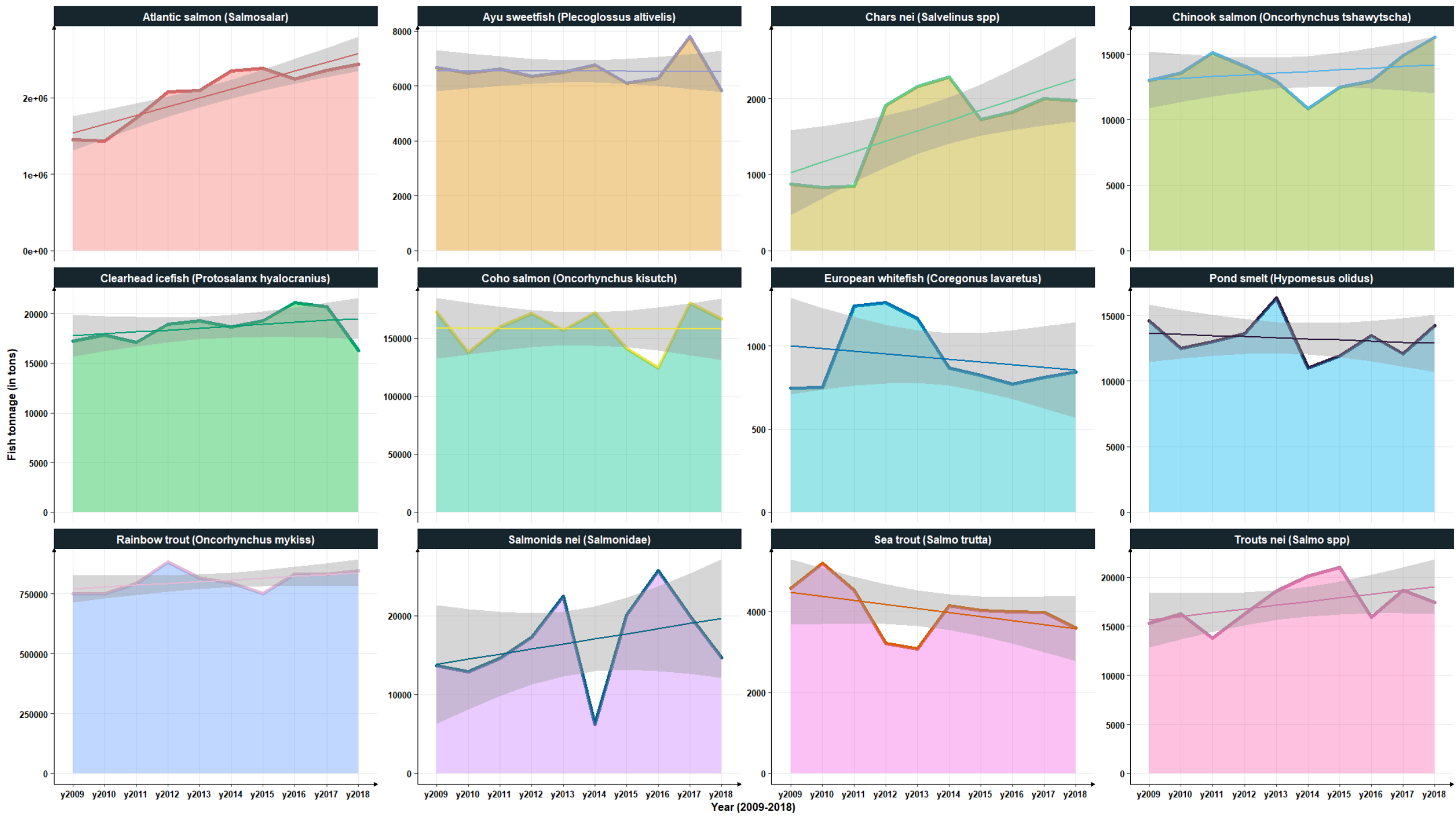
The triploid Atlantic salmon

Nomenclature and distribution area of the three genera of salmonids

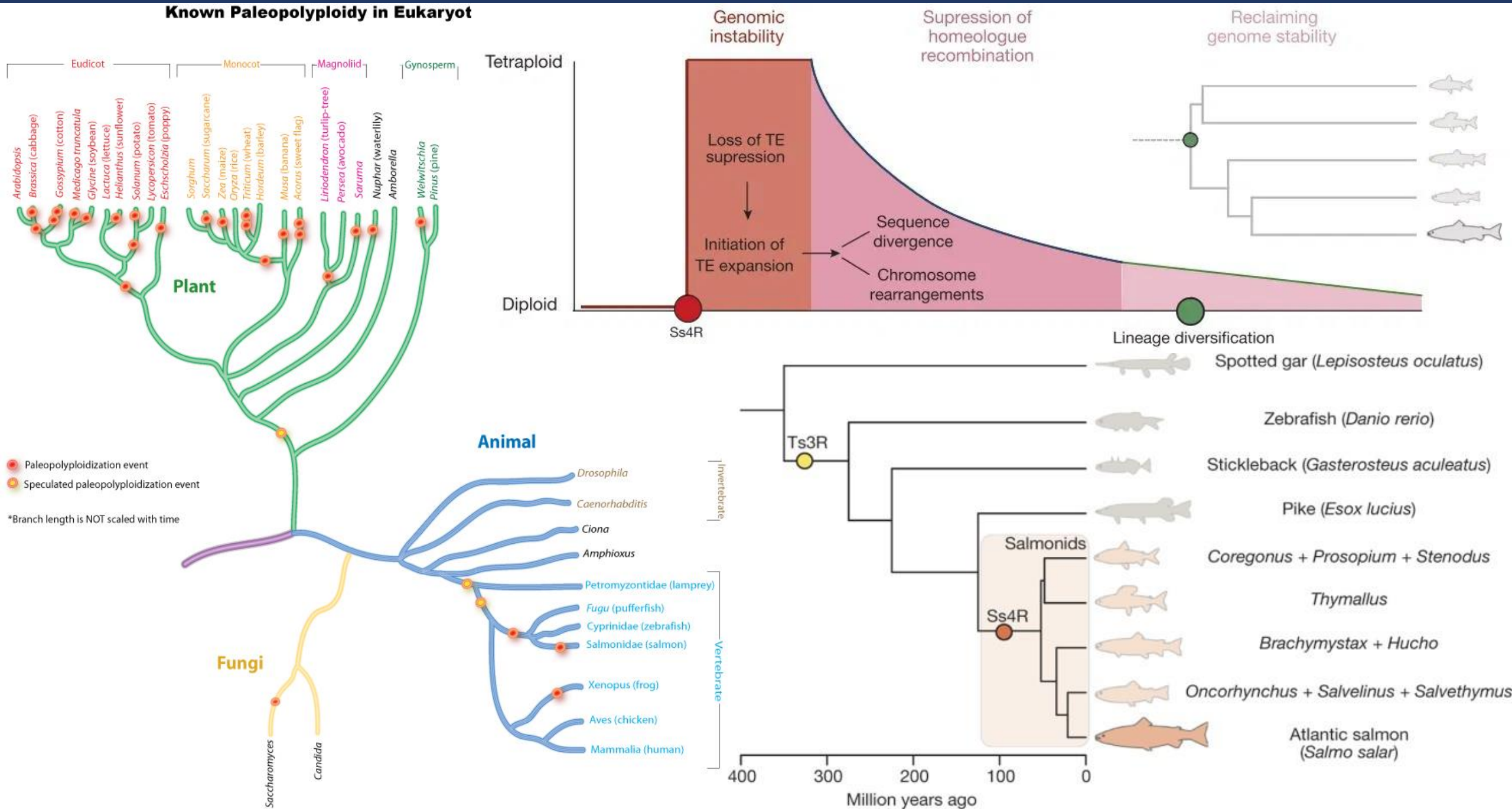
Taxonomy		Location
Genus	Scientific.and.vernicular.names	Native.distribution
Oncorhynchus		
	Oncorhynchus nerka (sockeye salmon)	North Pacific Rim: Japan: Columbia River
	O. gorbuscha (pink salmon)	North Pacific Rim: Korea to California
	O. keta (chum salmon)	North Pacific Rim: Korea to California
	O. tshawytscha (chinook salmon)	North Pacific Rim: Northern Japan to California
	O. rhodurus (amago salmon)	Southern Japan
	O. masou (masu salmon)	Japan, parts of Russia
	O. kisutch (coho Salmon)	North Pacific Rim: Northern Japan to California
	O. mykiss (steelhead and rainbow trout)	North Pacific Rim: Mexico to Russia and Interior of N. America mainly east of Rocky Mountains
	O. clarki (cutthroat trout)	West Coast of N. America, Alaska to California. Some interior western strains.
Salvelinus		
