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A BIBLIOGRAPHY OF TETRAPLOIDY IN FISH (1964 - 1991)

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1992

Canadian Technical Report of
Fisheries and Aquatic Sciences
No. 1901

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Cat. No. Fs 97-4/1901E ISSN 0706-6473

Correct citation for this publication:

Solar, I. I., W. E. Hajen and E. M. Donaldson. 1992. A bibliography of tetraploidy in fish (1964-1991). Can. Tech. Rep. Fish. Aquat. Sci. 1901: 22 p.

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ABSTRACT

Solar, I.I., W. E. Hajen and E.M. Donaldson. 1992. A Bibliography of Tetraploidy in Fish (1964-1991). Can. Tech. Rep. Fish. Aquat. Sci. No. 1901 : 22 p.

This bibliography presents a listing of 153 publications on the subject of tetraploidy in fish species. Included are references dealing with both artificially induced and ancestral or evolutionary tetraploidy published between the years 1964 and 1991. Also included are a number of reviews on the subject of chromosome set manipulation in which the subject of induced tetraploidy is discussed.

RÉSUMÉ

Solar, I.I., W. E. Hajen and E.M. Donaldson. 1992. A Bibliography of Tetraploidy in Fish (1964-1991). Can. Tech. Rep. Fish. Aquat. Sci. No. 1901 : 22 p.

La présente bibliographie rassemble 153 publications concernant la tétraploïdie chez les poissons. On y trouvera des références, publiées de 1964 à 1991, qui touchent à la fois la tétraploïdie artificielle et la tétraploïdie héritée ou évolutive. Le rapport présente aussi un certain nombre de comptes rendus sur la manipulation du génome avec référence à la tétraploïdie artificielle.

INTRODUCTION

Tetraploidy may be defined as a cytological mechanism leading to the increase in the genome size to four complete sets of chromosomes. Although a fairly common occurrence in the plant kingdom, polyploidy is rare among the vertebrates. This has been attributed to the bisexuality that characterizes the majority of higher animal species (Viktorovskii, 1972). Nevertheless, it has been hypothesized that numerous instances of duplication or continuous gains of new gene loci have occurred in the evolution of fish species (Ohno, 1970). Examples are the Catostomidae, Salmonidae, and certain Cyprinidae, Acipenseridae and Petromizontidae. Many species in these families have exceptionally high chromosome counts which most likely were brought about by ancestral polyploidization through repeated duplication of the chromosome set (Svärdson, 1945).

Tetraploidy was first induced experimentally in plants (Blackslee and Avery, 1937), amphibians (Fischberg, 1958) and mammals (Snow, 1973), using chemical agents (colchicine or cytochalasin B). Artificial induction of tetraploidy in fish species was first suggested and attempted by Refstie *et al.* (1977) in farmed rainbow trout and Atlantic salmon, by the use of cytochalasin B. Since then, tetraploidy has been induced in several fish species of economic importance, particularly in cyprinids and salmonids, using a variety of approaches, most commonly by physical shock (either temperature or hydrostatic pressure) applied to eggs at the beginning of first cleavage.

Much of the interest in induced tetraploidy derives from the potential for the use of this technique as an intermediate step in the aquacultural production of sterile triploid fish. This can be achieved by back-crossing tetraploid with diploid parents. Triploid rainbow trout thus produced were first reported by Chourrout *et al* (1986).

The references hereby presented were compiled from a variety of sources, mainly The Aquatic Sciences and Fisheries Abstracts (ASFA, CD Cambridge 1982 - 1991), BIOSIS Database and CANSDI, Science Citation Index. Many entries were also obtained from reference lists of major review articles on the subject, and from the authors' personal collections of reprints. The references were considered appropriate for inclusion in this bibliography if the term "polyploid" and/or "tetraploid" or their derivations were part of the title or appeared in the abstract, or if there was a heading or special paragraph dealing with the subject in review articles on fish evolution, sex determination, controlled reproduction, or chromosome set manipulation.

The references are listed alphabetically by author and numbered consecutively. To facilitate location of references we include a list of the numbers that refer to review articles, a list of papers dealing with induced tetraploidy, an author index and a species index.

This bibliography should be complete and up to date (1991), however we apologize for any omissions and ask that they be brought to our attention. With this publication we complete a series of bibliographies on chromosome set manipulation in fish (Benfey, 1989; Solar *et al*, 1991).

References

- Benfey, T.J. 1989. A bibliography of triploid fish, 1943 to 1988. Can. Tech. Rep. Fish. Aquat. Sci. 1682: 33 p.

- Blakeslee A. F., and A.G. Avery. 1937. Methods of inducing chromosome doubling in plants by treatment with colchicine. *Science*. 86: 408.
- Chourrout, D., B. Chevassus, F. Krieg, A. Happe, G. Burger, and P. Renard. 1986. Production of second generation triploid and tetraploid rainbow trout by mating tetraploid males and diploid females - potential of tetraploid fish. *Theor. Appl. Genet.* 72: 193-206.
- Fischberg, M. 1958. Experimental tetraploidy in newts. *J. Embryol. Exp. Morph.* 6: 393-402.
- Ohno, S. 1970. The enormous diversity in genome sizes of fish as a reflection of nature's extensive experiments with gene duplication. *Trans. Am. Fish. Soc.* 99: 120-130.
- Refstie, T., V. Vassvik, and T. Gjedrem. 1977. Induction of polyploidy in salmonids by cytochalasin B. *Aquaculture* 10: 65-74.
- Snow, M.H.L. 1973. Tetraploid mouse embryos produced by cytochalasin B during cleavage. *Nature*. 244: 513-515.
- Solar I.I., E.M. Donaldson, and D. Douville. 1991. A bibliography on gynogenesis and androgenesis in fish (1913-1989). *Can. Tech. Rep. Fish. Aquat. Sci.* 1788:41 p.
- Svärdson, G. 1945. Chromosome studies on Salmonidae. Rept. Swedish State Inst. Freshwater Fishery Research. Drottningholm. No. 23: 1-151.
- Viktorovskii, R.M. 1972. Possibilities of polyploidy in the evolution of fish. p. 91-97. In: Cherfas, B.I. (ed.). Genetics selection and hybridization of fish. Israel Program for Scientific Translations, Jerusalem.

