B. Atkin. 1968. On the diploid state of the fish order Ostariophysii. Chromosoma 24:59-66.
- Nygren, A., G. Bergkrist, R. Windahl, and G. Jahnke. 1974. Cytological studies in Gadidae (Pisces). Hereditas 76:173-178.
- \_\_\_\_\_, P. Edlund, U. Hirsch, and L. Ashsgren. 1968. Cytological studies in perch (*Perca fluviatilis* L.), pike (*Esox lucius* L.), pike-perch (*Lucioperca lucioperca* L.), and ruff (*Acerina cernua* L.). Hereditas 59:518-524.
- \_\_\_\_\_, and M. Jahnke. 1972. Cytological studies in *Myxine glutinosa* (Cyclostomata) from the Gullmaren fjord in Sweden. Swed. J. Agric. Res. 2:83-88.
- \_\_\_\_\_, U. Leijon, B. Nilsson, and M. Jahnke. 1971a. Cytological studies in *Coregonus* from Sweden. Acad. Reg. Sci. Upsaliensis 15:5-20. (Cited from Denton 1973).
- \_\_\_\_\_, B. Nilsson, and M. Jahnke. 1971b. Cytological studies in *Salmo trutta* and *Salmo alpinus*. Hereditas 67:259-268.
- \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_. 1971c. Cytological studies in Hypotremata and Pleurotremata (Pisces). Hereditas 67:275-282.
- Ohno, S. 1974. Protochordata, cyclostomata and pisces. Pages 1-91 in B. John, ed. Animal cytogenetics. Vol. 4, Chordata 1. Borntraeger, Berlin.
- \_\_\_\_\_, and N.B. Atkin. 1966. Comparative DNA values and chromosome complements of eight species of fishes. Chromosoma 18:455-466.
- \_\_\_\_\_, J. Muramoto, C. Stenius, L. Christian, W.A. Kitrell, and N.B. Atkin. 1969. Microchromosomes in holocephalian, chondrosteian and holostean fishes. Chromosoma 26:35-40.
- \_\_\_\_\_, U. Wolf, and N.B. Atkin. 1968. Evolution from fish to mammals by gene duplication. Hereditas 59:169-187.
- Ojima, Y., S. Hitotsumachi, and S. Makino. 1966. Cytogenetic studies in lower vertebrates. I. A preliminary report on the chromosomes of the Funa (*Carassius auratus*) and goldfish (a revised study). Proc. Jpn. Acad. 42:62-66.
- Park, E.H. 1974. A list of the chromosome numbers of fishes. College Rev. College of Liberal Arts and Sciences, Seoul Nat. Univ. 20:346-372.
- Pinney, E. 1918. A study of the relation of the behavior of the chromatin to development and heredity in teleost hybrids. J. Morphol. 31:225-292.
- Post, A. 1965. Vergleichende Untersuchungen der Chromosomenzahlen bei Süßwasser-Teleostern. Z. zool. Syst. Evolutionsforsch. 3:47-93.
- \_\_\_\_\_. 1972. Ergebnisse der Forschungsreisen des FFS "Walther Herwig" nach Sudamerika. XXIV. Die Chromosomenzahlen einiger atlantischer Myctophidenarten (Osteichthyes, Myctophidae). Arch. Fischereiwiss. 23(2):89-93.
- Potter, I.C., and B. Rothwell. 1970. The mitotic chromosomes of the lamprey, *Petromyzon marinus* L. Experimentia 26:429-430.
- Prehn, L.M., and E.M. Rasch. 1969. Cytogenetic studies of *Poecilia* (Pisces). I. Chromosome numbers of naturally occurring poeciliid species and their hybrids from Eastern Mexico. Can. J. Genet. Cytol. 11:880-895.
- Prokofieva, A. 1934. On the chromosome morphology of certain Pisces. Cytologia 5:498-506.
- Rachlin, J.W., A.P. Beck, and J.M. O'Connor. 1978. Karyotypic analysis of the Hudson River striped bass, *Morone saxatilis*. Copeia 1978(2):343-345.
- Rees, H. 1967. The chromosomes of *Salmo salar*. Chromosoma 21:472-474.

- Regan, J.D., M.M. Sigel, W.H. Lee, K.A. Llamas, and A.R. Beasley. 1968. Chromosomal alterations in marine fish cells in vitro. *Can. J. Genet. Cytol.* 10:448-453.
- Remy, R. 1977. A chromosomal study of selected species within the subgenus *Oligocephalus* (Percidae: *Etheostoma*). M.S. thesis. Samford University, Birmingham, Alabama. (Personal communication from D.A. Black, Department of Biology, Samford University.)
- Rishi, K.K. 1973. A preliminary report on the karyotypes of eighteen marine fishes. *Res. Bull. Panjab Univ.* 24(III-IV):161-162.
- \_\_\_\_\_. 1978. Chromosomal homogeneity in two Indian catfishes. *Geobios* 5:121-123.
- Roberts, F.L. 1964. A chromosome study of twenty species of Centrarchidae. *J. Morphol.* 115:401-418.
- \_\_\_\_\_. 1966. Cell culture of fibroblasts from *Clupea harengus* gonads. *Nature* 212:1592-1593.
- \_\_\_\_\_. 1968. Chromosomal polymorphism in North American landlocked *Salmo salar*. *Can. J. Genet. Cytol.* 10:865-875.
- \_\_\_\_\_. 1970. Atlantic salmon (*Salmo salar*) chromosomes and speciation. *Trans. Am. Fish. Soc.* 99(1):105-111.
