WorldFish

October 2022

Management and Marketing of Genetically Improved Carp

Slides presented at training workshops

Hotel Zabeer International, Jashore - 10 October 2022
Momo Inn, Bogura - 12 October 2022

Dr. Matthew Gray Hamilton and Mr. Mohammed Yeasin
WorldFish

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Bangladesh Agricultural University

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About WorldFish
WorldFish is a nonprofit research and innovation institution that creates, advances and translates scientific research on aquatic food systems into scalable solutions with transformational impact on human well-being and the environment. Our research data, evidence and insights shape better practices, policies and investment decisions for sustainable development in low- and middle-income countries.

We have a global presence across 20 countries in Asia, Africa and the Pacific with 460 staff of 30 nationalities deployed where the greatest sustainable development challenges can be addressed through holistic aquatic food systems solutions.

Our research and innovation work spans climate change, food security and nutrition, sustainable fisheries and aquaculture, the blue economy and ocean governance, One Health, genetics and AgriTech, and it integrates evidence and perspectives on gender, youth and social inclusion. Our approach empowers people for change over the long term: research excellence and engagement with national and international partners are at the heart of our efforts to set new agendas, build capacities and support better decision-making on the critical issues of our times.

WorldFish is part of One CGIAR, the world's largest agricultural innovation network.

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Event Schedule

Time	Subject	Moderator
09:00 – 09:30 am	Registration	Md. Rayhan Ali/ Md. Fakhruddin
09:30 – 09:45 am	Welcome note Getting introduced to each other	Mohammed Yeasin
09:45 – 10:10 am	WorldFish Carp Genetic Improvement Program	Matthew Hamilton/ Mohammed Yeasin
10:10 – 11:00 am	Genetic theory and broodfish genetics	Matthew Hamilton/ Prof. Mostafa Hossain
11:00 – 11:15 am	Tea break	
11:15 – 11:30 am	Broodfish care	Prof. Mostafa Hossain / Mohammed Yeasin
11:30 – 12:00 pm	Q&A	Mohammed Yeasin / Md. Rayhan Ali / Md. Fakhruddin
12:00 – 12:30 pm	Panel discussion – ‘first experience from G3 rohu spawning and marketing’	Benoy Kumar Barman/ Manos Kumar Saha
12:30 – 12:45 pm	Address by special guest(s)	
12:45 – 01:00 pm	Address by the chief guest	
01:00 – 01:15 pm	Closing remarks	Benoy Kumar Barman/ Md. Shamsul Kabir/ Manos Kumar Saha
01:15 – 02:00 pm	Lunch	

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Management and Marketing of Genetically Improved Carp

WorldFish Carp Genetic Improvement Program

Matthew Hamilton (M.Hamilton@cgiar.org)

Hotel Zabeer, Jashore, Bangladesh – 10 October 2022
Momo Inn, Bogura, Bangladesh – 12 October 2022

Photographer: Mr. Mustafizur Rahman

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WORLDFISH CARP GENETIC IMPROVEMENT PROGRAM

- Substantially increase aquaculture productivity in Bangladesh by developing and disseminating rapidly-growing rohu, catla, and silver carp strains

Rohu

Catla

Silver carp

These three species represent 34% of Bangladeshi aquaculture

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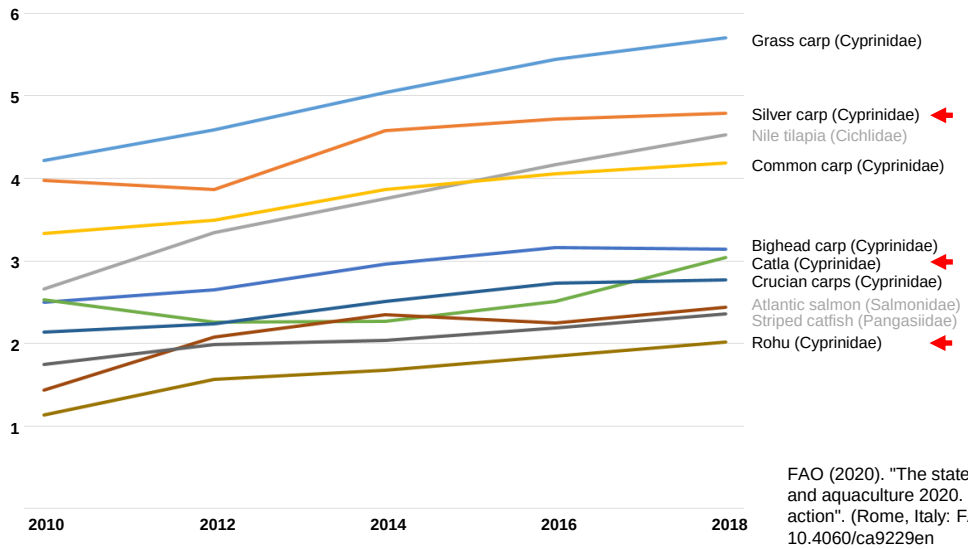
GLOBAL FINFISH AQUACULTURE (MT)



FAO (2020). "The state of World fisheries and aquaculture 2020. Sustainability in action". (Rome, Italy: FAO). doi: 10.4060/ca9229en

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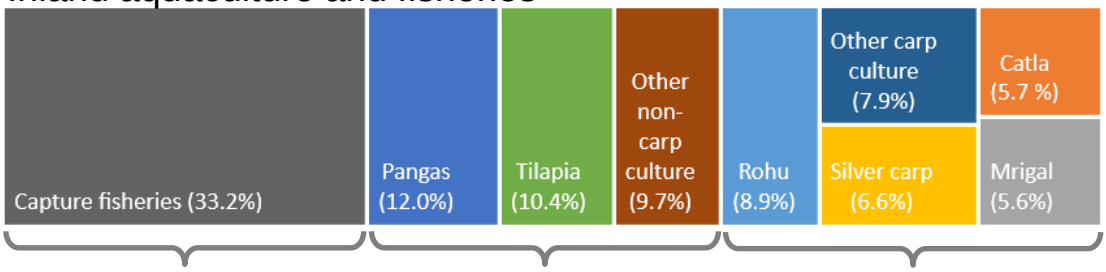
BANGLADESHI FINFISH AQUACULTURE

Inland aquaculture and fisheries



Capture fisheries (1.2 Mt) | Non-carp aquaculture (1.2 Mt) | Carp aquaculture (1.3 Mt)