ACKNOWLEDGMENTS

We wish to thank Dr. Gary Thorgaard and Dr. Tillmann Benfey for reviewing the Introduction to this bibliography and for valuable comments and suggestions.

BIBLIOGRAPHY

1. Agellon, L.B., S.L. Davies, C.M. Lin, T.T. Chen, and D.A. Powers. 1988. Rainbow trout has two genes for growth hormone. *Mol. Reprod. Dev.* 1: 11-17.
2. Agnese, J.F., P. Berribi, C. Leveque, and J.F. Guegan. 1990. Two lineages, diploid and tetraploid, demonstrated in African species *Barbus* (Osteichthyes, Cyprinidae). *Aquat. Living Resour.* 3: 305-311.
3. Aldridge, F.J., R.Q. Marston, and J.V. Shireman. 1990. Induced triploids and tetraploids in bighead carp, *Hypophthalmichthys nobilis*, verified by multi-embryo cytofluorometric analysis. *Aquaculture* 87: 121-131.
4. Allen, S.K. Jr., and J.G. Stanley. 1979. Polyploid mosaics induced by cytochalasin B in landlocked Atlantic salmon (*Salmo salar*). *Trans. Am. Fish Soc.* 108 : 462-466.
5. Allen, S.K. Jr., and J.G. Stanley. 1983. Ploidy of hybrid grass carp x bighead carp determined by flow cytometry. *Trans. Am. Fish. Soc.* 112: 431-435.
6. Allendorf, F.W. 1975. Genetic variability in a species possessing extensive gene duplication: Genetic interpretation of duplicate loci and examination of genetic variation in populations of rainbow trout, Ph.D. dissertation, University of Washington, Seattle.
7. Allendorf, F.W., and G.H. Thorgaard. 1984. Tetraploidy and the evolution of salmonid fishes. pp. 1-53. In: Turner, B.J. (ed.). *Evol. Genet. Fish. Monogr. Evol. Biol.*
8. Allendorf, F.W., and F.M. Utter. 1976. Gene duplication in the family Salmonidae III. Linkage between two duplicated loci coding for aspartate aminotransferase in the cut-throat trout (*Salmo clarki*) *Hereditas* 82: 19-24.
9. Allendorf, F.W., Utter, F.M., and B.P. May. 1975. Gene duplication within the family Salmonidae: Detection and determination of the genetic control of duplicate loci through inheritance studies and the examination of populations. In: Market, C.L. (ed.). *Isozymes IV. Genetics and Evolution*. pp. 415-431. Academic Press, New York.
10. Arai K., K. Matsubara, and R. Suzuki. 1991. Karyotype and erythrocyte size of spontaneous tetraploidy and triploidy in the loach *Misgurnus anguillicaudatus*. *Nippon Suisan Gakkaishi*. 57 : 2167-2172.
11. Arefev, V.A. 1983. Polykaryographic analysis of sheep sturgeon, *Acipenser nudiventris* (Acipenseridae). *J. Ichthyol.* 23: 26-35.
12. Bailey, G.S., R.T.M. Poulter, and P.A. Stockwell. 1978. Gene duplication in tetraploid fish: Model for gene silencing at unlinked duplicated loci. *Proc. Natl. Acad. Sci. USA.* 75: 5575-5579.

