

# Applications of Genetics in Aquaculture and Fisheries Practices

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# Contents

- Main Genetic Parameters (phenotype and genotype)
- Qualitative and quantitative traits
- Phenotypic and genotypic variation
- Heritability and breeding programs
- Applications of genetics in aquaculture
  - Broodstock management
  - Selection
  - Hybridization
- Advanced genetics approaches (ploidy, androgenesis, gynogenesis and genetic engineering)
- Applications of genetics in fishery management (fishing practices, stock enhancement)
- Conclusion

# Main Genetic Parameters

## phenotype and genotype

- **Phenotype (P)** tells how an individual looks = appearance (e.g. color, body shape, scaled, length, weight, etc.)
- **Phenotype** could be qualitative or quantitative
- **Genotype (G)** is the genetic make up of an individual

Improving a phenotype through genetics is done via working on a hidden element (genetic make up)

# Qualitative traits

Qualitative genetics is known after Gregor Mendel who established the mathematical basis of the inheritance in peas

Qualitative traits have a distinct appearance (phenotype): either **this** or **that**; individuals can be placed in one of few discrete classes

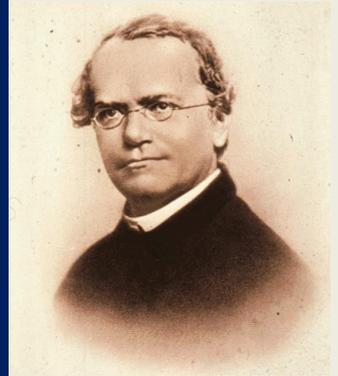
Each trait is controlled by **one gene** in most situations

Inherited disease or colorations are examples

These traits are not influenced by environmental conditions

Selection for qualitative traits are designed to **fix** desired traits and **eliminate** undesired ones

With some exceptions, qualitative traits are less important in aquaculture



# Qualitative traits in:

## Aquaculture



Red tilapia for Sushi dishes



## Ornamental fish



Coloration, small size could be far important than weight or FCR



# Qualitative traits and: Social & processing considerations

Mirror carp a strain of  
common carp



Extremely important when  
scaleless fish is not socially  
acceptable

Less scales is  
advantageous  
in regard to  
processing



Naturally fully scaled  
common carp

# Quantitative traits

Most productive traits are quantitative (weight, length, feed conversion “FCR”, fecundity,...)

**Unlike** qualitative traits, Quantitative phenotypes in a population exhibit **continuous distributions**

Controlled by several genes as well as could be affected by environment factors. Hence: the phenotype:  $P = G + E + G-E$

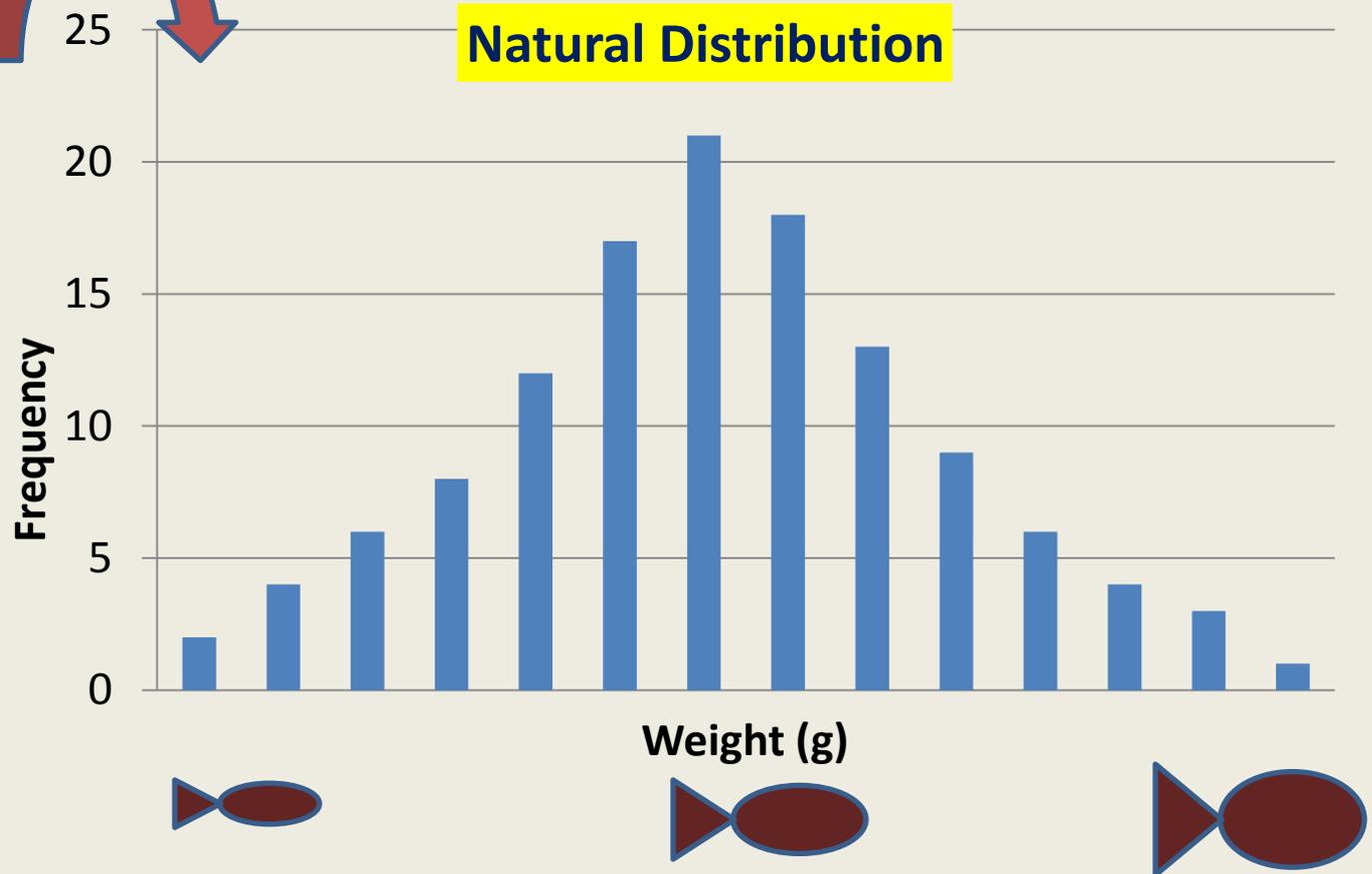
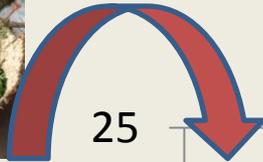
In order to improve a phenotype trait, its variance should be analyzed and sorted into heritable and non-heritable components