- Rohu alone worth around one billion USD wholesale
- No genetically improved carp strains available until recently

DoF, 2020. Yearbook of fisheries statistics of Bangladesh 2018-19. Fisheries Resources Survey System (FRSS), Department of Fisheries. Bangladesh

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WORLDFISH CARP GENETIC IMPROVEMENT PROGRAM

- Program initiated in 2012 with the collection of catla and rohu founders as spawn from the Halda, Jamuna and Padma rivers
- Silver carp founders were sourced as adults from 17 Bangladeshi hatcheries

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WORLDFISH CARP GENETIC IMPROVEMENT PROGRAM

- Produce and maintain rapidly growing rohu, catla, and silver carp strains
  - Family-based selective breeding
- Validate response to selection and impact
- Dissemination of genetically-improved fish through hatchery partners

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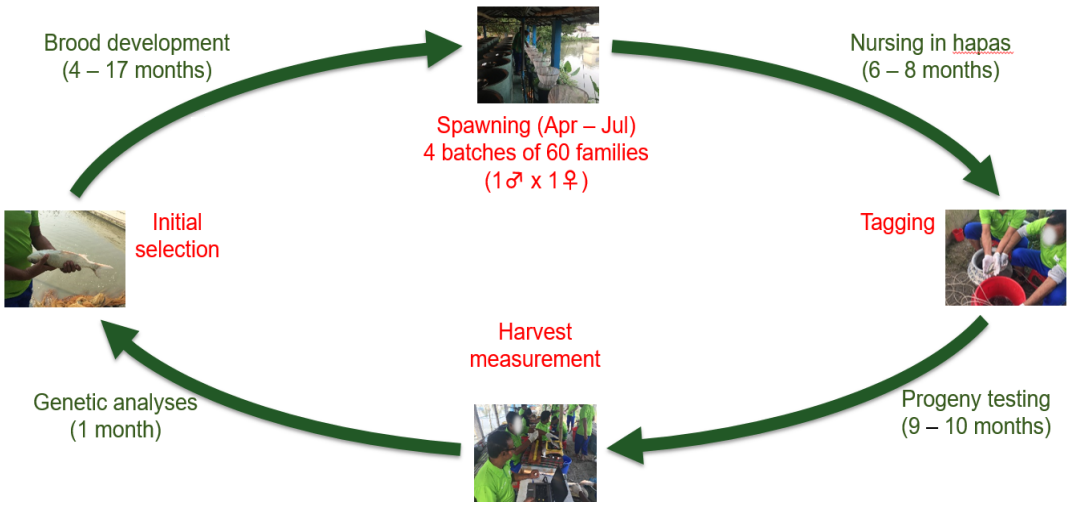
FAMILY-BASED SELECTIVE BREEDING



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WORLDFISH CARP GENETIC IMPROVEMENT PROGRAM

- Maintain 3 lines for each species
  - **Positively selected** line: selected for rapid growth rate
  - **Control** line: equivalent to unimproved river populations
  - **Negatively selected** line: selected for slow growth rate

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WORLDFISH CARP GENETIC IMPROVEMENT PROGRAM

- Hamilton, M.G., Mekkawy, W., Benzie, J.A.H. (**2019**). Sibship assignment to the founders of a Bangladeshi *Catla catla* breeding population. Genet. Sel. Evol. 51, 17. https://doi.org/10.1186/s12711-019-0454-x
- Hamilton, M.G., Mekkawy, W., Kilian, A., Benzie, J.A.H. (**2019**) Single Nucleotide Polymorphisms (SNPs) reveal sibship among founders of a Bangladeshi rohu (*Labeo rohita*) breeding population. Frontiers in Genetics. 10. https://doi.org/10.3389/fgene.2019.00597
- Hamilton, M.G., Mekkawy, W., Barman, B.K., Alam, M.B., Karim, M., Benzie, J.A.H. (**2021**) Genetic relationships among founders of a silver carp (*Hypophthalmichthys molitrix*) genetic improvement program in Bangladesh. Aquaculture, 736715. https://doi.org/10.1016/j.aquaculture.2021.736715
- Hamilton, M.G., Mekkawy, W., Alam, M.B., Benzie, J.A.H. (**2022**) Early selection to enhance genetic gain in a rohu (*Labeo rohita*) genetic improvement program. Aquaculture. 553, 738058. https://doi.org/10.1016/j.aquaculture.2022.738058
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- Hamilton, M.G., Yeasin, M., Chadag, V.M., Delamare-Debouteville, J.R.M., Debnath, P.P., Benzie, J.A., (**2022**) Genetic correlations between harvest weight and secondary traits in a silver carp (*Hypophthalmichthys molitrix*) genetic improvement program. Aquaculture International. https://doi.org/10.1007/s10499-022-00977-6
- Arick, M.A. et al. (**submitted**) A high-quality chromosome-level genome assembly of rohu carp, *Labeo rohita*, and discovery of SNP markers to aid in diversity and sex determination studies. G3. https://doi.org/10.1101/2022.09.08.507226
- Hamilton, M.G., Yeasin, M., Alam, M.B., Ali, M.R., Fakhruddin, M., Islam, M.M., Barman, B.K., Shikuku, K.M., Shelley, C.C., Rossignoli, C.M., and Benzie, J.A.H. (**submitted**). On-farm performance of genetically improved rohu (*Labeo rohita*) in Bangladesh. Frontiers in Aquaculture.
- Hamilton, M.G. et.al. (**In prep**) Cost-effective parentage assignment in a rohu (*Labeo rohita*) genetic improvement program.