13. Bender, K., and S. Ohno. 1968. Duplication of the autosomally inherited 6-phosphogluconate dehydrogenase gene locus in tetraploid species of cyprinid fish. *Biochem. Genet.* 2: 101-107.
14. Berberovic, L. 1980. Karyologic properties and natural hybridization of cyprinid fishes. *Acta Biol. Jugosl. (E Ichthyol.)*. 12: 1-8. (Croatian with English Abstract).
15. Bidwell, C.A., C.L. Chrisman, and G.S. Libey. 1985. Polyploidy induced by heat shock in channel catfish *Ictalurus punctatus*. *Aquaculture*. 51: 25-32.
16. Birstein, V.J., and V.P. Vasilev. 1987a. Nucleolar organizer regions their function and polyploidy in fish. *Zhurnal Obshchei Biologii*. 48: 729-747. (Russian).
17. Birstein, V.J., and V.P. Vasilev. 1987b. Tetraploid-octoploid relationships and karyological evolution in the order *Acipenseriformes* (Pisces). Karyotypes, nucleoli, and nucleolus-organizer regions in four acipenserid species. *Genetica*. 72: 3-12.
18. Blanc, J.M., D. Chourrout, and F. Krieg. 1987. Evaluation of juvenile rainbow trout survival and growth in half-sib families from diploid and tetraploid sires. *Aquaculture*. 65: 215-220.
19. Buth, D.G. 1982. Glucosephosphate-Isomerase Expression in a Tetraploid Fish, *Moxostoma lachneri* (Cypriniformes, Catostomidae): Evidence for "Retetraploidization"? *Genetica*. 57: 171-175.
20. Cassani, J.R., D.R. Maloney, H.P. Allaire, and J.H. Kerby. 1990. Problems associated with tetraploid induction and survival in grass carp *Ctenopharyngodon idella*. *Aquaculture*. 88 (3-4): 273-284.
21. Chevassus, B. 1987. Characteristics and performances of uniparental lines and of polyploids of cold water fish. *Sel. Hybr. Gen. Eng. Aqua*. 2: 145-161. (French).
22. Chourrout, D. 1982. Tetraploidy induced by heat shocks in the rainbow trout (*Salmo gairdneri* R.). *Reprod. Nutr. Develop.*, 22 (3): 569-574.
23. Chourrout, D. 1984. Pressure-induced retention of the second polar body and suppression of first cleavage in rainbow trout: Production of all-triploids, all-tetraploids, and heterozygous and homozygous diploid gynogenesis. *Aquaculture*. 36 (1-2): 111-126.
24. Chourrout, D. 1987. Genetic manipulations in fish: Review of methods, p. 111-126. In: Tiews, K. (ed.). *Selection, hybridization and genetic engineering in aquaculture*. Vol. 2. Schr. Bundesforschungsanst. Fisch., Hamb., Verlag, H. Heenemann GmbH, Berlin.
25. Chourrout, D. 1988. Induction of gynogenesis triploidy and tetraploidy in fish. *Isi. Atlas. Sci. Anim. Plant. Sci.* 1: 65-70.

26. Chourrout, D., B. Chevassus, F. Krieg, A. Happe, G. Burger, and P. Renard. 1986. Production of second generation triploid and tetraploid rainbow trout by mating tetraploid males and diploid females - potential of tetraploid fish. *Theor. Appl. Genet.* 72: 193-206.
27. Chourrout, D., and I. Nakayama. 1987. Chromosome studies of progenies of tetraploid female rainbow trout. *Theor. Appl. Genet.* 74: 687-692.
28. Collares-Pereira, M.J. 1987. The evolutionary role of hybridization: The example of natural Iberian fish populations, p. 83-92. In: Tiews, K. (ed.). Selection, hybridization and genetic engineering in aquaculture. Vol. 1. Schr. Bundesforschungsanst. Fisch., Hamb., Verlag, H. Heenemann GmbH, Berlin.
29. Curtis, T.A., F.W. Sessions, D. Bury, M. Rezk, and R.A. Dunham. 1989. Induction of polyploidy in striped bass, white bass and their hybrids with hydrostatic pressure. *Proc. Southeast. Fish Wildlife Agencies*, 41: 63-69.
30. Delany, M.E., and S.E. Bloom. 1984. Replication banding patterns in the chromosomes of the rainbow trout *Salmo gairdneri*. *J. Hered.* 75: 431-434.
31. Dingerkus, G., and M.W. Howell. 1976. Karyotypic analysis and evidence of tetraploidy in the North American paddlefish *Polyodon spathula*, *Science* 194: 842-844.
32. Diter, A., R. Guyamard, and D. Chourrout. 1988. Gene segregation in induced tetraploid rainbow trout: Genetic evidence of preferential pairing of homologous chromosomes. *Genome*. 30: 547-553.
33. Don, J., and R.R. Avtalion. 1988. Production of viable tetraploid tilapias using the cold shock technique. *J. Aquacult.* 40: 17-21.
34. Donaldson, E.M. 1986. The integrated development and application of controlled reproduction techniques in Pacific salmonid aquaculture. *Fish Phys. Biochem.* 2: 9-24.
35. Donaldson, E.M., and G.A. Hunter. 1982. Sex control in fish with particular reference to salmonids. *Can. J. Fish. Aquat. Sci.* 39: 99-110.
36. Emelyanova, O.V. 1985. Cytological study of maturation and fertilization in crucian and common carp hybrids. *Tsitologiya*. 26: 1427-1433. (Russian).
37. Engel, W., J. Schmidike, and U. Wolf. 1975. Diploid-tetraploid relationships in teleostean fishes. In: Markert, C.L. (ed.). Isozymes. Vol. IV, pp. 449-462. Academic Press. New York.
38. Ferris, S.D. 1984. Tetraploidy and the evolution of the catostomid fishes. In: Turner, B.J. (ed.). Evolutionary genetics of fishes. Monogr. Evol. Biol. pp. 55-93.
39. Ferris, S.D., and G.S. Whitt. 1977. Duplicate gene expression in diploid and tetraploid loaches (Cypriniformes, Cobitidae). *Biochem. Genet.* 15: 1097-1111.