Heritable component is what breeders are interested in

P= phenotype G=genotype E= environmental influence

G-E= genetic x environment interaction

# Quantitative phenotype



# Phenotypic and genotypic variance

- There should be a variance in order to attain some improvements through genetics
- If all individual are identical and look the same, there will not be a real chance for their improvement
- Variance in the appearance is phenotypic variance ( $V_p$ )
- Phenotypic variance ( $V_p$ ) is the sum of: genetic variance ( $V_G$ ), environmental variance ( $V_E$ ), and the variance resulting from genetic-environmental interaction ( $V_{G-E}$ )

$$V_P = V_G + V_E + V_{G-E}$$

# Environment Variance ( $V_E$ )

$V_E$  Has **no genetic basis**. This means that a phenotype could improve via environment regardless the genetic make up of the organism. An example of that when fish stocks perform better when farmed under optimum conditions compared to marginal growing conditions (water quality, feed, etc.)

If  $V_E$  is neither controlled nor quantified or got confound with  $V_G$ , it will not be possible to evaluate the genetic improvement and this can ruin a breeding program

$V_E$  is **not** transmitted from parents to offspring

# Environmental variance $V_E$ (examples)

**Shooting:** This phenomenon was found in common carp, *Cyprinus carpio*. It is defined as a sudden and dramatic growth of the shoot individuals (shooters; jumpers)

Shooting have been attributed mainly to the competition for food and/or space. This could result of high stocking density & insufficient natural food, or due to the inadequate size of feed particles

If shooters are selected as broodstock, no progress should be expected

# Environmental variance (examples- Cont.)

**Egg size (Maternal effect):** This occurs when a pronounced effect is found of egg size on the growth rate of early life of fish and when this effect disappears as fish gets older. In Nile tilapia, the effect was virtually gone by 20 days. Thus, **selection should not be carried out before such effect disappears**

Because egg size could be influenced by environmental factors as well as genetics, in evaluation programs, it is crucial to use females of same age and comparable size, otherwise, detected differences in their progeny may be due to mother's age, size, or diet, and not to genetic makeup

# Heritability ( $h^2$ )

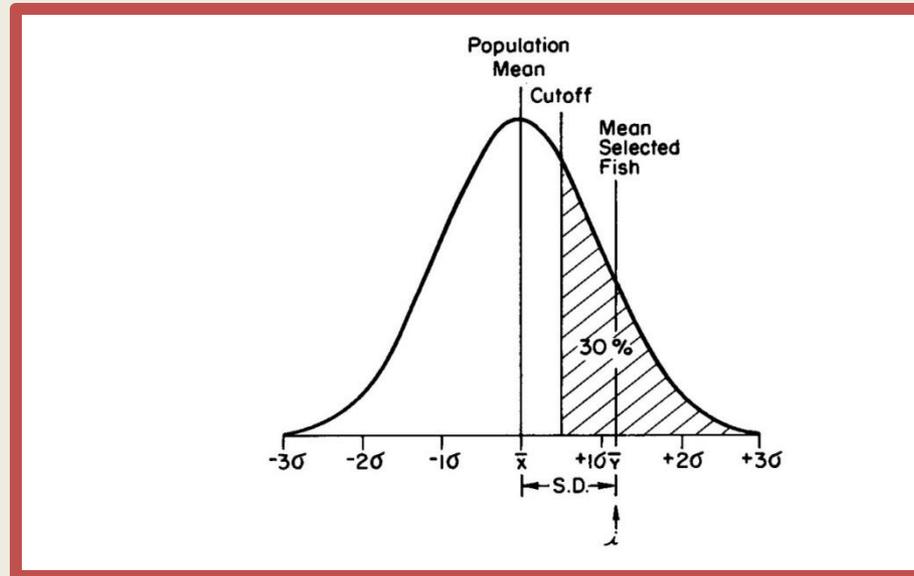
Heritability ( $h^2$ ) is the proportion of variation in a quantitative phenotype trait that is caused by additive genetic variation among individuals

$$h^2 = V_A/V_p$$

The remaining phenotypic variation is usually attributed to environmental factors

Heritability coefficient ( $h^2$ ) ranges from 0 – 1 whereas zero refers to the non-genetic reason behind phenotypic variation while theoretical value “ $h^2=1$ ” means that all of phenotypic variation is attributed to genetics

# “Realized Heritability” and selection

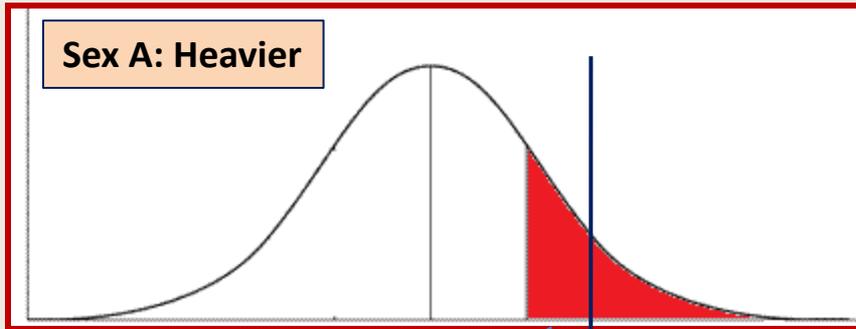


Response to selection  $R = \text{Heritability } h^2 \times \text{Selection Differential } D$

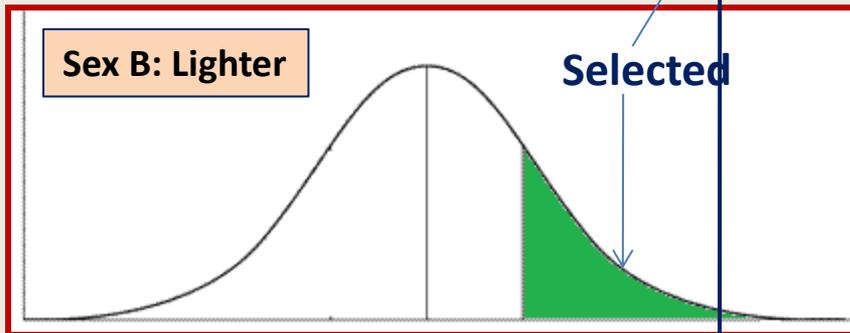
In selection, the response to selection could be adequately estimated

# Sexual dimorphism

Sex A: Heavier



Sex B: Lighter



Selected

**Sexual dimorphism:** phenotypic differences (qualitative or quantitative) for some traits between individuals of different sex in the same species.