	Salvelinus alpinus (Arctic charr)	Circumpolar, and southward as relict populations
	S. malma (Dolly Varden charr)	Western North America and Eastern Asia
	S. confluentus (bull trout)	North Western North America
	S. fontinalis (Eastern brook charr)	Northeastern North America
	S. namaycush (lake charr or lake trout)	Northern Canada and southward relict populations
Salmo		
	Salmo salar (Atlantic salmon)	North Atlantic Ocean and surrounding land masses and water bodies
	Salmo trutta (brown trout)	European continent, U.K, Ireland


Atlantic salmon (Salmosalar)
Ayu sweetfish (Plecoglossus altivelis)
Chars nei (Salvelinus spp)
Chinook salmon (Oncorhynchus tshawytscha)
Clearhead icefish (Protosalanx hyalocranius)
Coho salmon (Oncorhynchus kisutch)
European whitefish (Coregonus lavaretus)
Pond smelt (Hypomesus olidus)
Rainbow trout (Oncorhynchus mykiss)
Salmonids nei (Salmonidae)
Sea trout (Salmo trutta)
Trouts nei (Salmo spp)
Fish tonnage (in tons)
Year (2009-2018)
y2009
y2010
y2011
y2012
y2013
y2014
y2015
y2016
y2017
y2018