40. Ferris, S.D., and G.S. Whitt. 1978. Phylogeny of tetraploid catostomid fishes based on the loss of duplicate gene expression. *Syst. Zool.* 27: 189-206.
41. Ferris, S.D., and G.S. Whitt. 1979. Evolution of the differential regulation of duplicate genes after polyploidization. *J. Mol. Evol.* 12: 267-317.
42. Ferris, S.D., and G.S. Whitt. 1980. Genetic variability in species with extensive gene duplication: The tetraploid catostomid fishes. *Am. Nat.* 115: 650-666.
43. Flajshans, M. 1989. Artificial polyploidization in Salmonids (A review). *Bul. Vurh Vodnany.* 25 (2):14-17.
44. Deleted
45. Gold, J.R. 1979. Cytogenetics. In: "Fish Physiology" (W.S.Hoar, D.J. Randall, and J.R. Brett. eds.) Vol VIII, pp. 353-405. Academic Press, N.Y.
46. Gomelskii, B.I., A.V. Rekoubratsky, O.V. Emelyanova, E.V. Pankratyeva, and T.I. Lekontseva. 1989. Obtaining diploid gynogenetic progeny of carp using heat treatment of developing eggs. *Vopr. Ikhtiol.* 29 (1): 168-170. (Russian).
47. Gui, J., Y. Li, K. Li, Y. Hong, and T. Zhou. 1986. Studies on the karyotypes of chinese cyprinid fishes VI. Karyotypes of three tetraploid species in Barbinae and one tetraploid species in Cyprininae. *Acta. Gen. Sin.* 12 (4): 302-308. (Chinese).
48. Hafez, R. 1980. Studies on cytogenetics and genetical evolution in some Cyprinidae of the Mid-Pyrenees region. These Doct. Etat, Natural Sci. (appl. ichtyol.), Institut National Polytechnique, Toulouse, France.
49. Hartley, S.E., and M.T. Horne. 1984. Chromosome relationships in the genus *Salmo*. *Chromosoma.* 90 (3): 229-237.
50. Hollister, A., K.R. Johnson, and J.E. Jr. Wright. 1984. Linkage association in hybridized *Salvelinus* genomes. The duplicate loci encoding pepsidase-D and glucosephosphate isomerase and the unduplicated sorbitol dehydrogenase locus. *J. Hered.* 75 (4): 253-259.
51. Hong, Y. 1990. Tetraploidy induced by heat shock in bighead carp *Aristichthys nobilis*. *Acta Zool. Sin.* 36 (1): 70-75.
52. Johnson, K.R., and J.E. Jr. Wright. 1984. Linkage maps in tetraploid salmonid fishes. *Genetics.* 107 (2): s53. (Abstr.)
53. Johnson, K.R., J.E. Jr. Wright, and B. May. 1987. Linkage relationships reflecting ancestral tetraploidy in salmonid fish. *Genetics.* 116 (4): 579-591.
54. KhudaBukhsh, A.R., T. Chanda, and A. Barat. 1986. Karyomorphology and evolution in some Indian hillstream fishes with particular reference to polyploidy in some species. pp.

- 886-898. In: Indo-Pac. Fish Biol.: 2nd. Int. Con. Tokyo National Museum, Ueno Park, Tokyo, July 29 - August 3, 1985.
55. Kijima, A., and Y. Fujio. 1980. Duplicated isozyme loci in chum salmon. *Tohoku J. Agric. Res.* 31 (3): 159-172.
56. Klose, J., U. Wolf, H. Hitzeroth, H. Ritter, N.B. Atkin, S. Ohno. 1968. Duplication of the LDH gene loci by polyploidisation in the fish order Clupeiformes. *Humangenetik* 5: 190-196.
57. Kowtal, G.V. 1987. Preliminary experiments in induction of polyplodiy, gynogenesis and androgenesis in the white sturgeon, *Acipenser transmontanus* Richardson, p. 317-324. In: Tiews, K. (ed.). Selection, hybridization and genetic engineering in aquaculture. Vol. 2. Schr. Bundesforschungsanst. Fisch., Hamb., Verlag, H. Heenemann GmbH, Berlin.
58. Lee, G.M., and J.E. Jr. Wright. 1981. Mitotic and meiotic analyses of brook trout *Salvelinus fontinalis*. *J. Hered.* 72 (5): 321-327.
59. Leipoldt, M., and A. Ebrecht. 1984. Kinetic analysis of nucleolar RNA polymerase I in diploid and phylogenetically tetraploid fish species. *Comp. Biochem. Physiol.* 77B (3): 483-491.
60. Leipoldt, M., H.G. Kellner, and S. Stark. 1984. Comparative analysis of ribosomal RNA in various fish and other vertebrate species, hidden breaks and ribosomal function in phylogenetically tetraploid species of Cyprinidae. *Comp. Biochem. Physiol. B. Comp Biochem.* 77 (4): 769-778.
61. Li, W.J. 1980. Rate of gene silencing at duplicate loci: A theoretical study and interpretation of data from tetraploid fishes. *Genetics* 95: 237-258.
62. Linhart, O., M. Flajshans, and P. Kvasnicka. 1991. Induced triploidy in the common carp (*Cyprinus carpio L.*): a comparison of two methods. *Aquat. Living Resour.* 4: 139-145.
63. Liu, S.M., K. Sezaki, K. Hashimoto, and M. Nakamura. 1980. Distribution of polyploids of "Ginbuna" *Carassius auratus langsdorfi* in Japan. *Bull. Jap. Soc. Sci. Fish./Nissuishi.* 46 (4): 413-418.
64. Longwell, C.A. 1987. Critical review of methodology and potential for interspecific hybridization. pp. 3-22. In: Tiews, K. (ed.). Selection, hybridization and genetic engineering in aquaculture. Vol. 2. Schr. Bundesforschungsanst. Fisch., Hamb., Verlag, H. Heenemann GmbH, Berlin.
65. Lou, Y.D., and C.E. Purdom. 1984. Polyploidy induced by hydrostatic pressure in rainbow trout, *Salmo gairdneri* Richardson. *J. Fish Biol.* 25 (3): 345-351.
66. Luo, L., and C. Wang. 1987. Studies on developmental genetics of isozymic systems in goldfish *Carassius auratus* 3. Duplication and polyploidization of the gene loci in goldfish. *Acta. Genet. Sin.* 14 (1): 56-62.