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FAMILY-BASED SELECTIVE BREEDING

To date

- three generations of selection for rohu (G3)
- two generations of selection for silver carp (G2)
- one generation of selection for catla (G1)

Anticipate improvement in growth rate of approximately 10% per generation in Bangladeshi carp polyculture systems

Photo: Shafiujjaman Momin holding a G3 rohu (by Mohammed Yeasin)

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SPAWNING

Parent selection

Fin clipping

Spawning induction

Single-pair mating (full-sibling family)

Incubation (one family per tank)

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NURSING

One family per hapa

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TAGGING

Measurement

~50 individuals per family are measured and tagged

Insert passive integrated transponder (PIT) tags

Data entry

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GROW OUT ('PROGENY TESTING')

- Different polyculture combinations
- With and without supplementary feeding

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HARVEST MEASUREMENT

Harvest

Measurement

Read tags and enter data

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GENETIC ANALYSIS

Family-based genetic improvement

- Use measurement data from:
  - individuals
  - relatives
- Estimate 'breeding values' for (i.e. genetic quality of) every fish for every trait
- Allow selection of the genetically best parents while controlling average relatedness and inbreeding
- Maintain genetic diversity over the long term

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- Maintain genetic diversity over the long term

Genetic improvement programs that use mass selection cannot do this

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FAMILY-BASED SELECTIVE BREEDING

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Rohu	Base		G1		G2		**G3**			G4	
Catla				Base				G1			G2
Silver carp				Base		G1			G2		G3

Rohu G3 multiplier released to hatcheries as hatchlings

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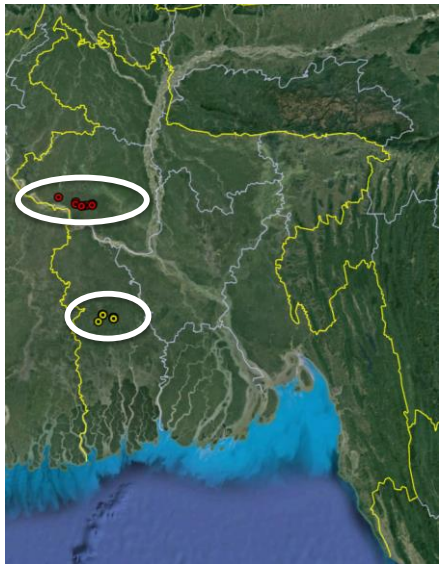
ON-FARM PERFORMANCE TRIALS

- Completed on-farm performance trials of G3 rohu in June 2022
- 19 semi-commercial farms in Rajshahi (NW) and Khulna (SW) divisions
- Three treatments – G3 multiplier, unimproved (equivalent to riverine stocks) and commercial rohu strains



Farm locations

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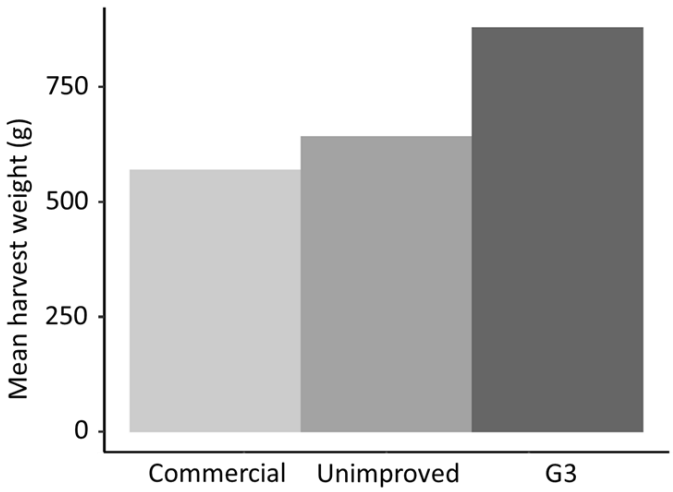
ON-FARM PERFORMANCE TRIAL



G3 outperformed other treatments at all 19 farms

Overall G3 fish weighed ~37% more than fish from the unimproved rohu strain at harvest

Hamilton, M.G., Yeasin, M., Alam, M.B., Ali, M.R., Fakhruddin, M., Islam, M.M., Barman, B.K., Shikuku, K.M., Shelley, C.C., Rossignoli, C.M., and Benzie, J.A.H. (submitted). On-farm performance of genetically improved rohu (Labeo rohita) in Bangladesh. Frontiers in Aquaculture.

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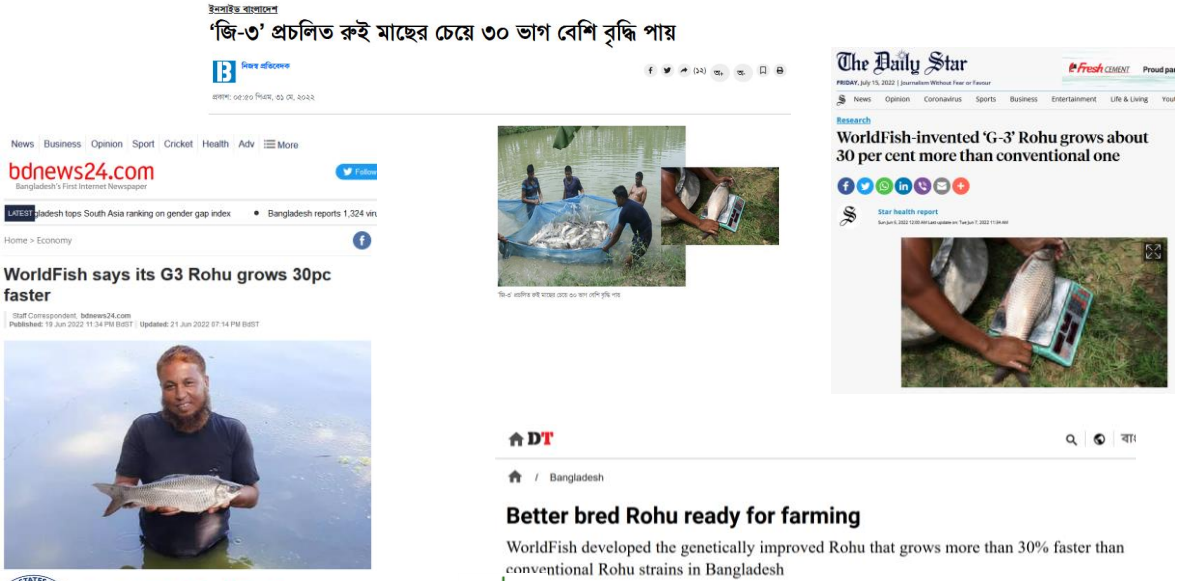
ON-FARM PERFORMANCE TRIAL



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DISSEMINATION OF WORLDFISH G3 ROHU

- Sale of G3 rohu seed from commercial hatcheries commenced in 2022
- 30 hatcheries are known to have G3 rohu broodstock

Hatcheries with G3 rohu broodstock

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FUTURE DISSEMINATION OF GENETICALLY IMPROVED CARP

- Access to improved strains by farmers will be via hatchery partners
- WorldFish to release additional G3 rohu broodstock to hatcheries in 2023
- WorldFish to release G3 silver carp broodstock to hatcheries in 2024