- Robinson, E.S., I.C. Potter, and C.J. Webb. 1974. Homogeneity of holarctic lamprey karyotypes. *Caryologia* 27(4):443-454.
- Ross, M.R. 1973. A chromosome study of five species of Etheostomine fishes (Percidae). *Copeia* 1973(1):163-165.
- Sasaki, M., S. Hitotsumachi, S. Makino, and T. Terao. 1968. A comparative study of the chromosomes in the chum salmon, the Kokanee salmon and their hybrids. *Caryologia* 21(4):389-394.
- Scheel, J.J. 1972. Rivuline karyotypes and their evolution (Rivulinae, Cyprinodontidae, Pisces). *Z. zool. Syst. Evolutionsforsch.* 10:180-209.
- Schreck, C.B., and R.J. Behnke. 1971. Trout of the upper Kern River basin, California, with reference to systematics and evolution of western North American *Salmo*. *J. Fish. Res. Board Can.* 28:987-998.
- Schultz, R.J. 1961. Reproductive mechanism of unisexual and bisexual strains of the viviparous fish *Poeciliopsis*. *Evolution* 15:302-325.
- Sick, K., M. Westergaard, and O. Frydenberg. 1962. Haemoglobin pattern and chromosome number of American, European, and Japanese eels (*Anguilla*). *Nature* 193:1001-1002.
- Simon, R.C. 1963. Chromosome morphology and species evolution in the five North American species of Pacific salmon (*Oncorhynchus*). *J. Morphol.* 112:77-95.
- \_\_\_\_\_. 1964. Cytogenetics, relationships, and evolution in Salmonidae. Ph.D. thesis. University of Washington, Seattle. (Cited from Schreck and Behnke 1971.)
- \_\_\_\_\_, and A.M. Dollar. 1963. Cytological aspects of speciation in two North American teleosts, *Salmo gairdneri* and *Salmo clarki lewisi*. *Can. J. Genet. Cytol.* 5:43-49.
- Srivastava, M.D.L., and B. Das. 1968. Somatic chromosomes of *Clarias batrachus* (L.) (Clariidae: Teleostomi). *Caryologia* 21:349-352.
- Stebbins, G.L. 1958. Longevity, habitat, and release of genetic variability in the higher plants. *Cold Spring Harbor Symp. Quant. Biol.* 23:365-378.
- Stevenson, M.M. 1975. A comparative chromosome study in the pupfish genus *Cyprinodon* (Teleostei: Cyprinodontidae). Ph.D. thesis. The University of Oklahoma, Norman. 98 pp.
- Svårdson, G. 1945. Chromosome studies on Salmonidae. *Inst. Freshwater Res. Drottningholm, Rep.* 23:1-51. (Cited from Denton 1973.)
- Taylor, K.M. 1967. The chromosomes of some lower chordates. *Chromosoma* 21:181-188.
- Thompson, K.W. 1976. Some aspects of chromosomal evolution of the Cichlidae (Teleostei: Perciformes) with emphasis on neotropical forms. Ph.D. thesis. The University of Texas, Austin. 126 pp.
- \_\_\_\_\_, C. Hubbs, and R.J. Edwards. 1978. Comparative chromosome morphology of the black basses. *Copeia* 1978(1):172-175.
- Thorgaard, G. 1976. Robertsonian polymorphism and constitutive heterochromatin distribution in chromosomes of the rainbow trout (*Salmo gairdneri*). *Cytogenet. Cell Genet.* 17:174-184.
- \_\_\_\_\_. 1977. Heteromorphic sex chromosomes in male rainbow trout. *Science* 196:900-902.
- \_\_\_\_\_. 1978. Sex chromosomes in the Sockeye salmon: a Y-autosome fusion. *Can. J. Genet. Cytol.* 20:349-354.
- Turner, B.J. 1974. Genetic divergence of Death Valley pupfish species: biochemical versus morphological evidence. *Evolution* 28:281-294.
- Uyeno, T. 1973. A comparative study of chromosomes in the teleostean fish order Osteoglossiformes. *Jpn. J. Ichthyol.* 20(4):211-217.
- \_\_\_\_\_, and R.R. Miller. 1971. Multiple sex chromosomes in a Mexican cyprinodontid fish. *Nature* 231:452-453.
- \_\_\_\_\_, and \_\_\_\_\_. 1973. Chromosomes and the evolution of the plagioteleostean fishes (Cyprinidae) of the Colorado River system. *Copeia* 1973(4):776-782.
- \_\_\_\_\_, and G.R. Smith. 1972. Tetraploid origin of the karyotype of Catostomid fishes. *Science* 175:644-646.
- Vasil'yev, V.P. 1975. Karyotypes of different forms of the Kamchatka trout, *Salmo mykiss*, and the rainbow trout, *Salmo gairdneri*. *Vopr. Ikhtiol.* 15(6):889-900 (in Russian).
- Winge, Ö. 1922. One-sided masculine and sex-linked inheritance in *Lebistes reticulatus*. *J. Genet.* 12:145-162.
- Wolf, U., H. Ritter, N.B. Atkin, and S. Ohno. 1969. Polyploidization in the fish family Cyprinidae, order Cypriniformes. I. DNA-content and chromosome sets in various species of Cyprinidae. *Humangenetik* 7:240-244.
- Yamamoto, T., and T. Kajishima. 1968. Sex hormone induction of sex reversal in the goldfish and evidence for male heterogamety. *J. Exp. Zool.* 168:215-222.

Accepted 5 July 1979