67. May, B. 1980. The salmonid genome: Evolutionary restructuring following a tetraploid event, Ph.D. dissertation, Pennsylvania State University, University Park, Pennsylvania.
68. Mazik, E.J., A.T. Toktosunov, and P. Rab. 1989. Karyotype study of four species of the genus *Diphtychus* Pisces Cyprinidae with remarks on polyploidy of Schizothoracine fishes. *Folia Zool.* 38 (4): 325-332.
69. Murayama, Y., M. Hijikata, K. Kojima, M. Nakakuki, M. Noda, and T. Kajishima. 1986. The appearance of diploid-triploid and diploid-triploid-tetraploid mosaic individuals in polyploid fish, ginbuna (*Carassius auratus langsdorffii*). *Experientia.* 42 (2): 187-188.
70. Myers, J.M. 1985. An assessment of spawning methodologies and the induction of tetraploidy in two *Oreochromid* species. Masters Thesis, U. of Washington, Seattle Wa. USA.
71. Myers, J.M. 1986. Tetraploid induction in *Oreochromid* spp. pp. 281-287. In: Gall, G.A.E., and C.A. Busack. (ed.). Sec. Int. Symp. Genet. Aquacult. Seattle, Wash., USA.
72. Myers, J.M., and W.K. Hershberger. 1991. Early growth and survival of heat-shocked and tetraploid-derived triploid rainbow trout (*Oncorhynchus mykiss*). *Aquaculture* 96 (2): 97-107.
73. Myers, J.M., W.K. Hershberger, and R.N. Iwamoto. 1986. The induction of tetraploidy in salmonids. *J. World. Aquacult. Soc.* 17: 1-7.
74. Nagy, A. 1987. Genetic manipulations performed on warm water fish. pp. 163-173. In: Tiews, K. (ed.). Selection, hybridization and genetic engineering in aquaculture. Vol. 2. Schr. Bundesforschungsanst. Fisch., Hamb., Verlag, H. Heenemann GmbH, Berlin.
75. Nakanishi, T. 1987. Histocompatibility analyses in tetraploids induced from clonal triploid crucian carp and in gynogenetic diploid goldfish. *J. Fish Biol.* 31(Suppl. A): 35-40. Selected papers from the Fisheries Society of the British Isles Symposium on Immunology and Disease Control Mechanisms of Fish, Plymouth, England, UK, July 20-24, 1987.
76. Nikonorov, S.I., G.D. Ryabova, I.G. Kutergina, and M.V. Ofitserov. 1985. An electrophoretic analysis of genetic variations in stellate sturgeon *Acipenser stellatus* (Pallas). *Dokl. AN S.S.S.R.* 284 (1): 209-211. (Russian).
77. Ohno, S. 1970. The enormous diversity in genome sizes of fish as a reflection of nature's extensive experiments with gene duplication. *Trans. Am. Fish. Soc.* 99: 120-130.
78. Ohno, S., J. Muramoto, L. Christian, and N.B. Atkin. 1967. Diploid - tetraploid relationship among old world members of the fish family Cyprinidae. *Chromosoma* 23: 1-9.
79. Ohno, S., J. Muramoto, J. Klein, and N.B. Atkin. 1969. Diploid tetraploid relationship in clupeoid and salmonoid fish. *Heredity*. 139-147.

80. Oliva-teles, A., and S.J. Kaushik. 1987. Metabolic utilization of diets by polyploid rainbow trout *Salmo gairdneri*. *Comp Biochem. Physiol. A Comp. Physiol.* 88 (1): 45-48.
81. Onozato, H. 1983. Artificial polyploidization of salmonids by hydrostatic pressure. p. 10. In: *Salmonid Reproduction: An Int. Symp. Publ. Wash. Sea Grant. Seattle, Wash. USA.*
82. Onozato, H. 1985. Artificial polyploidization of salmonids by hydrostatic pressure. pp. 64-65. In: Iwamoto, R.N. and S. Sower (ed.). *Salmonid Reprod.: Int. Symp. Bellevue, Wash. USA. Oct 31-Nov 2, 1983.*
83. Onozato, H., M. Torisawa, and M. Kusama. 1983. Distribution of the gynogenetic polyploid crucian carp, *Carassius auratus* in Hokkaido, Japan. *Jap. J. Ichthyol.* 30 (2): 184-190.
84. Oshiro, T. 1989. Control of sex and maturation in fish by means of chromosome set manipulation. The fifth French-Japanese scientific symposium and the second French-Japanese symposium of Oceanography, Tokyo and Shimizu, Japan, October 3-13, 1988. *Mer (Tokyo)* 27(3): 126-127.
85. Osinov, A.G., E.D. Vasileva, and V.P. Vasilev. 1990. Contribution to the problem of reticular speciation in vertebrates: Diploid-triploid-tetraploid complex in the genus *Cobitis* (Cobitidae). 2. Characteristics of triploid form. *Vopr. Ikhtiol./ J. Ichthyol.* 30 (2): 214-220.
86. Pandian, T.J., and K. Varadaraj. 1987. Techniques to regulate sex ratio and breeding in tilapia. *Curr. Sci.* 56 (8): 337-345.
87. Phillips, R.B., and P.E. Ihssen. 1984. Chromosome banding difference between the X and Y chromosome of lake trout. *Genetics*. 107: s82-s83. (Abstract only).
88. Phillips, R.B., and P.E. Ihssen. 1985. Identification of sex chromosomes in lake trout (*Salvelinus namaycush*). *Cytogenet. Cell Genet.* 39: 14-18.
89. Phillips, R.B., K.D. Zajicek, and F.M. Utter. 1986. Chromosome banding in salmonid fishes: nucleolar organizer regions in *Oncorhynchus*. *Can. J. Genet. Cytol.* 28 (4): 502-510.
90. Purdom, C.E. 1983. Genetic engineering by the manipulation of chromosomes. *Aquaculture* 33: 287-300.
91. Purdom, C.E. 1984. Atypical modes of reproduction in fish. pp. 303-340. In: Clarke, J. (ed.). *Oxford Rev. Reprod. Biol. Vol 6. (Review)*
92. Purdom, C.E. 1986. Genetic techniques for control of sexuality in fish farming. *Fish Phys. Biochem.* 2: 3-8.