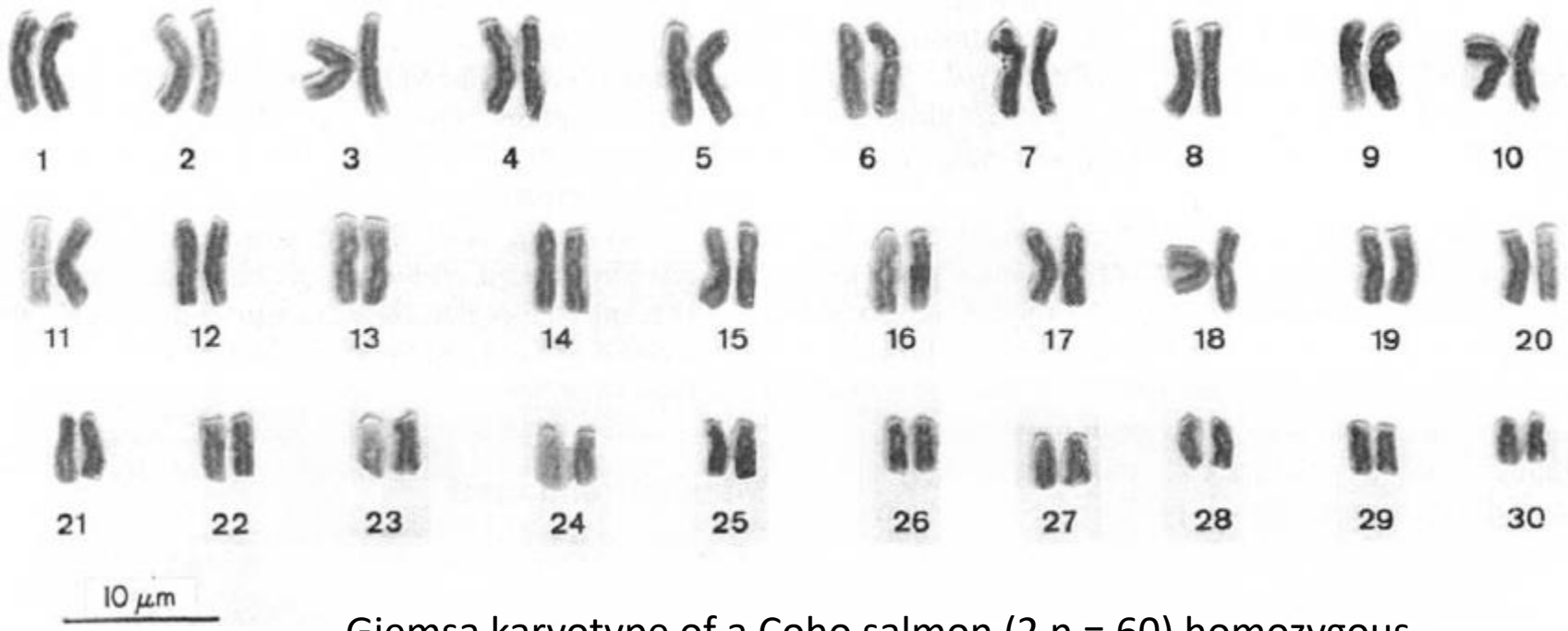
Major traits of the salmons

Table 1: Important breeding traits in the Atlantic salmon

Traits	Values		
Trait	Sample.Size	Mean.SD	Heritability.SE
Harvest Weight	1524	2.57 (0.63)	0.52 (0.05)
Gutted Weight	1616	2.35 (0.58)	0.53 (0.05)
Gutted Yield	1447	0.92 (0.02)	0.04 (0.01)
Deheaded Weight	1604	2.06 (0.52)	0.52 (0.05)
Fillet Weight	1516	1.70 (0.42)	0.53 (0.05)
Fillet Yield	1363	0.66 (0.04)	0.05 (0.02)
Fat Percentage	1679	12.2 (5.58)	0.18 (0.03)
Fillet Colour	1322	29.0 (0.73)	0.14 (0.03)
Head Weight	1475	0.32 (0.08)	0.21 (0.03)a
Gut Weight	1447	0.42 (0.08)	0.30 (0.04)a
Body Waste Weight	1426	0.33 (0.12)	0.15 (0.02)a
Total Waste Weight	1422	0.65 (0.17)	0.32 (0.04)a


Known Paleopolyploidy in Eukaryot
Eudicot
Monocot
Magnoliid
Gynosperm
Arabidopsis
Brassica (cabbage)
Gossypium (cotton)
Medicago truncatula
Glycine (soybean)
Lactuca (lettuce)
Helianthus (sunflower)
Solanum (potato)
Lycopersicon (tomato)
Eschscholzia (poppy)
Sorghum
Saccharum (sugarcane)
Zea (maize)
Oryza (rice)
Triticum (wheat)
Hordeum (barley)
Musa (banana)
Acorus (sweet flag)
Liriodendron (tulip-tree)
Persea (avocado)
Saruma
Nuphar (waterlily)
Amborella
Welwitschia
Pinus (pine)
Plant
Paleopolyploidization event
Speculated paleopolyploidization event
*Branch length is NOT scaled with time
Animal
Drosophila
Caenorhabditis
Ciona
Amphioxus
Petromyzontidae (lamprey)
Fugu (pufferfish)
Cyprinidae (zebrafish)
Salmonidae (salmon)
Xenopus (frog)
Aves (chicken)
Mammalia (human)
Invertebrate
Vertebrate
Fungi
Saccharomyces
Candida
Genomic instability
Supression of homeologue recombination
Reclaiming genome stability
Tetraploid
Diploid
Loss of TE supression
Initiation of TE expansion
Sequence divergence
Chromosome rearrangements
Ss4R
Lineage diversification
Spotted gar (Lepisosteus oculatus)
Zebrafish (Danio rerio)
Stickleback (Gasterosteus aculeatus)
Pike (Esox lucius)
Coregonus + Prosopium + Stenodus
Thymallus
Brachymystax + Hucho
Oncorhynchus + Salvelinus + Salvethymus
Atlantic salmon (Salmo salar)
Ts3R
Salmonids
Ss4R
400
300
200
100
0
Million years ago

Salmonid's ploidy



Giemsa karyotype of a Coho salmon (2 n = 60) homozygous

Salmonidae	European whitefish (Coregonus lavaretus)	80 or 81	4N
	Peled (Coregonus peled)	74	4N
	Arctic char (Salvelinus alpinus)	78	4N
	Brook trout (S. Fontinalis)	84	4N
	Atlantic salmon (Salmo salar)	54-58	4N
	Brown trout (S. Trutta)	78-84	4N
	Sevan trout (S. Ischchan)	80-82	4N
	Chinook salmon (Oncorhynchus tshawytscha)	68	4N
	Chum salmon (O. Keta)	74	4N
	Coho salmon (O. Kisutch)	60	4N
	Rainbow trout (O. Mykiss)	58-64	4N
	Golden trout (O. Mykiss aguabonita)	58	4N
	Masu salmon (O. Masou)	66	4N
	Sockeye salmon (O. Nerka)	57 or 58	4N
	Danube salmon (Hucho hucho)	82	4N
	European grayling (Thymallus thymallus)	102	4N

How about me?