In regard to size, females of eels grow to larger size than males of the same age

In contrary, males of Nile tilapia are larger than females of same age

Sexual dimorphism for size should be considered in selection programs otherwise most of selected fish would come from one sex (e.g. the heavier)

# Inbreeding

Inbreeding is the mating of relatives. Related individuals may share alleles (genes) through one or more common ancestors

If the harmful & recessive genes that are hidden in the heterozygous state are expressed through the mating of relatives, they will produce abnormal phenotypes which are known by “inbreeding depression” as expressed in deformity, poor performance, and could lead to mortality

Smaller mating population will result in higher possibility of inbreeding problems

Inbreeding and Effective Breeding Number – **will follow**

# Genetic management of broodstock

## Effective Breeding Number ( $N_e$ )

$N_e$  is the best term describing the population size (from genetics point of view). Since population of fish is finite, it is better to describe it by  $N_e$  rather than absolute number.

Effective breeding number depends on the number of breeding individuals, sex ratio and mating system (random; pedigreed)

$$N_e = \frac{4(\# \text{ females})(\# \text{ males})}{\# \text{ females} + \# \text{ males}}$$

In random mating

# Effective Breeding Number ( $N_e$ )

## Why important?

Tendency to keep less males due to:

Females and not males are the spawners.

Males compete with females for space/feed.

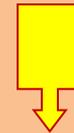
Males can mate with many females. Why keep more?

$$\begin{aligned} \text{Genetic value of } 20 \text{ M} + 80 \text{ F} &= 64 \\ 15 \text{ M} + 85 \text{ F} &= 51 \end{aligned}$$

When value of numbers are not the absolute numbers?

**Genetic value of 100**

Could be obtained from:



$$50 \text{ M} + 50 \text{ F} = 100 \quad \underline{\text{OR}}$$

$$31 \text{ M} + 130 \text{ F} = 161 \quad \underline{\text{OR}}$$

Other M & F combinations

Low  $N_e$  = High inbreeding

# Bottlenecks

Bottlenecks are sudden drastic decreases in population size

The genetic effects of bottlenecks can be devastating/long-term problems

The mean  $N_e$  over a series of generations is the harmonic mean, not the arithmetic mean. Thus, the generation with the smallest  $N_e$  has a disproportionate influence on the average value.

A bottleneck can dramatically lower mean  $N_e$ , and consequently will increase inbreeding and genetic drift ( $N_e$  over five generations)

100	100	40	100	100	arithmetic mean = 88
0.01	0.01	0.025	0.01	0.01	harmonic mean = 76.9
100	100	20	100	100	arithmetic mean = 84
0.01	0.01	0.05	0.01	0.01	harmonic mean = 55.5

A **single bottleneck** can cause **permanent genetic damage** to the population

# Generation

Generation is the average time interval between the birth of parents and the birth of their offspring

Generation interval is species-dependent. For example, it ranges from hours for bacteria, to weeks for many organisms, to about 6 years in dairy cattle

In regard to farmed fish, generation intervals are about 3 years for trout, 4 years for salmon and about 6 months for Nile tilapia

Because fish are cold blooded animals, shorter generation intervals for given species are possible in region with higher temperature

Several biological outcomes are dependent on generation intervals; these include genetic gain and inbreeding levels. The shorter generation interval will be advantageous in selection gain while be disadvantageous in the accumulation of inbreeding

# Enhancing the Effective Breeding Number

## Number of spawners/their sex ratio

This is done through spawning a sufficient number of broodstock that produces the target  $N_e$

This approach might come into conflict with the views of most hatchery managers who tend –for economic reasons- to spawn the fewest number of fish that meets production goals.

This matter is more obvious with highly fecund fish

Bringing the sex ratio closer to equal ratio

If produced eggs/fingerlings are in excess of hatchery needs, an equal random sample from each spawn is kept; extras could be sold or even discarded

## Pedigreed mating

The  $N_e$  of a population can be “artificially” increased by using “pedigreed mating.” whereas each female leaves one daughter and each male leaves one son to be used as brood fish in the following generation



This is an example of a conflict between production efficiency and proper genetic management of fish population

# Genetic consideration in broodstock management

## Wild sources of hatchery broodstock:

- For first time ever

- For stock enhancement programs

- For species which cannot mature in captivity

- Others

## From other hatchery/farm

- Proven efficiency under particular environments (GxE)

- Not passing through genetic bottlenecks (Brazil to USA)

- From maximum number of spawns

# Genetic-environment interaction (GxE)

## Does Exist When:

Various genotypes perform differently in different environments

If compared genotypes maintained their rank in various environments

**No GxE interaction**

**Example:** Common carp strains (Chinese and Polish) in:

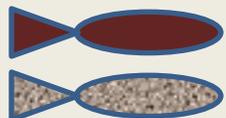
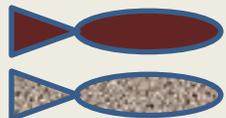
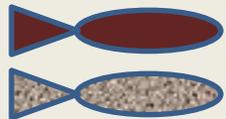
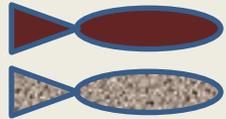
Different stocking densities

Different feeding regimes (fertilization and artificial feed)

# GXE (Example)

	Environment A	Environment B	
Strain A	80	60	No interaction
Strain B	60	40	
Strain A	80	50	Strong interaction
Strain B	60	70	

# Genetic Environment Interaction (GXE) in fish

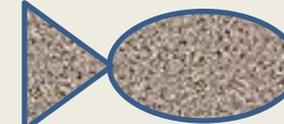
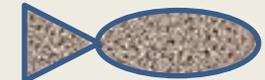
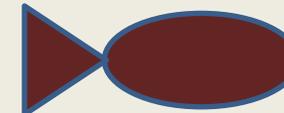
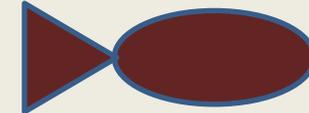
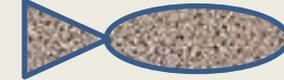
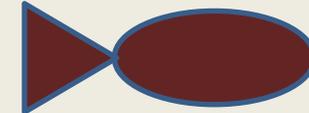