93. Purdom, C.E., D. Thompson, and Y.D. Lou. 1985. Genetic engineering in rainbow trout, *Salmo gairdnerii* Richardson, by the suppression of meiotic and mitotic metaphase. *J. Fish Biol.* 27: 73-79.
94. Quillet, E., B. Chevassus, and A. Devaux. 1988. Timing and duration of hatching in gynogenetic, triploid, tetraploid, and hybrid progenies in rainbow trout. *Genet. Sel. Evol.* 20 (2): 199-210.
95. Rab, P., and O. Linhart. 1989. Genomic manipulation in fish: A review. *Vurh Vodnany/pap. Rish Vodnany.* 18: 42-52.
96. Raicu, P., and E. Taisescu. 1972. *Misgurnus fossilis*, a tetraploid fish species. *J. Hered.* 63: 92-94.
97. Reddy, P.V.G.K., G. John, and R.K. Jana. 1987. Induced polyploid mosaics in Indian major carp *Labeo rohita* Ham. *J. Inl. Fish. Soc. India.* 19 (1): 9-12.
98. Reddy, P.V.G.K., G.V. Kowtal, and M.S. Tantia. 1990. Preliminary observations on induced polyploidy in Indian major carps *Labeo rohita*(Ham.) and *Catla-catla* (Ham.). *Aquaculture.* 87 (3-4): 279-288.
99. Rees, H. 1964. The question of polyploidy in the Salmonidae. *Chromosoma (Berl.)* 15: 275-279.
100. Refstie, T. 1981. Tetraploid rainbow trout produced by cytochalasin B. *Aquaculture.* 25 (1): 51-58.
101. Rekoubratsky, A.V., B.I. Gomelskii, O.V. Emelyanova, E.V. Pankratyeva. 1989. Obtaining triploid and tetraploid carp progeny with heat shocks. In: *Stornik naucnych trudov voprosy selekcii, genetiki i plemennoj dela v rybovodstve.* VNIIPRCH, Moscow, 91-95 (in Russian with English summary).
102. Rishi, K.K., J. Singh, and M.M. Kaul. 1983. Chromosomal analysis of *Schizothoracichthys progastus* (McClell.) (Cyprinidae: Cypriniformes). *Chromosome Inf. Serv.* 34: 12-13.
103. Ryabova, G.D., and I.G. Kutergina. 1990. Analysis of allozyme variability of starred sturgeon *Acipenser stellatus* Pallas north of the Caspian Sea. *Genetika.* 26 (5): 902-911.
104. Saat, T.V. 1990. In-vitro oocyte maturation in diploid and polyploid spinous loaches, Cobitidae. *Ontogenet.* 21 (4): 416-421.
105. Saitoh, K., A. Takai, and Y. Ojima. 1984. Chromosomal study on the three local races of the striated spined loach (*Cobitis taenia striata*). *Proc. Japan Acad., Ser.B.* 60B: 187-190.
106. Schmidtke, J., and W. Engel. 1975. Gene action in fish of tetraploid origin. I. Cellular and biochemical parameters in Cyprinid fish. *Biochem. Genet.* 13: 45-51.