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WORLDFISH CARP GENETIC IMPROVEMENT PROGRAM SUMMARY

- Initiated in 2012
- Accomplished three generations of selection for rohu (G3), two generations for silver carp (G2), and one generation for catla (G1)
- Released G3 rohu to hatcheries in 2020-21
- Hatchery partners began producing G3 rohu seed in May 2022
- Completed on-farm performance trial of G3 rohu in June 2022
- Backup populations in place

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WORLDFISH CARP GENETIC IMPROVEMENT PROGRAM FUTURE

- Produce new generations with higher growth rates - G4 rohu in 2023, G2 catla and G3 silver carp in 2024, etc
- Release of G3 silver carp to hatcheries in 2024
- Additional traits (e.g., disease resistance, resilience, etc)
- Genomic tools (parentage assignment and genomic selection)
- Cryopreservation of milt
- Long-term research and dissemination partnerships for sustainability

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Management and Marketing of Genetically Improved Carp

Genetic theory

Matthew Hamilton (M.Hamilton@cgiar.org)

Hotel Zabeer, Jashore, Bangladesh – 10 October 2022
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Photographer: Mr. Mustafizur Rahman

DRIVERS OF SEED QUALITY

- **Hatchery environment**
- Hatchery rearing and handling practices

- **Disease status**
- The movement of fish among rivers, hatcheries and farms represents a biosecurity risk
- Hatcheries have an important role in minimising risks

- **Genetic quality**
- Minimise **inbreeding**
- Maximise the level of **genetic improvement**

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CLOSED POPULATIONS AND STRAINS

A population descended from a finite number of founder individuals into which no subsequent introduction of individuals or genes has occurred.

There is no universally accepted definition of a strain but here it is considered synonymous with a closed population.

closed population = strain

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CLOSED POPULATIONS AND STRAINS

Many hatcheries in Bangladesh maintain their own strains of introduced carp (e.g. silver carp) over multiple generations.

WorldFish maintains closed genetically improved populations of rohu, catla and silver carp.

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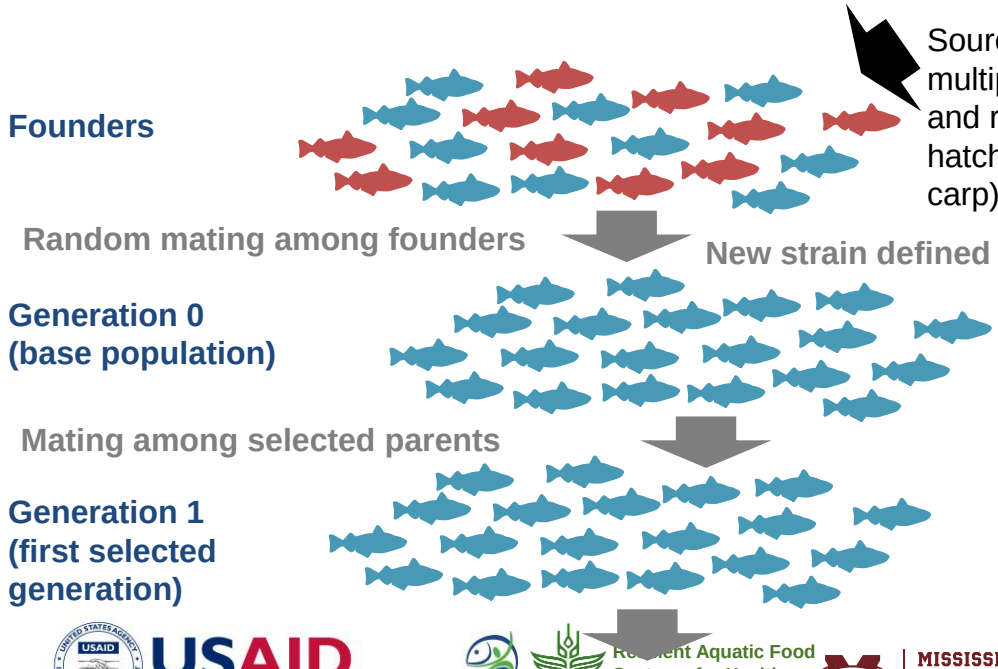
WORLDFISH STRAINS



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WORLDFISH STRAINS

Founders of WorldFish genetically improved carp strains

- Hamilton MG, Mekkawy W, Benzie JAH (2019). Sibship assignment to the founders of a Bangladeshi *Catla catla* breeding population. Genet Sel Evol 51(1): 17. https://doi.org/10.1186/s12711-019-0454-x
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- Hamilton MG, Mekkawy W, Barman BK, Alam MB, Karim M, Benzie JAH (2021). Genetic relationships among founders of a silver carp (*Hypophthalmichthys molitrix*) genetic improvement program in Bangladesh. Aquaculture: 736715. https://doi.org/10.1016/j.aquaculture.2021.736715

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GENETIC THEORY

- Genetic value of an individual fish for a given trait (e.g. weight at harvest)

Total genetic value

=

Additive genetic value

+

Non-additive genetic value

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GENETIC THEORY

Total genetic value

=

Additive genetic value

- transmitted from one generation to the next
- also called the **breeding value** of an individual

+

Non-additive genetic value

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GENETIC THEORY

Total genetic value

=

Additive genetic value

- transmitted from one generation to the next
- also called the **breeding value** of an individual

+

Non-additive genetic value

- not transmitted from one generation to the next
- **inbreeding depression** is a component of this

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GENETIC THEORY

Total genetic value

=

Breeding value

Increased with artificial selection (i.e. a genetic improvement program)

-

Inbreeding depression

Reduced with good broodstock management

+

Other non-additive effects

Difficult to quantify and exploit (we will ignore this)

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INBREEDING DEPRESSION

Inbreeding depression can result in:

- poor growth
- poor survival
- poor reproductive performance
- disease susceptibility
- morphological deformities

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WHAT IS INBREEDING?

Inbreeding results from the mating of related parents.

Related parents have at least one common ancestor.

The more closely related parents are, the greater the level of inbreeding in the progeny.

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WHAT IS INBREEDING?

Inbreeding results from the mating of related parents.

Founders
(assumed unrelated)

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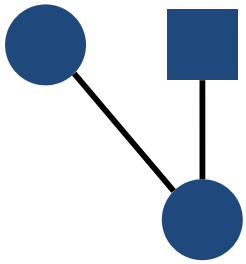

Generation 0
(base population)

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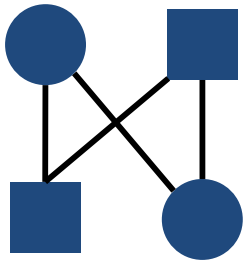
WHAT IS INBREEDING?