Genetic x environment does exist when evaluated strains perform differently in different farming environments

**Environment A:** earthen ponds whereas the nutrition relies more on organic manure & supplemented by artificial feed

**Environment B:** earthen ponds with aeration and higher stocking density whereas complete artificial feed is the only source of nutrition

The data should be statistically analyzed and result of well-designed experiment starting with fish of the same size/age



NO  
GXE

YES  
GXE

# Application of genetics

# Genetic enhancement approaches

## **Traditional Approaches**

- Selection
- Hybridization

## **Advanced approaches**

- Ploidy induction
- Gynogenesis - Androgenesis
- Genetic engineering

# Selection – Selective breeding

The oldest approach for genetic improvement

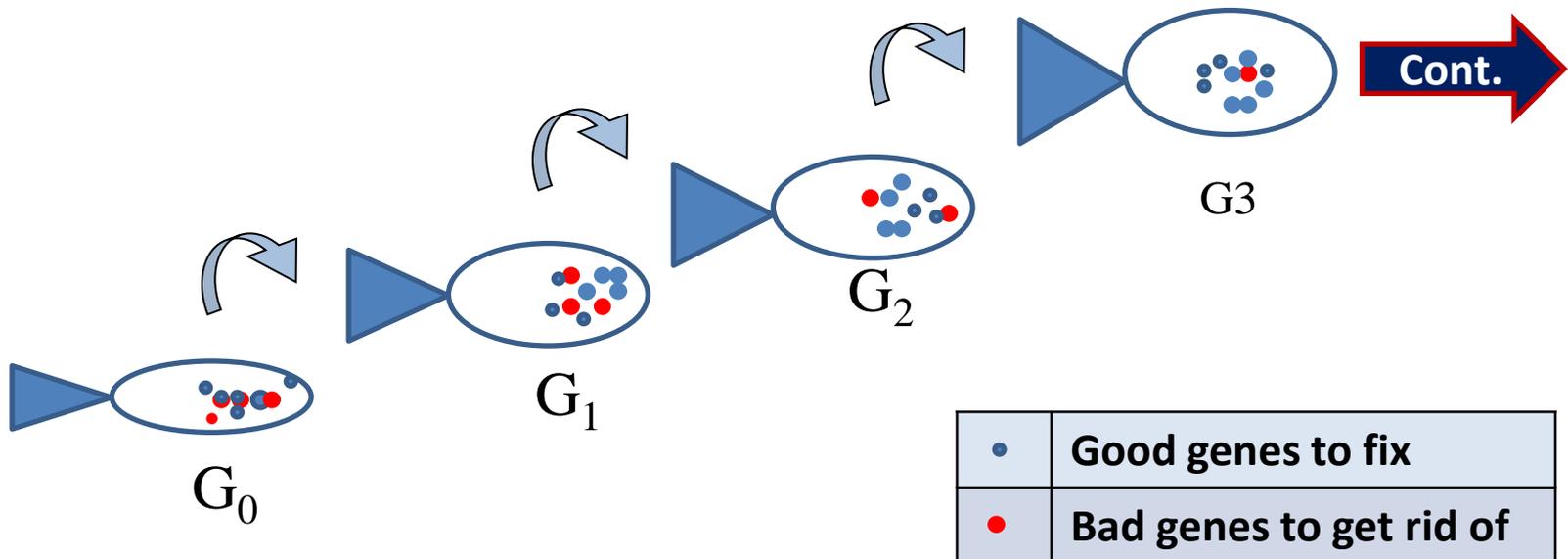
It is simply a choosing the parents of coming generations (positive selection) and through culling (negative selection)

As long as  $V_A$  exists, progress due to selection accumulates over generations = response to selection as long as the raw material is there (variation)

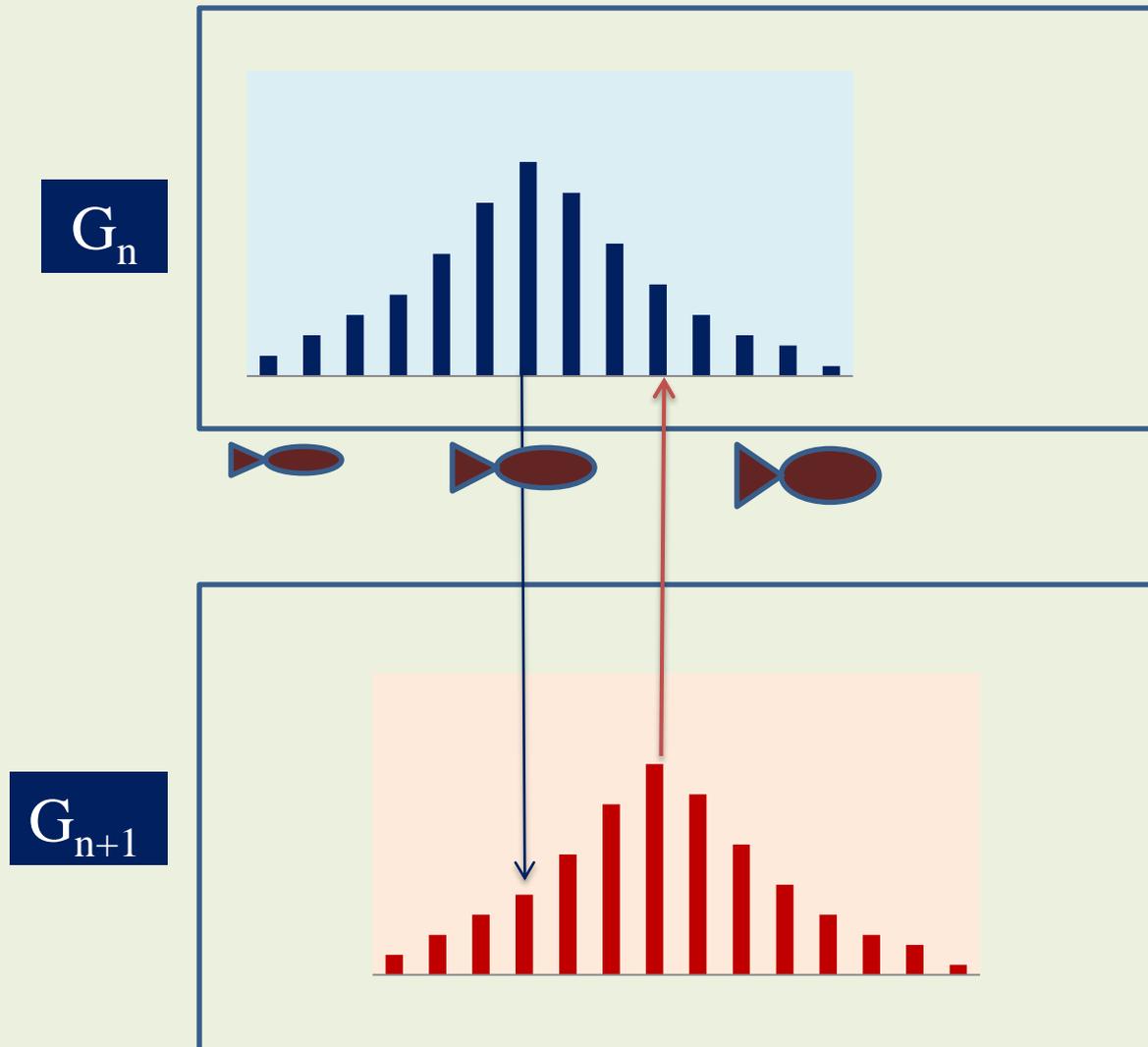
Selection plateau is reached when genetic variation  $V_A$  is consumed – **No more progress**. In such case, an external interventions will be needed to create variations (e.g. mutation)