107. Schmidtke, J., and W. Engel. 1976. Gene action in fish of tetraploid origin. III. Ribosomal DNA amount in Cyprinid fish. *Biochem. Genet.* 14: 19-26.
108. Schmidtke, J., and I. Kandt. 1981. Single-copy DNA relationships between diploid and tetraploid teleostean fish species. *Chromosoma*. 83 (2): 191-197.
109. Schmidtke, J., N. B. Atkin, and W. Engel. 1975. Gene action in fish of tetraploid origin. II. Cellular and biochemical parameters in Clupeoid and Salmonoid fish. *Biochem. Gent.* 13: 301-308.
110. Schmidtke, J., M.T. Zenzes, H. Dittes, and W. Engel. 1975. Regulation of cell size in fish of tetraploid origin. *Nature (Lond.)* 254: 426-427.
111. Schmidtke, J., M.T. Zenzes, C. Weiler, K. Bross, and W. Engel. 1976. Gene action in fish of tetraploid origin. IV. Ribosomal DNA amount in Clupeoid and Salmonid fish. *Biochem. Genet.* 14: 293-297.
112. Schmidtke, J., B. Schulte, P. Kuhl, and W. Engel. 1976. Gene action in fish of tetraploid origin. V. Cellular DNA and protein content and enzyme activities in Cyprinid, Clupeoid, and Salmonid species. *Biochem. Genet.* 14: 975-980.
113. Schmidtke, J., E. Schmitt, E. Matzke, and W. Engel. 1979. Non-repetitive DNA sequence divergence in phylogenetically diploid and tetraploid teleostan species of the family Cyprinidae and the order Isospondyli. *Chromosoma* 75: 185-198.
114. Schultz, R.J. 1969. Hybridization, unisexuality, and polyploidy in the teleost *Poeciliopsis* (Poeciliidae) and other vertebrates. *Am. Nat.* 108: 605-619.
115. Schultz, R.J. 1980. Role of polyploidy in the evolution of fishes. In: *Polyploidy: Biological Relevance* (W.H. Lewid, ed.). pp. 313-340. Plenum Press, New York.
116. Sezaki, K., and H. Kobayashi. 1978. Comparison of erythrocyte size between diploid and tetraploid in spinous loach, *Cobitis biwae*. *Bull. Jpn. Soc. Sci. Fish.* 44: 851-854.
117. Sezaki, K., H. Kobayashi, S. Watabe, and K. Hashimoto. 1985. Erythrocyte size and polyploidy of cobitid fishes in Japan. *Bull. Jap. Soc. Fish./ Nissuishi*. 51 (5): 777-781. (Japanese with English abstract).
118. Shelton, W.L. 1986. Control of sex in cyprinids for aquaculture, p. 179-194. In: Billard, R. and J. Marcel. (eds). *Aquaculture of Cyprinids*. Coll. Hydrobiol. Aquacult.
119. Shelton, W.L. 1987. Genetic manipulations - sex control of exotic fish for stocking, p. 176-189. In: Tiews, K. (ed.). *Selection, hybridization and genetic engineering in aquaculture*. Vol. 2. Schr. Bundesforschungsanst. Fisch., Hamb., Verlag, H. Heenemann GmbH, Berlin.
120. Simon, R.C. 1964. Cytogenetics, relationships and evolution in Salmonidae, Ph.D. Thesis. University of Washington, Seattle.

121. Sola, L., R. Arcangeli, and S. Cataudella. 1986. Nucleolus organizer chromosomes in a teleostean species of tetraploid origin *Cyprinus carpio*. *Cytogenet. Cell Genet.* 42: 183-186.
122. Sola, L., S. Cataudella, S. Gentili, and G. Monaco. 1983. An experimental carp x tench hybrid karyological analysis and scanning electron microscopic morphological observations. *Boll. Zool.* 50 (3-4): 159-172.
123. Stanley, J.G. 1981. Manipulation of developmental events to produce monosex and sterile fish, p. 485-495. In: Lasker, R., and K. Sherman (eds). 1981 ICES Symposium on the early life history of fish: recent studies. Rapp. P.-V. Reun. Ciem.
124. Stoneking, M., B. May, and J.E. Wright. 1981. Loss of duplicate gene expression in salmonids: evidence for a null allele polymorphism at the duplicate aspartate aminotransferase loci in brook trout (*Salvelinus fontinalis*). *Biochem. Genet.* 19: 1063-1077.
125. Suzuki, A., and Y. Taki. 1981. Karyotype of tetraploid origin in a tropical Asian cyprinid, *Acrossocheilus sumatranaus*. *Jap. J. Ichthyol.* 28 (2): 173-176. (English with Japanese abstract).
126. Takahata, N., and T. Maruyama. 1979. Polymorphism and loss of duplicate gene expression: A theoretical study with application to tetraploid fish. *Proc. Nat. Acad. Sci. (Wash.)* 76: 4521-4525.
127. Thorgaard, G.H. 1983. Chromosome set manipulation and sex control in fish, p. 405-434. In: Hoar, W.S., D.J. Randall, and E.M. Donaldson (eds). *Fish Phys.*, Vol. 9: Reproduction. Part B: Behavior and Fertility Control. Academic Press, New York
128. Thorgaard, G.H., and S.K. Allen Jr. 1987. Chromosome manipulation and markers in fishery management, p. 319-331. In: Ryman, N., and F. Utter (eds). *Population Genetics and Fishery Management*. Publ. Wash. Sea Grant.
129. Thorgaard, G.H., F.W. Allendorf, and K.L. Knudsen. 1983. Gene-centromere mapping in rainbow trout: High interference over long map distances. *Genetics*. 103: 771-783.
130. Thorgaard, G.H., M.E. Jazwin, and A.R. Stier. 1981. Polyploidy induced by heat shock in rainbow trout. *Trans. Am. Fish. Soc.* 110 (4): 546-550.
131. Thorgaard, G.H., P.D. Scheerer, W.K. Hershberger, and J.M. Myers. 1990. Androgenic rainbow trout produced using sperm from tetraploid males show improved survival. *Aquaculture*. 85 (1-4): 215-221.
132. Tsoi, S.C.M., S.C. Lee, and W.C. Chao. 1989. Duplicate gene expression and diploidization in an asian tetraploid catostomid *Myxocyprinus asiaticus* Cypriniformes Catostomidae. *Comp. Biochem. Physiol. B. Comp. Biochem.* 93 (1): 27-32.