Inbreeding results from the mating of related parents.

Founders
(assumed unrelated)

Generation 0 Full siblings
(base population)



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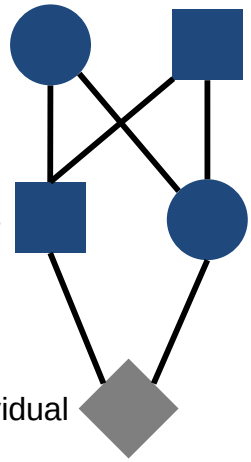

Generation 1 Inbred individual

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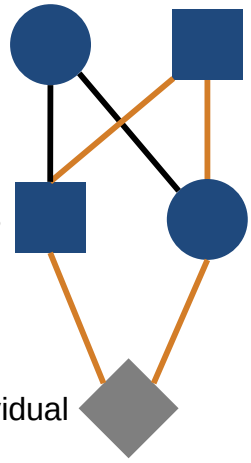

Generation 1 Inbred individual

Path Analysis
See http://www.fao.org/3/x3840e/X3840E00.htm

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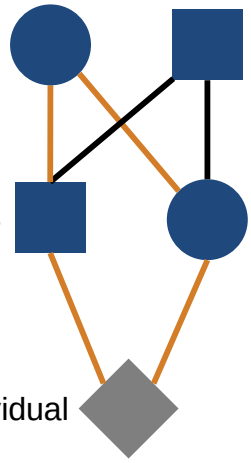

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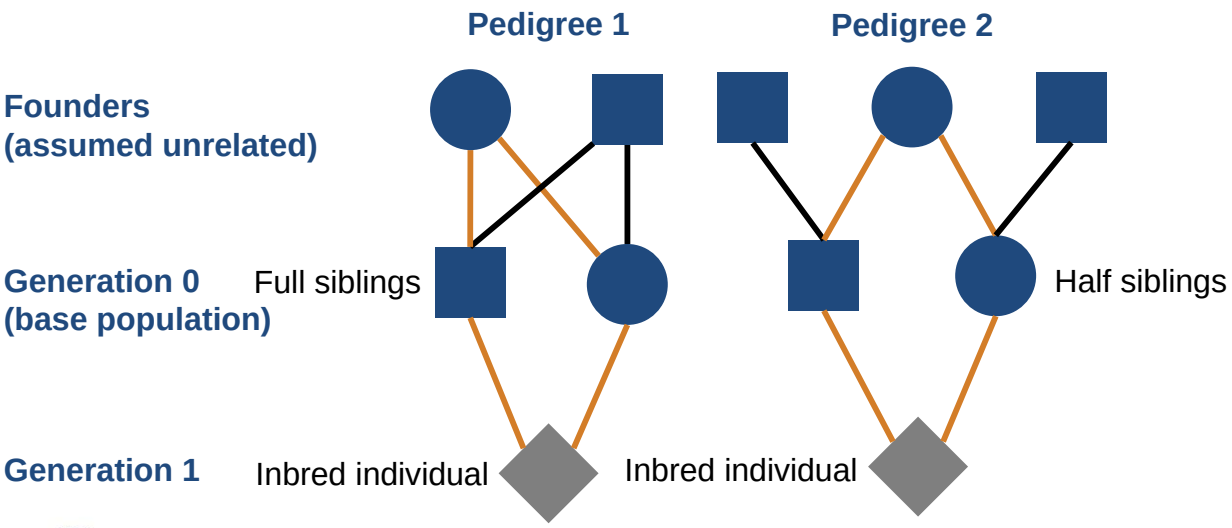

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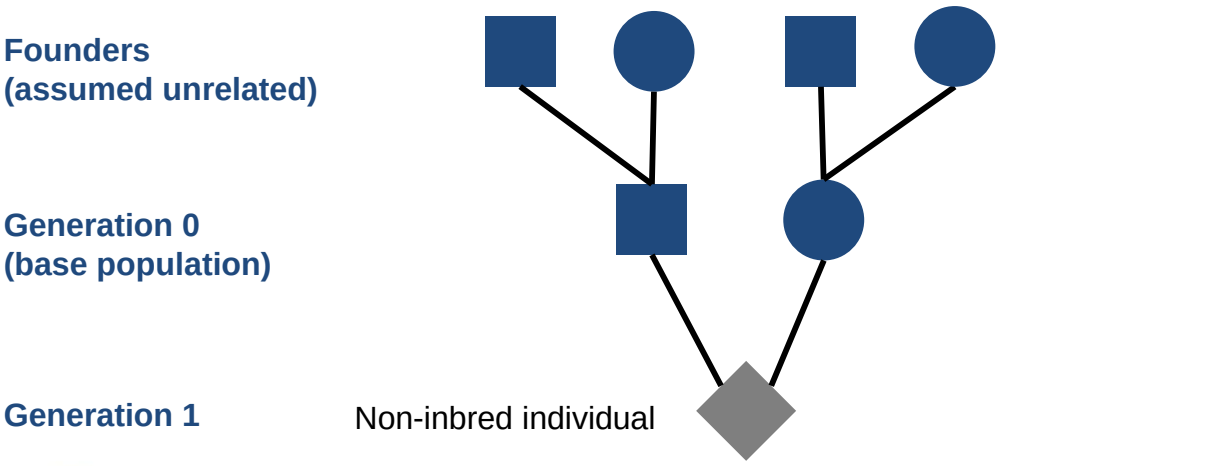

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QUANTIFYING INBREEDING

Coefficient of relationship (r)

- a measure of relationship **between individuals**
- the proportion of genes shared by two individuals as a result of the transmission of genes from parents to offspring

Inbreeding coefficient (F)

- a measure of inbreeding **in an individual**
- half the coefficient of relationship between an individual's parents