# Selection (Selective breeding)

**The concept:** Choosing the “best” individuals to be the breeders



# Selection - moving the mean

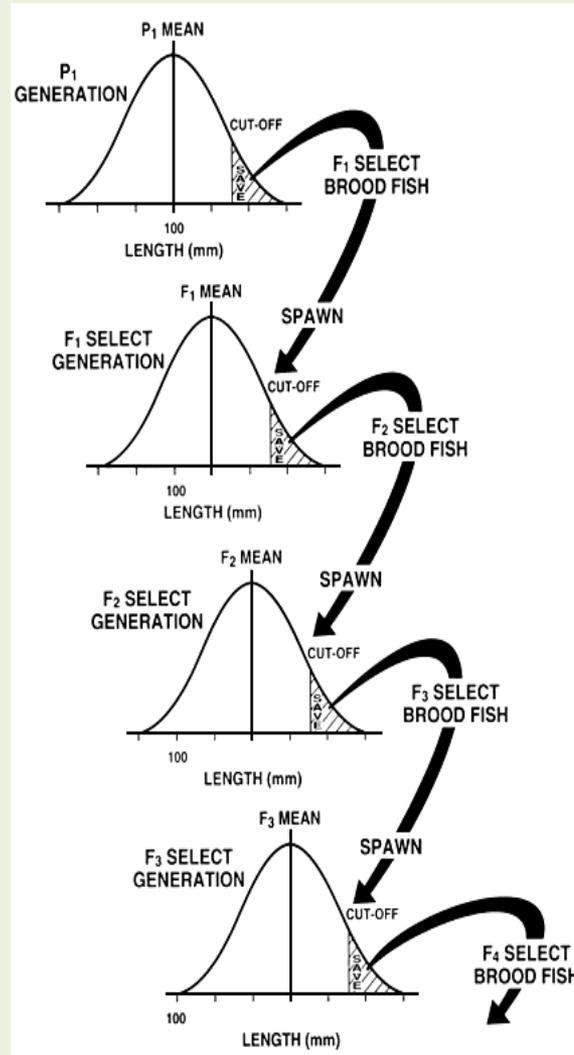


The bell-shape curve remains

**But**  
Population mean moves rightward

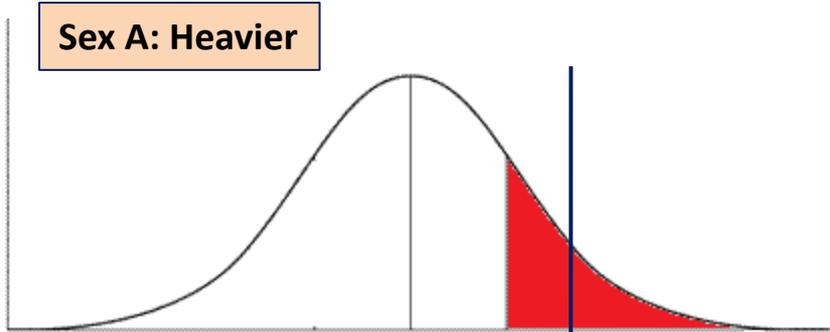
# Accumulated selection gain

The response to selection continues in each generation until the genetic variation is consumed up = selection plateau

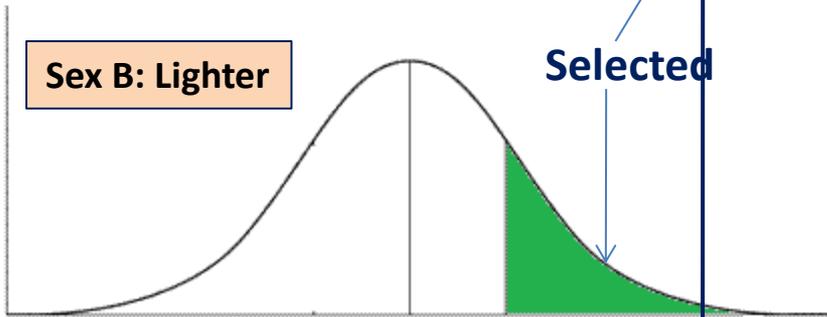


# Selection and sexual dimorphism

Sex A: Heavier



Sex B: Lighter



Selected

If the same cut-off value is used for both sexes in case of dimorphism

**Sexual dimorphism:** phenotypic differences (qualitative or quantitative) for some traits between individuals of different sex in the same species.

In regard to size, females of eels grow to larger size than males of the same age

In contrary, males of Nile tilapia are larger than females of same age

Sexual dimorphism for size should be considered in selection programs otherwise most of selected fish would come from the heavier

How to determine the selection cut-off value for each sex?