Pilot-scale evaluation of triploid Atlantic salmon for aquaculture

60 years ago - first reported production of triploid Atlantic salmon (*Salmo salar*)

Took 30 years before further attempts were to produce triploid Atlantic salmon -unsuccessful

Success followed 10 years later

- Scotland
- Atlantic Canada
- Tasmania
- USA
- Ireland
- Norway

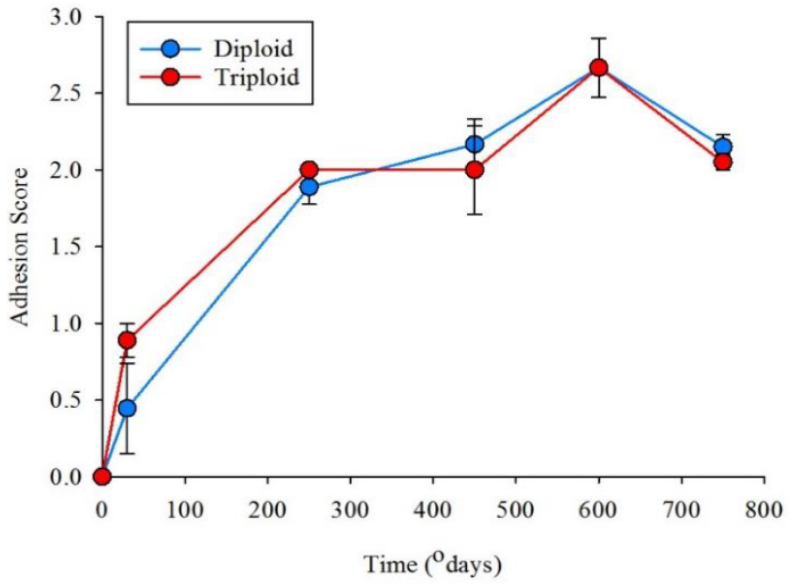
- Pancreas disease & sea lice—Similar resistance in triploid and diploid Atlantic salmon

- The response of triploids to...”—Bacterial disease —Amoebic gill disease—Vaccination

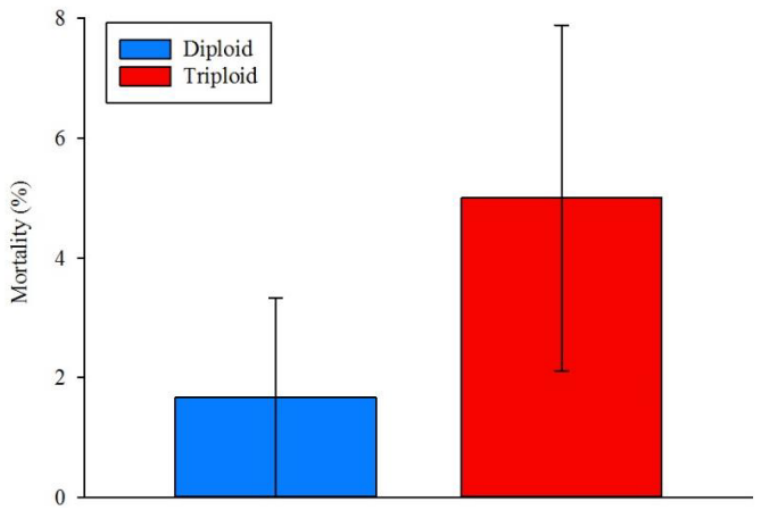
Effect of the triploid on the disease resistance

Health in triploid salmon

- **Bacterial disease & vaccination**



Similar development of adhesions



No difference in protection elicited by vaccine

- Triploids have comparable disease resistance to diploids
- Triploids are not more susceptible to disease as believed in the past
- Salmon producers can be confident in stocking triploid Atlantic salmon