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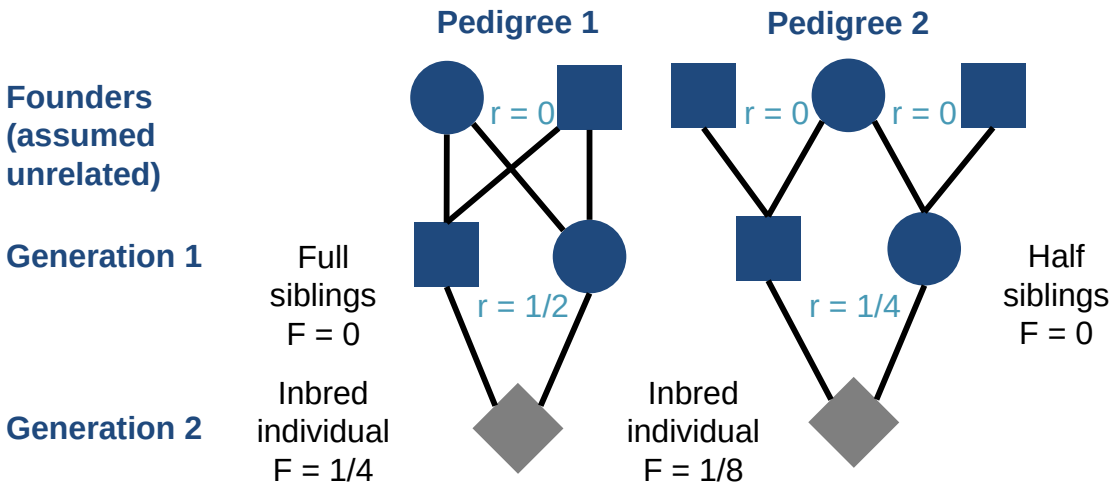

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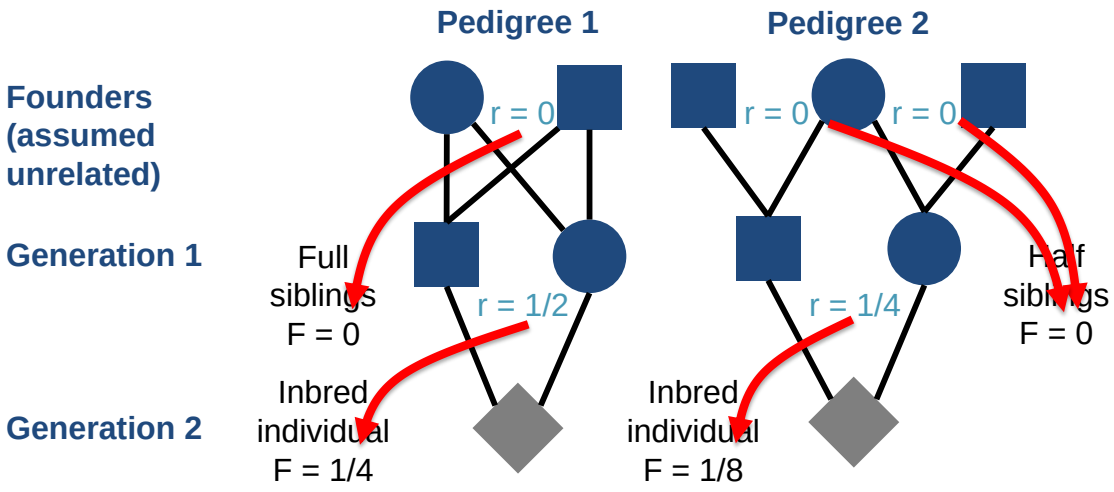

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QUANTIFYING INBREEDING

- Inbreeding increases in closed populations over generations because **average relatedness** among individuals increases.

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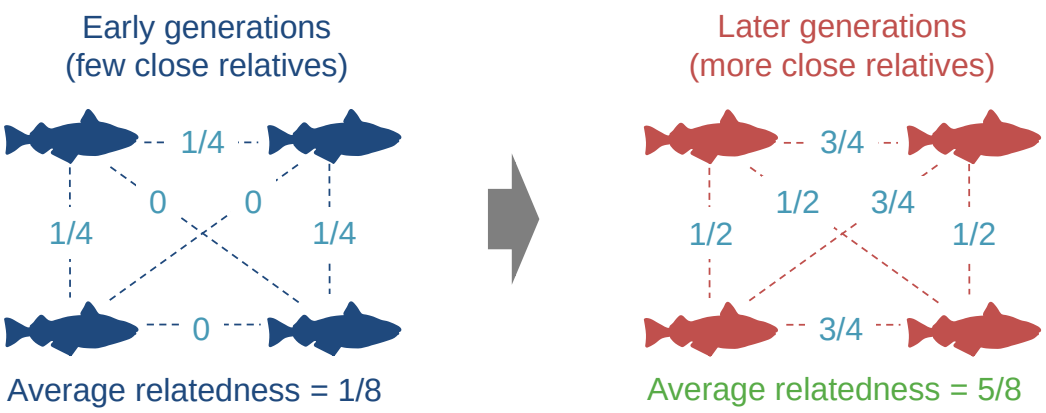

- Can implement broodstock management strategies to slow down the increase in average relatedness over generations.

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INBREEDING - KEY POINTS

Inbreeding results from the mating of related parents.

Inbreeding increases in closed populations over generations because **average relatedness** among individuals increases.

Can implement broodstock management strategies to slow down the increase in average relatedness over generations.

- e.g. maximise the number of unrelated (or not closely related) parents that contribute to the next generation

If two highly inbred but unrelated parents are crossed their progeny will not be inbred.

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GENETIC IMPROVEMENT

Is the process of making cumulative desirable changes to the average **breeding value** of a strain, for one or more characteristics.

Genetic improvement is achieved by selecting the best individuals from each generation as parents of the next generation.

Select parents that are believed to have high breeding values:

- measured characteristics of an individual
- measured characteristics of relatives
- control average relatedness

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Mass selection
(cheap and simple)

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- control average relatedness

Family-based breeding (expensive and complex)

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Management and Marketing of Genetically Improved Carp

Broodfish genetics

Matthew Hamilton (M.Hamilton@cgiar.org)

Hotel Zabeer, Jashore, Bangladesh – 10 October 2022
Momo Inn, Bogura, Bangladesh – 12 October 2022

Photographer: Mr. Mustafizur Rahman

BROODSTOCK MANAGEMENT

1. Source broodstock from wild populations
   - Only applicable to local species
   - Doesn't allow genetic improvement

2. Manage closed populations
   - Added complexity
   - May be necessary in the case of introduced species

3. Source broodstock from genetic improvement programs

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1. BROODSTOCK FROM RIVERS

To avoid relatedness between broodstock:

- should be from large water bodies with large populations
- if collected as fertilised eggs, should be obtained at the peak of the spawning season from areas in which the species is prevalent

Biosecurity must be considered.