133. Ueno, K., S. Iwai, and Y. Ojima. 1980. Karyotypes and geographical distribution in the genus *Cobitis* (Cobitidae). Bull. Jap. Soc. Sci. Fish. 46: 9-18. (Japanese with English abstract).
134. Ueno, K., A. Nagase, and Y.J. Ye. 1988. Tetraploid origin of the karyotype of the asian sucker *Myxocyprinus asiaticus*. Jpn. J. Ichthyol. 34 (4): 512-514.
135. Uyeno, T., and G.R. Smith. 1972. Tetraploid origin of the karyotype of catostomid fishes. Science (Washington, D.C.) 175: 644-646
136. Vasilev, V.P., L.I. Sokolov, and Y.V. Serebryakova. 1980. Karyotypes of the Siberian sturgeon, *Acipenser baeri*, of the Lena River and some aspects of karyotype evolution in Acipenseriformes. J. Ichthyol. 20 (6): 37-45.
137. Vasilev, V.P., and E.D. Vasileva. 1982. A new diploid-polyplid complex in fish. Dokl. An S.S.S.R. 226 (1): 250-252. (Russian)
138. Vasilev, V.P., and E.D. Vasileva. 1990. The problem of reticular speciation in vertebrates diploid-triploid-tetraploid complex in the genus Cobitidae III. The origin of the triploid form. Vopr. Ikhtiol. 30 (4): 543-550.
139. Vasileva, E.D., A.G. Osinov, and V.P. Vasilev. 1989. On the problem of reticular speciation in vertebrates: Diploid-triploid-tetraploid complex in the genus Cobitis (Cobitidae). 1. Diploid species. Vopr. Ikhtiol./J. Ichthiol. 29 (5): 705-717.
140. Vasetzky, S.G. 1967. Changes in the ploidy of sturgeon larvae induced by heat treatment of eggs at different stages of development. Dokl. Akad. Nauk. SSSR 172: 1234-1237. (translation Dokl. Biol. Sci. 172: 23-26).
141. Vervoort, A. 1980. Tetraploidy in Protopterus (Dipnoi). Experientia 36: 294-295.
142. Viktorovskii, R.M. 1972. Possibilities of polyplidy in the evolution of fish, p. 91-97. In: Cherfas, B.I. (ed.). Genetics selection and hybridization of fish. Israel Program for Scientific Translations, Jerusalem.
143. Vuorinen, J. 1984. Biochemical genetic studies on salmonid populations. Joensuun Yliopiston Luonnonlaitteellisia Julk. 0 (2): 1-11.
144. Wetzel, M.C., and J. Charlemagne. 1985. Antibody diversity in fish. Isoelectrofocalization study of individually-purified specific antibodies in three teleost fish species: Tench, carp and goldfish. Dev. Comp. Immunol. 9 (2): 261-270.
145. Wolf, U., W. Engel, and J. Faust. 1970. The mechanism of diploidization in vertebrate evolution: Coexistence of tetrasomic and disomic gene loci for the isocitrate dehydrogenases in trout (*Salmo trutta*). Humangenetik 9: 150-156.
146. Wolf, U., H. Ritter, N.B. Atkin, and S. Ohno. 1969. Polyplidization in the fish family Cyprinidae, order Cypriniformes. I. DNA-content and chromosome sets in various species of Cyprinidae. Humangenetik 7: 240-244.

147. Woods, T.D., and D.G. Buth. 1985. High level of gene silencing in the tetraploid goldfish *Carassius auratus*. *Biochem. Syst. Ecol.* 12 (4): 415-422.
148. Wright, J.E. Jr., K.R. Johnson, A. Hollister, and B. May. 1983. Meiotic models to explain classical linkage, pseudolinkage and chromosome pairing in tetraploid derivative salmonid genomes, p. 239-260. In: Isozymes: Current Topics in Biological and Medical Research. M.C. Rattazi, J.G. Scandalios, and G.S. Whitt (eds). Alan R. Liss, New York.
149. Wu, Weixin, Chuanwu Li, Guoan Liu, Dayi Xu, Chunshan Liu, Jinyun Xie, and Chaxiu Shan. 1988. Studies on tetraploid hybrid between red common carp (*Cyprinus carpio*) and grass carp (*Ctenopharyngodon idellus*) and its common backcross triploid. *Acta Hydrobiol. Sin./ Shuisheng Shenwu Xuebao.* 12 (4): 355-363.
150. Yu, X., T. Zhou, K. Li, Y. Li, and M. Zhou. 1987. On the karyosystematics of cyprinid fishes and a summary of fish chromosome studies in China. *Genetica (The Hague).* 72 (3): 225-236.
151. Zan, R., W. Liu, and Z. Song. 1985. Tetraploid-hexaploid relationship in *Schizothoracinae*. *Acta. Genet. Sin.* 12 (2): 137-142.
152. Zan, R., Z. Song, and W. Liu. 1986. Studies on karyotypes and nuclear DNA contents of some cyprinoid fishes, with notes on fish polyploids in China, p. 877-885. In: Indo-Pacific Fish Biology. T. Uyeno, R. Arai, T. Taniuchi, and K. Matsuura (eds). Sec. Int. Con. Ueno Park, Tokyo, July 29 - August 3, 1985.
153. Zenzes, M.T., and I. Voiculescu. 1975. C-banding patterns in *Salmo trutta*, a species of tetraploid origin. *Genetica* 45: 531-536.

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