Effect of the triploid on the disease resistance

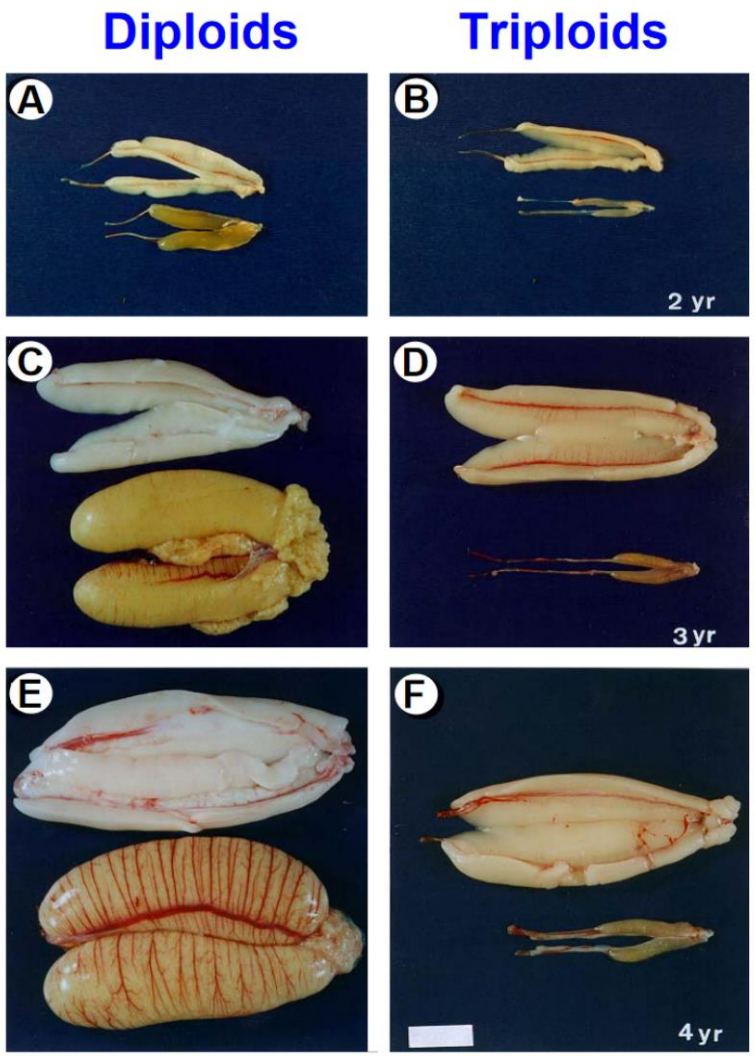
Table 1: Results of polyploid experiments						
Fish species	Pressure shock applied	Time period	Shock Time	Induction rate for Polyploidy		Reference
Nile tilapia	8,000 psi	2 minutes	9 minutes	100%	91.8±2.1 %	Hussain et al. (1991)
Rainbow trout	8,000 psi	10 minutes	40 minutes	80-90%	51%	Lou and Purdom (1984)
Rainbow trout	7,000 psi	4 minutes	40 minutes	100%		Chourrout (1984)
Rainbow trout	7,000 psi	4 minutes	5 to 50 minutes	100%		Chourrout (1984)
Coho salmon	6.9 x 10 kPa	4 minutes	20 to 40 minutes	100%		Teskeredzic et al. (1993)
Brook trout	700 Kg / square meter	6 minutes	10 minutes	75%		Arai et al. (1989)
Chum salmon	680 Kg / square meter	7 minutes	13.2 mn	3 (4n) + Aneuploïdy		Yamazaki and Goodier (1993)
Land lock Atlantic salmon	10,150 psi	3 to 6 minutes	17 to 14 minutes	100%		Benfey and Sutterlin (1984)
Yellow Perch	9,000 psi 11,000 psi	8 to12 minutes	5 minutes	30-70%		Malison et al. (1993)
Pacific abalone	200 Kg / square meter	7 minutes	60 minutes	50%		Arai et al. (1986)
Pacific abalone	200 Kg / square meter	22 minutes	60 minutes	65%		Arai et al. (1986)
Note: psi = pressure unit, psi = 6.894 kPa						

Table 4: Artificial or synthetic polyploids used in aquaculture

Taxonomy		Genetics	Manipulations	
Family	Species.or.variety	Ploidy	Inducing.or.synthetized.methods	References
1.Fish				
Cyprinidae	Grass carp (C. Idella)	3N	Hydrostatic pressure treatment	
	"xiangyun" crucian carp	6N	Interspecific hybridization and	(Chen et al., 2009)
	"Xiangyun No. 2" crucian carp	6N	Interploid crossing	
	"Changfeng" gibel carp	8N	Incorporating an alien	(Li et al., 2016)
	(Synthetized allopolyploid)		sperm genome	
Cobitidae	Cyprinid loach (M. Anguillicaudatus)	3N	Interploid crossing	(Hulata, 2001)(Piferrer et al., 2009b)
Salmonidae	Rainbow trout (O. Mykiss)	3Na	Thermal shock or Hydrostatic	(Solar et al., 1984)
			pressure treatment	(Hulata, 2001)
			Interploid crossing	(Piferrer et al., 2009b)
	Brown trout (S. Trutta)	3Na	Hydrostatic pressure treatment	
	Brook trout (S. Fontinalis)	3Na	"	
	Atlantic salmon (S. Salar)	3Na	" also NO, Freon, Cytochalasin B	
	Chinook salmon (O. Tshawytscha)	3Na	"	
	Arctic char (S. Alpinus)	3Na	"	
	Amago salmon (O. Rhodurus)	3Na	"	(Arai, 2001)
	Masu salmon (O. Masou)	3Na	"	(Arai, 2001)
	Coho salmon (O. Masou)	3Na	"	
	Allotriploid rainbow trout amago	3Na	Interspecific hybridization and	
	.. (X) Salmon hybrids		Heat-shocked	
	Rainbow trout Japanese charr hybrids	3Na		(Arai, 2001)
Siluridae	Thai walking catfish African	3N	Interspecific hybridization and	(Na-Nakorn et al., 2004)
	.. (X) Catfish hybrids		Heat-shocked	
Plecoglossidae	Ayu (P. Altivelis)	3N	Thermal shock or hydrostatic	(Arai, 2001)(Hulata, 2001)(Piferrer et al., 2009b)
Paralichthyidae	Hirame (P. Olivaceus)	3N	Pressure treatment	(X et al., 1996)
2. Shellfish				
Ostreidae	Pacific oyster (C. Gigas)	3N	Thermal shock, hydrostatic pressure	
			Treatment or interploid crossing	
Pectinidae	Catarina scallop (Argopecten ventricosus)	3N	Cytochalasin B	