# Cut-off values when sexual dimorphism exists

Determining the cut-offs:

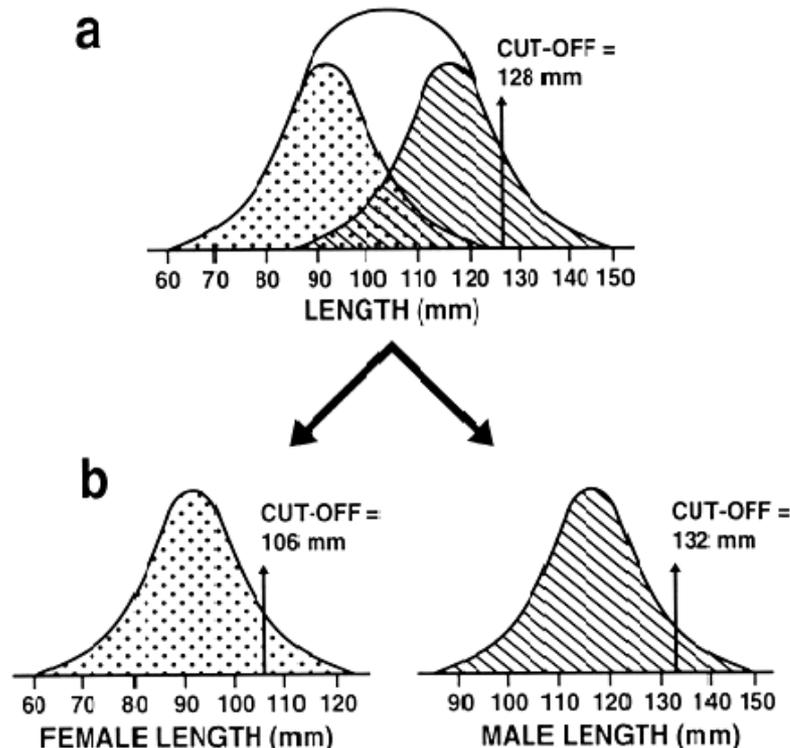
Begin with random sample  
Separate the sexes  
Get individual values for the  
trait

Sort values in descending  
order

Scroll-down till reaching the  
planned number of fish to  
be selected – value against  
it is the cut-off value

In the example, the cut-off  
value is:

132 mm for males  
106 mm for females

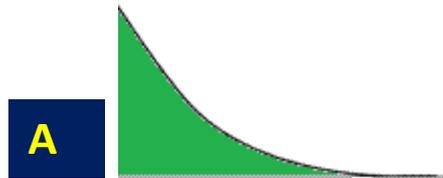
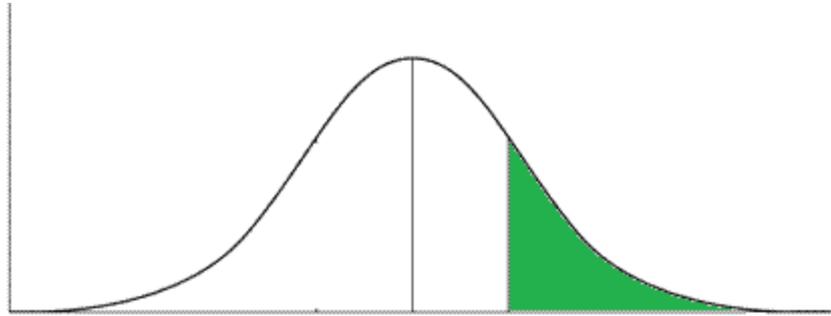


One cut-off  
for both male  
& female

Independent  
cut-off for  
each sex

Diagram source: FAO

# Selection intensity - selection differential & the response to selection



## Theoretically:

The smaller the selected portion, the largest the selection differential (SD) as in B

The largest the selection differential (SD), the highest will be the response to selection

$$R = SD \times h^2$$

(assuming the heritability coefficient  $h^2$  is constant)

The question will remain how small the selected portion that leads to largest selection gain without **inbreeding** problems

# Selection strategies

## **Individual (mass) Selection: Choose the best**

When  $h^2$  for selected traits is high

Easy to conduct (methodology, facilities and recording)

Requires high heritability  $\geq 0.25$

Not favored by many fish breeders

## **Family Selection (select or reject the whole family)**

When  $h^2$  for selected traits is lower

Require more tagging & recording

Is a must for traits such as meat quality & dressing percentage

May lead to the loss of superior individuals in rejected families

## **Within Family selection**

Saves superior individuals through keeping the best of each family regardless the family status

Similar age of evaluated strains is a must

A day difference can result in faulty outcomes

Superior individuals may be discarded because of low family credit

# Multiple-traits selection

## **Tandem selection**

One trait at a time

Correlation between trait is an issue (especially negative)

Requires long time

**The more the traits are, the most difficult will be the program**

## **Independent culling**

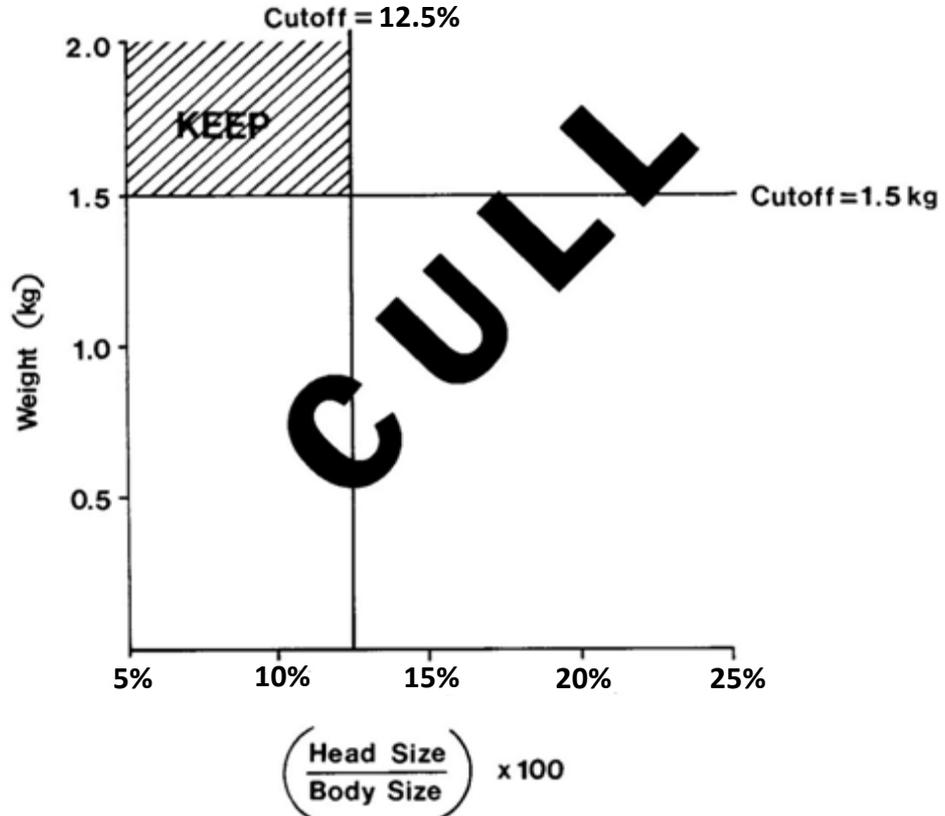
May restrict the size of selected population (depending on the cut-off value)