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2. MANAGE CLOSED POPULATIONS

Remember the basic principles and determine what is affordable and practical.

- Inbreeding results from the mating of related parents
- Average relatedness within strains increases with each generation
  - aim to minimise average relatedness to minimise inbreeding
  - maximise the number of unrelated (or not closely related) parents that contribute to the next generation
- If two highly inbred but unrelated parents (or strains) are crossed, their progeny will not be inbred

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2. MANAGE CLOSED POPULATIONS

- Genetic improvement is achieved by selecting the best individuals from each generation as parents of the next generation
  - always select healthy fish but the biggest fish are not always the best fish (age, environment and management also affect size)
- Biosecurity issues must be considered when moving fish to and from hatcheries

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2. MANAGE CLOSED POPULATIONS

Hamilton MG. 2019. Management of inbreeding in carp hatcheries in Myanmar. Inland Myanmar Sustainable Aquaculture Programme (INLAND MYSAP), Mandalay, Myanmar, p 31. https://digitalarchive.worldfishcenter.org/handle/20.500.12348/3859

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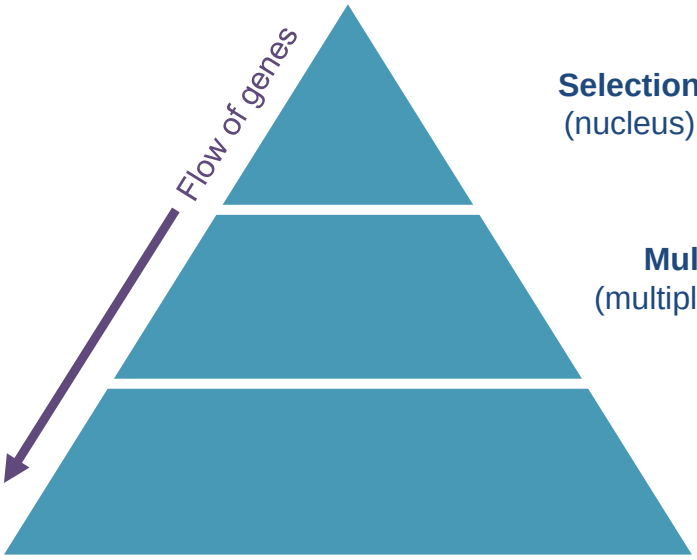
3. SOURCE EXTERNAL BROODSTOCK



Selection
(nucleus)

Multiplication
(multiplier hatcheries)

Production
(grow out farm)

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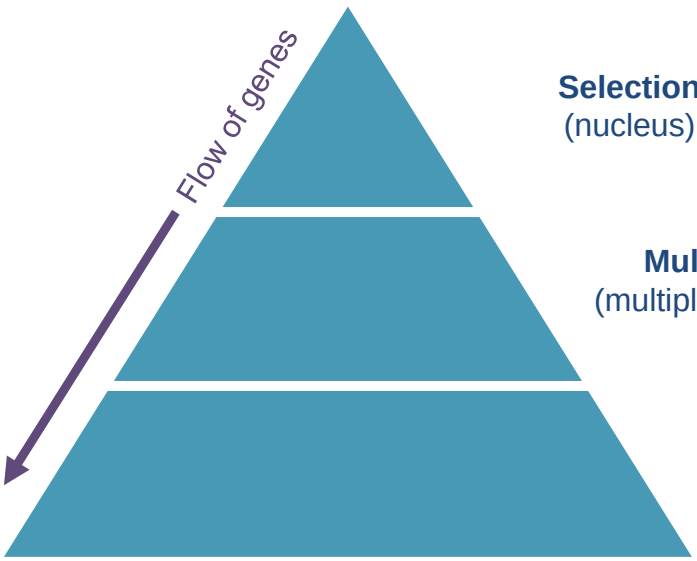

Selection
(nucleus)

WorldFish provided G3 rohu 'multiplier' to hatcheries

Multiplication
(multiplier hatcheries)

Hatcheries selling G3 seed to nurseries and farmers

Production
(grow out farm)

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WORLDFISH G3 ROHU MULTIPLIER

Fish from the third selected generation in the WorldFish Rohu Genetic Improvement population

- High ranking G3 families selected for rapid growth (nothing else!)
- Essentially unrelated families

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WORLDFISH G3 ROHU MULTIPLIER

There may be differences between WorldFish Rohu and other strains that were not deliberately selected for

- origins of the founders – multiple rivers (Halda, Jamuna and Padma)
- indirect selection – traits genetically correlated with growth rate

Only growth rate should be used for marketing purposes.

Differences in other traits are not validated.

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WORLDFISH G3 ROHU MULTIPLIER

Expected coefficient of inbreeding (F) for the progeny of the 2020 G3 multiplier is very low (0.029)

Expected F is not zero primarily because some mating between brothers and sisters will occur in hatcheries

WorldFish could provide two lines

- Lines maintained separately in hatcheries
- Only mate between lines (expected F = 0)
- Added complexity with limited benefits at this point

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FUTURE WORLDFISH PRACTICES

WorldFish will release a rohu multiplier every year or at least every second year (G3, G4, G5 etc)

Has developed a commercialization plan

- may change the terms under which the multiplier is provided to hatcheries

Will release multiplier as tagged fingerlings, not spawn.

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FUTURE WORLDFISH PRACTICES

WorldFish will release fish to hatcheries only (not nurseries or farmers) – with the exception of some trials

WorldFish is developing genetic markers to allow validation of fish origins (i.e. is G3 sold to farmers true G3)

WorldFish will release additional improved strains

- WorldFish G3 Silver Carp to hatcheries in 2024
- G4, G5 etc rohu
- catla

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Management and Marketing of Genetically Improved Carp

Broodfish care

Mohammed Yeasin (M.Yeasin@cgiar.org)

Hotel Zabeer, Jashore, Bangladesh – 10 October 2022
Momo Inn, Bogura, Bangladesh – 12 October 2022

Photographer: Mr. Mustafizur Rahman

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TITLE

- Content
- Broodfish care

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BROODFISH CARE

Genetic integrity

- Maintain WorldFish G3 multiplier separate from other rohu strains

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BROODFISH CARE

Why is it important?