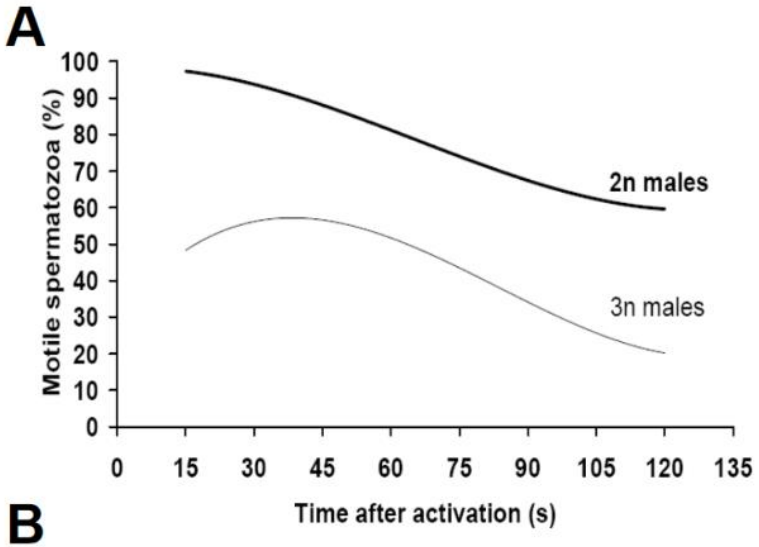
[1] *a* Triploids (3N) are defined as the natural tetraploid species are regarded as diploids

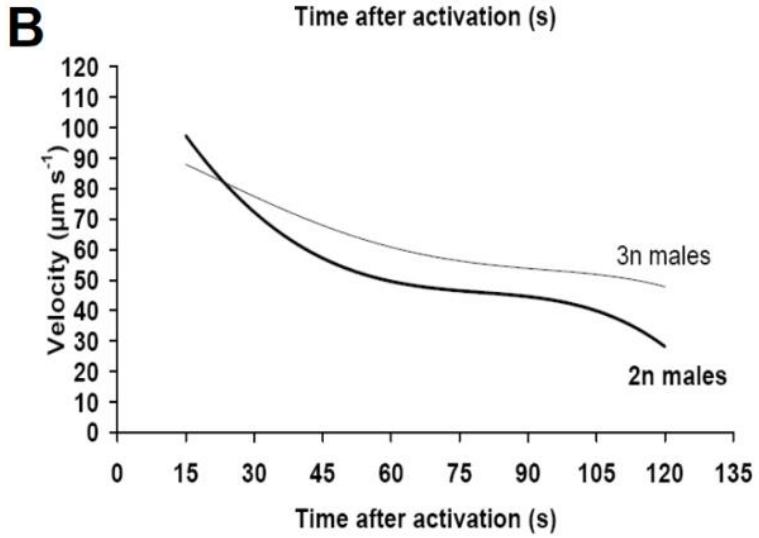
[2] *(X)* Animal crossing



- Gonadial atrophy
- Defective and reduced gametogenesis
- Fertility (decreased sperm count and motility)
- Fertility of 0 to 10% in salmon (vs. diploid)

Effect of triploidy on fertility and gametogenesis





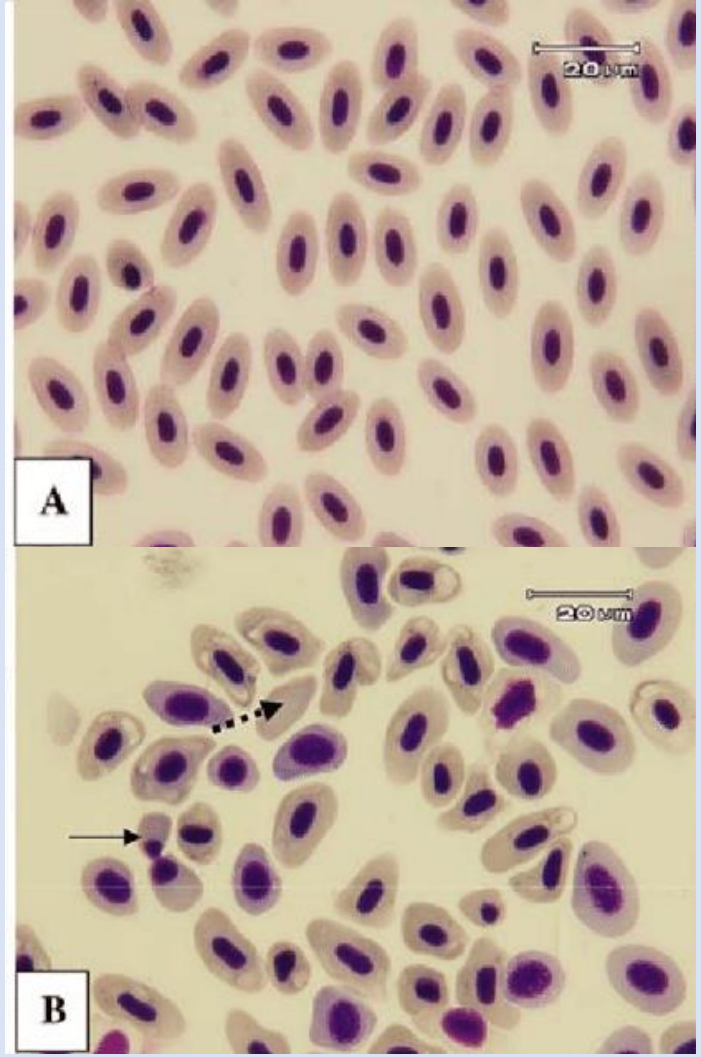
- Sperm motility and velocity decreased in Atlantic salmon for triploids (3N) vs. diploids (2N)

- Fertility is defined by a lower success rate of reproduction due to less vigorous sperm.