Possible loss of superior individuals because a shortage in another trait (shown in the graph)

**Some modification was felt needed**

# Multiple Trait Selection Independent Culling

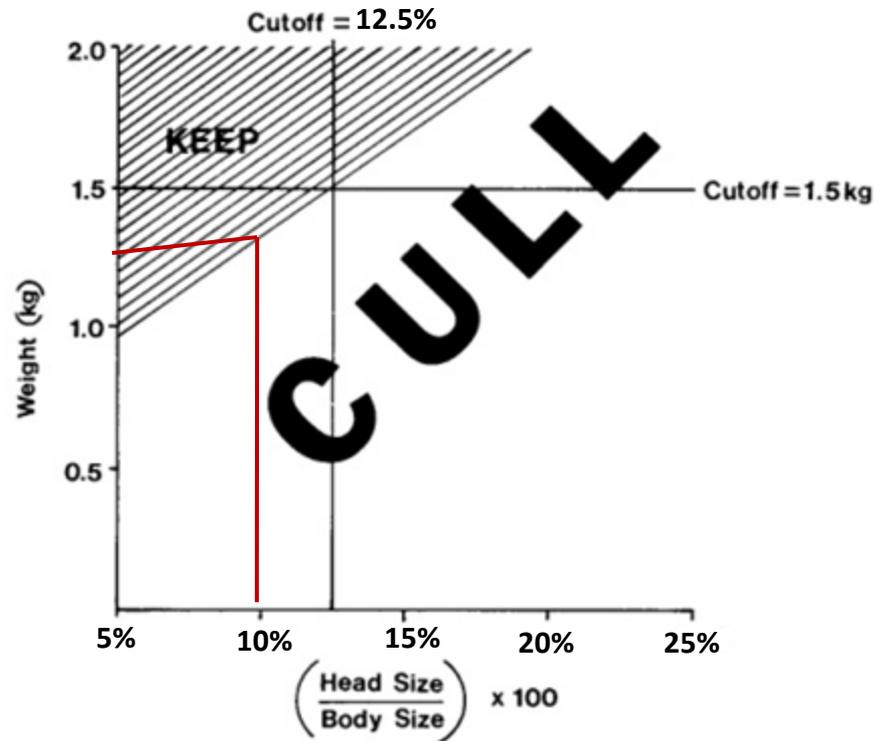
**Only** individuals with 1.5 kg and above and with head : body of 12.5% and less **are kept**



# Multiple Trait Selection Independent Culling (Modified)

Relaxing the cut-off value for a trait has saved superior individuals for the second trait

Example:  
individual of 1.3 kg  
is selected due to  
its better dressing  
percentage (10%)



# Multiple trait selection

## Selection index

Economical in terms of time, money and effort when performing selection on several characters simultaneously

Reflect better the industry views (**tilapia**: growth, cold tolerance/late maturation; **shrimp**: growth, disease resistance)

Has been applied to key finfish (e.g. Atlantic salmon)

Currently applied for Pacific white shrimp, *Litopenaeus vannamei*

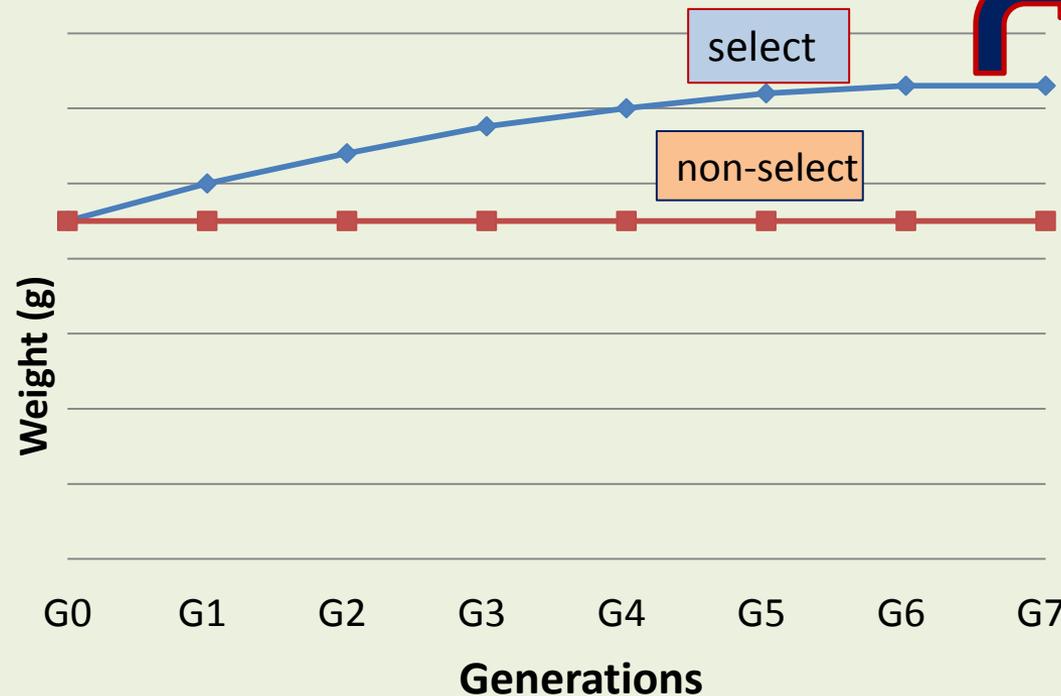
Relative importance of traits is considered in this program