- Development of gonads
- Response to induced breeding and the extent of fertilization and hatching
- Health of hatchlings and even their survival

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BROODFISH CARE

Ideal ponds for carp broodfish

- May vary from 0.5 to 6 acres
- Rectangular shape
- 1.5 to 2.5 meters depth
- Drainable, and have the facility to flush with good clean water

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BROODFISH CARE

Stocking

- Ideally, not more than 12 kg/decimal
- Typically, co-stocked with multiple species
- If co-stocked, needs to consider the feeding habits of various species

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BROODFISH CARE

Stocking: a generic guideline on species ratio

Niche/Natural Food	Species	%
Surface Feeders		
Phytoplankton	Silver carp	24
Zooplankton	Bighead carp	12
Zooplankton	Catla	12
Bottom Feeder		
Detritus	Mrigal	12
Bottom-Column Feeders		
Browser	Rohu	20
Macro-Vegetation Feeders		
Aquatic Foliage	Grass carp	20

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BROODFISH CARE

Pond fertilization and manuring

- To enhance the production of natural food
- Less supplementary feed is required if natural food is abundant
- Compensate for missing nutritive elements in the supplementary feed
- In a healthy, appropriately fertilised and managed pond, the colour of the water is light green, reddish green or brownish green

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BROODFISH CARE

Pond fertilization and manuring

- Urea: 250g/decimal/month
- TSP: 250g/decimal/month
- Fermented mustard oil cake (with or without wheat bran and molasses) or compost: 200g/decimal/month
- The rate should be increased if Secchi disc visibility is greater than 30 cm and suspended if less than 25 cm

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BROODFISH CARE

Liming

- Increases buffering capacity against pH fluctuation, reduces turbidity, maintains alkalinity and hardness
- 200g/decimal/month

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BROODFISH CARE

Feeding

- Required quantity of supplementary feed depends on fish biomass and natural food availability
- Essential fatty acid, vitamins
- Excessive carbohydrate causes lipid deposition
- External factors (e.g., temperature) have an influence on feeding rate

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BROODFISH CARE

Feeding rate

Age/ average weight	Daily ration (% of body weight)	Feedings per day	Approx. protein content (%)
0 – 10 days	200 – 20	6 – 4	45 - 40
11 – 40 days (<2g)	20 – 10	5 – 3	40
2-5g	10	4 – 3	32
5-20g	10 – 6	3	32
20-180g	6 – 3	2	28
180-1000	3 – 2	2	28
>1000g	2-1	2	28

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WORLDFISH TEAM

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- **Dr. Matthew Hamilton (Geneticist)**
- **Md. Masud Akhter (CGIP Platform Manager)**
  - Aashish Kumar Roy, Uzzal Kumar Sarkar, Ramprosad Kundu, Sirajum Monira Shanta, Md. Mustafizur Rahman, Md. Kamruzzaman (Research Assistants)
  - Md. Jamal Hossain, Mojammel Haque (Jr. Research Assistants)
  - Md. Tutul Hossain (Jr. Field Assistant)
  - Md. Faruk Hossain Biswas, Md. Iqbal Hossan, Anutosh Kumar Sarkar, Md. Hafizur Rahaman, Md. Foizur Rahman (Assistant Field Facilitators)
- **Mohammed Yeasin (Dissemination Manager)**
  - Md. Fakhruddin, Md. Mazharul Islam (Research Assistants)

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  - Prof. Terrence Tiersch, Louisiana State University Agricultural Center
  - Dr. Mostafa Hossain, Bangladesh Agricultural University
- **G3 Dissemination Hatchery Partners**
  - Afil Aqua Fish Ltd, BRAC Fish Hatchery, Fishtech Hatchery Limited, Jamuna Fish limited, Ma Fatima Fish Hatchery, Madhumoty Matsha Utpadon Kendro, Matri Fish Hatchery & Agribased Farm, Mukteshary Fish Hatchery and Rupaly Fish Hatchery.
- **On-farm Performance Trial Partners**
  - Ahsanuzzaman (Sweet), Ali-Abdullah Dairy Farm and Matsha Khamar, Ashroy Trainning Center, Fahad Hatchery and Fish Farm, Golden Fish and Nursery Complex, Insar Ali, Jalal Uddin, Jui-Jerin Matsya Khamar, Madina Fish Nursery, Md. Labu, Md. Sofiuzzaman, Md. Abu Rayhan, Mehedi Enterprise, Molla Fish Nursery and Dairy Farm, Muttakim Traders, Osit Matsya Khamar, Razib Kumar Sarkar, Sagor Fish Hatchery and Saifujjaman Pintu.

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CGIP FUNDING

- **USAID Feed the Future Innovation Lab for Fish (FIL) 'Advancing aquaculture systems productivity through carp genetic improvement' (7200AA18CA00030)**

- USAID Feed the Future Innovation Lab for Fish (FIL) 'Genome sequencing and development of single nucleotide polymorphism (SNP) markers from Rohu in Bangladesh' (7200AA18CA00030)
- USAID Feed the Future 'Bangladesh Aquaculture and Nutrition Activity' (72038818IO00002)
- USAID Feed the Future 'Aquaculture for Income and Nutrition project' (EEM-G-00-04-00013-00)
- International Fund for Agricultural Development (IFAD) (2000001001)
- European Commission-IFAD (2000001539)
- BMGF 'Aquaculture: Increasing Income, Diversifying Diets and Empowering Women in Bangladesh and Nigeria project' (INV009865)
- CGIAR 'Research Program on Fish Agrifood Systems' (FISH)
- CGIAR 'Resilient Aquatic Food Systems for Healthy People and Planet' (RAqFS)

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About WorldFish

WorldFish is a nonprofit research and innovation institution that creates, advances and translates scientific research on aquatic food systems into scalable solutions with transformational impact on human well-being and the environment. Our research data, evidence and insights shape better practices, policies and investment decisions for sustainable development in low- and middle-income countries.

We have a global presence across 20 countries in Asia, Africa and the Pacific with 460 staff of 30 nationalities deployed where the greatest sustainable development challenges can be addressed through holistic aquatic food systems solutions.

Our research and innovation work spans climate change, food security and nutrition, sustainable fisheries and aquaculture, the blue economy and ocean governance, One Health, genetics and AgriTech, and it integrates evidence and perspectives on gender, youth and social inclusion. Our approach empowers people for change over the long term: research excellence and engagement with national and international partners are at the heart of our efforts to set new agendas, build capacities and support better decision-making on the critical issues of our times.

WorldFish is part of One CGIAR, the world's largest agricultural innovation network.

For more information, please visit www.worldfishcenter.org