  (decreased sperm count and motility)

Effect of triploidy on sperm activity

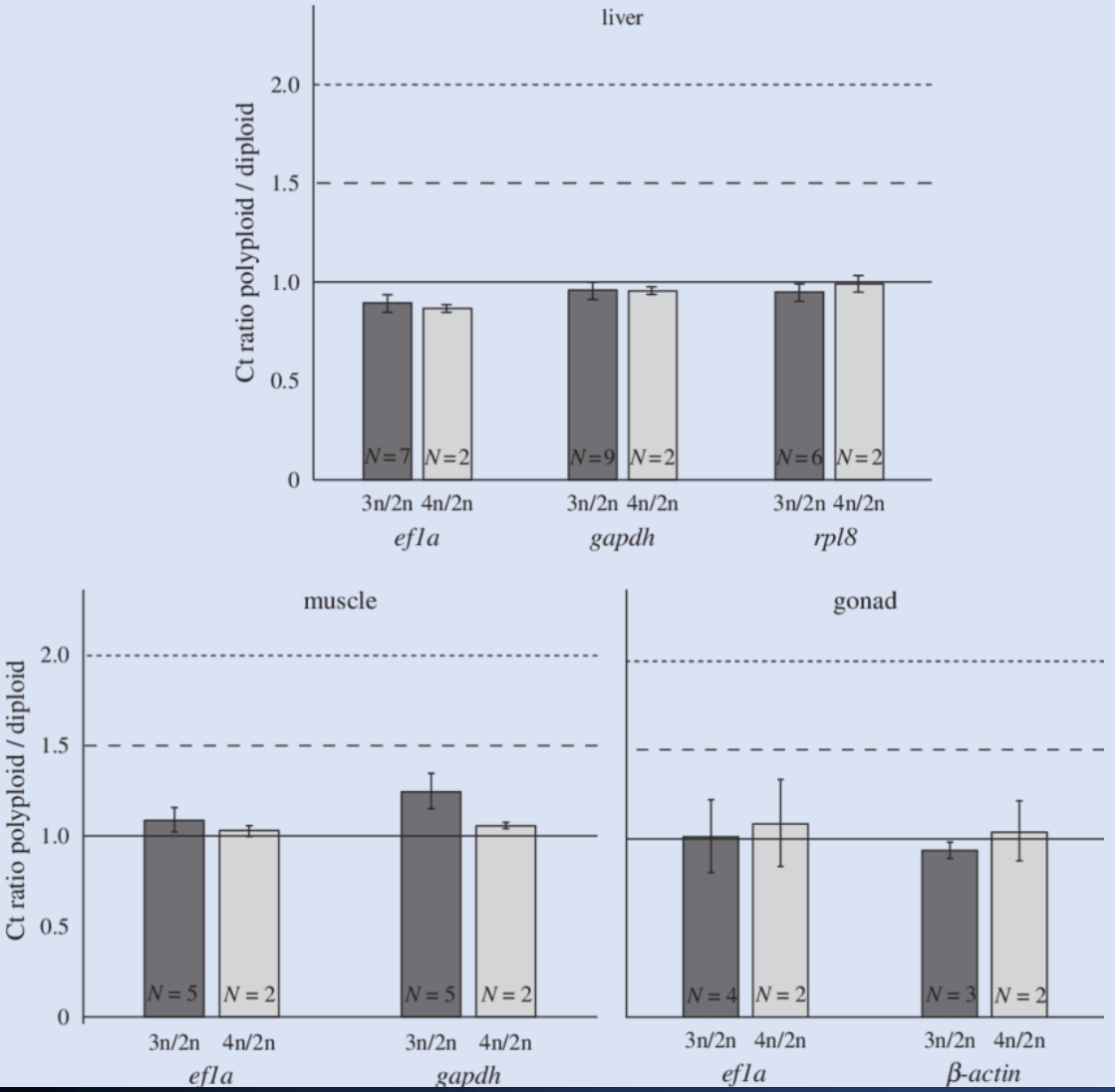
Effect of triploidy on cell morphology



Diploid (a) and triploid (b) Caspian salmon erythrocytes

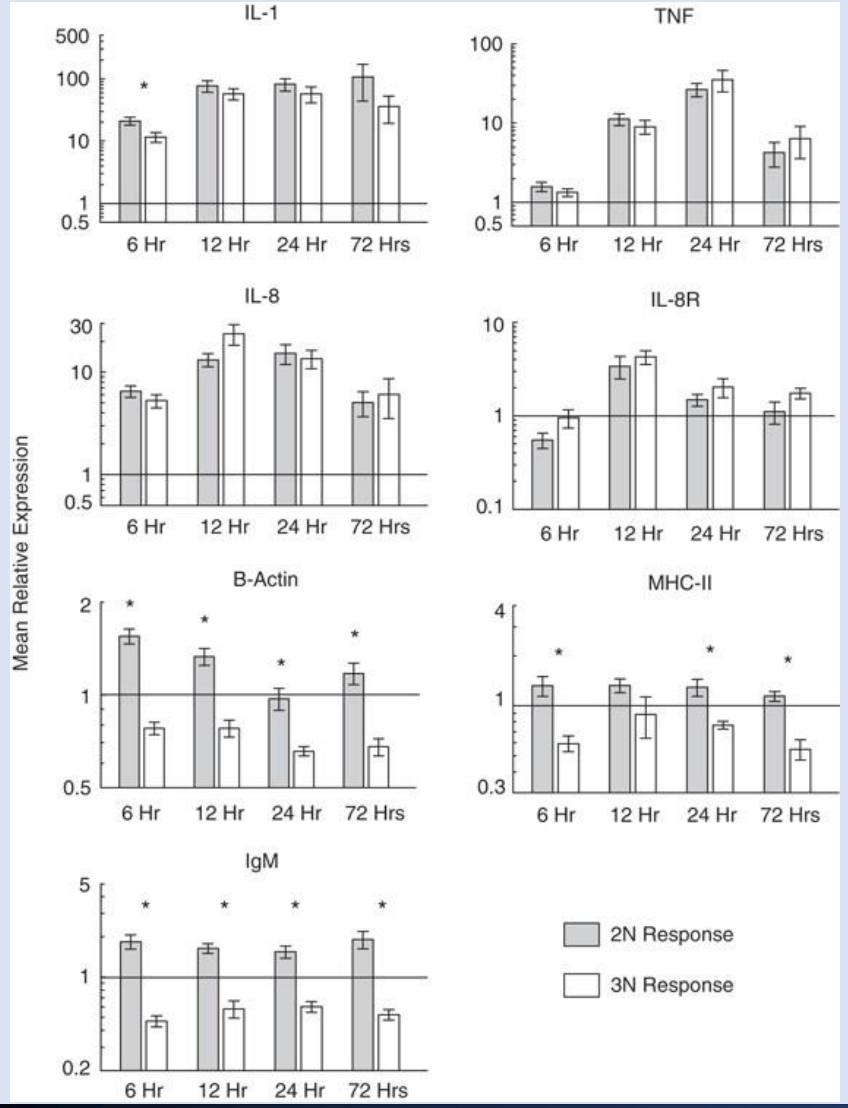
- Cell cytoplasm increase up to 150%
- More water = Diluted mRNAs
- Bigger nucleus 150% bigger.
- Dilution of transcription factors such as EF-1a
- Gene expression expected to be reduced by 1/3rd

BUT . . .



- Because of the increase in ploidy 2N -> 3N
- Transcript abundance must increase by 1/3rd
- The +150% mRNA abundance effect is cancelled due to +150% cell size.
- Gene expression in triploid is not too different from diploids

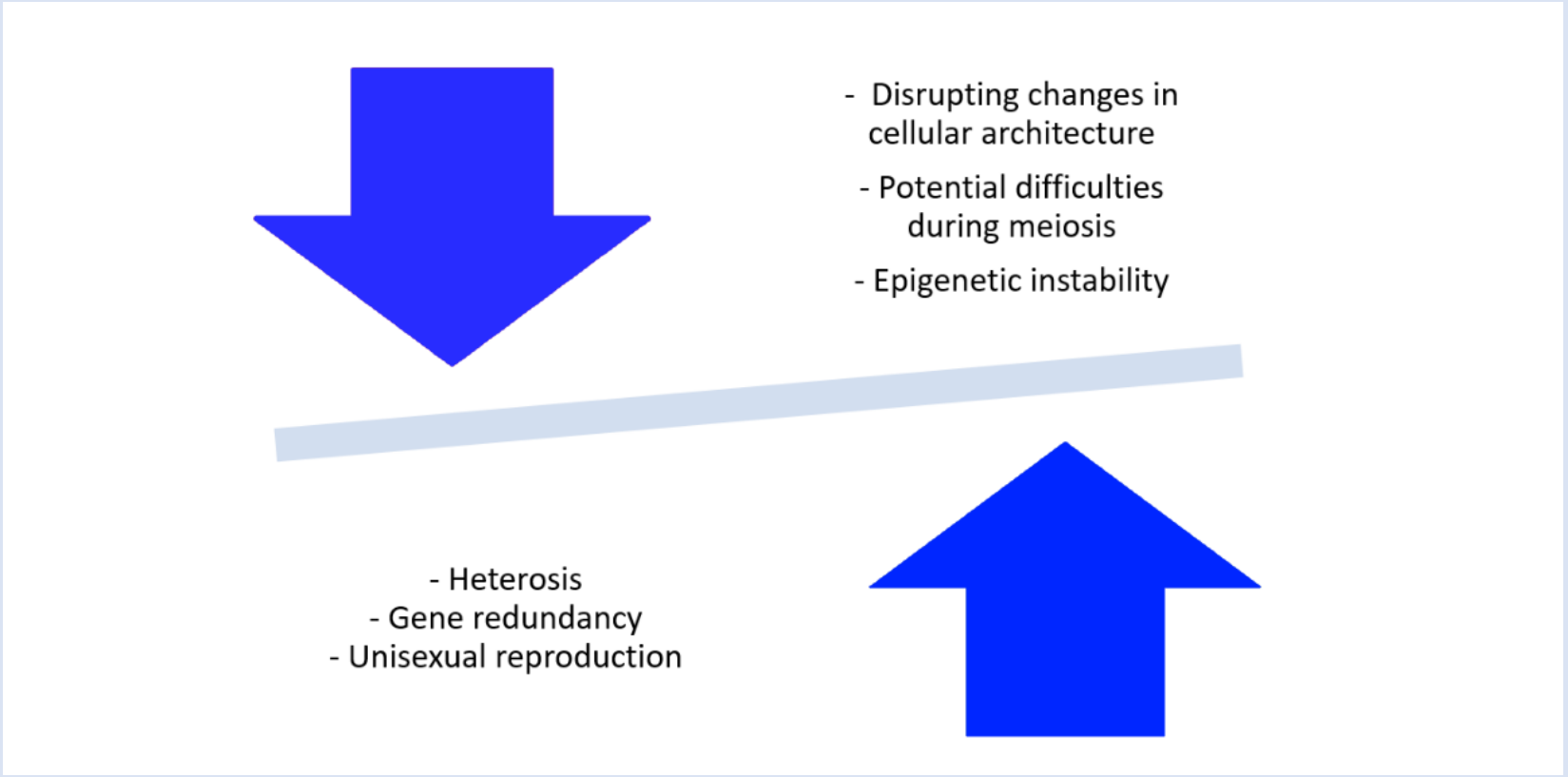
Effect of triploidy on transcription factors



- However, triploids have a different gene response for some genes.
- It does not always produce a different observable phenotype
- As shown previously, the response to diseases and vaccination in salmon is similar in 2N, 3N.

Effect of triploidy on gene expression

Advantages & Disadvantages



THANK YOU