Adding few grams to the weight may be less important than adding 1-2 degree centigrade in the tolerance to cold that means life or death

# Response to selection on growth

species	Gain per generation %	Number of generations	References
Coho	10.1	4	Hershberger <i>et al.</i> , 1990
Rainbow trout	10.0	3	Kincaid <i>et al.</i> , 1977
Rainbow trout	13.0	2	Gjerde, 1986
Atlantic salmon	14.4	1	Gjerde, 1986
Atlantic salmon	12.0	6	Gjerde and Korsvoll, 1999
Atlantic salmon	12.5	1	Flynn <i>et al.</i> , 1999
Channel catfish	12.0-18.0	1	Dunham, 1987
Channel catfish	20.0	1	Bondary, 1983
Nile tilapia	15.0	5	Rye and Eknath, 1999
Rohu carp	17.0	2	Mahapatra <i>et al.</i> , 2000

# Fish selection and selection plateau



Selection plateau

## Assumptions:

Weight of non-select remains constant over the generations

## Observations:

Selected populations continued to enjoy selection responses over generations  
However, the response to selection occurred at a declining rate over generations till the plateau is reached

The response to selection (R) is an accumulated gain every generation

$R = \text{heritability coefficient } (h^2) \times \text{selection differential } (SD)$

Even  $h^2$  is constant, the decrease in R results from the declining of SD – till reaching the plateau

selection plateau = selection variation is consumed

Selection plateau once reached, no gain could be achieved **unless:**

Variance is again created whether naturally or artificially (mutation)

# Traditional approaches

## Hybridization

### **Species purity and hybridization barriers:**

Purity of species in nature is maintained through hybridization barriers:

- Biological: (chromosomal no.)

- Spawning seasons

- Reproduction requirements

In general, hybridization in nature is minimum while in captivity, chances may increase

### **Hybridization could be:**

- Intergeneric (among genera)

- Interspecific (among species)

- Intraspecific (strains within species- cross breeding)

# Traditional approaches

## Hybridization

**Hybridization is carried out for:**

**Hybrid Vigor:** The tendency of hybrids to grow faster, get larger, tolerance more to specific conditions, or better dressing than their parents. Also called heterosis.

**Sterility**

**Production of uniform progeny**

# Traditional approaches

## Hybridization

**All-male production – all-female production:** Sexual maturation causes aggressiveness and reduce growth. This may favor one sex over other. In rainbow trout, all-female production is almost universally used in Europe as females are still immature at harvest. **In tilapia**, all-male production is preferred because of higher growth rate and to avoid unwanted reproduction

### **Sterility: Examples:**

grass carp x bighead carp

silver carp x common carp

**Note:** some hybrids are fertile; e.g. tilapia – Indian carps

# Interspecific hybridization (e.g. tilapia)

Two species of tilapia can be crossed to yield all-male offspring

Male Hornorum or aureus tilapia can be hybridized with the female of Nile tilapia to produce all-male offspring (**theoretically**)

Tilapia hybrid is **fertile** and can backcross with parent species which could **upset** the purity of parent species (Nile tilapia in Lake Victoria)

It is not recommended to carry out tilapia hybridization in Africa (the home of tilapia)

# Interspecific Hybridization



**Male Hornorun/aureus**

**ZZ**



**XZ**

**XX**



**Nile tilapia female**



**All-male hybrid tilapia**

**Why not 100% males?**

# Catfish

## Interspecific Hybridization

Asian catfish



♀

African catfish



♂



The hybridization between Asian catfish (*Clarias macrocephalus* – female) X African catfish (*Clarias gariepinus* - male) produced a hybrid that is superior to both parents in regard to growth rate).

The hybrid is favored for Thai aquaculture

While Asian catfish is native to Southeast Asia, African catfish was introduced into Thailand a long time ago.

# Indian major carps

## Intergeneric Hybridization

♀	♂	Hybrid
<u>Labeo rohita</u>	<u>Catla catla</u>	~ 60% hatchability – high mortality of hatchlings – fry growth was higher than rohu .....
<u>Cirrhina mrigala</u>	<u>Labeo rohita</u>	> 90% of eggs were fertilized. Most of the body characteristics were intermediate to those of the parents. Both the hybrids matured fully in two years
<u>Labeo rohita</u>	<u>Cirrhina mrigala</u>	
<u>Labeo rohita</u>	<u>Cirrhina reba</u>	Twenty percent of the fertilized eggs hatched out but all of them died on the third day

Source: H. Chaudhuri, Fish hybridization in Asia  
with special reference to India - FAO

# Hatchery Broodstock

Hybrids which could be excellent for grow-out **cannot be broodstock**

For species purity, if hybridization is carried out in a hatchery, hybrids should be kept in isolate



**Case: Red  
tilapia**



# Ploidy induction in fish

## Why?

**Sterility:** (for environmental reasons): triploid (3n) fish are sterile (e.g. grass carp)

**Higher growth rate:** through saving the energy which could be spent in gonad development and spawning (triploidy)

**Indirect means** to produce triploidy (when tetraploidy (4n) mates with diploidy)

## How?

**Shock application**

**Heat shock:** water bath

**Cold shock:** chiller, refrigerator

**Pressure:** pressure chamber

**Chemicals:** (e.g. cytochalasin B)

### Marion lab hosts top egyptian scientist to conduct research on fish genetics

#### From staff reports

The Calaha River is not the Nile, but Marion will be home to Egyptian scientist Dr. Abdel-Rahman El-Gamal for the next six months. With funding from the Egyptian National Agricultural Research Project (NARP), Dr. El-Gamal will be conducting research on fish genetics at the U. S. Fish and Wildlife Service Southeastern Fish Cultural Laboratory in Marion.

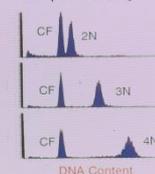
This joint research project got its start a year ago when Dr. Les Terras, Director of the Southeastern Fish Cultural Lab, was reviewing aquaculture projects in Egypt at the request of the NARP. Dr. Terras and El-Gamal met at the National Aquaculture Center, which Dr. El-Gamal directs. They spent several days visiting aquaculture operations around the Nile delta, and soon became good friends. Upon leaving Egypt, Terras invited El-Gamal to carry out a research project in Marion as a visiting scientist. The project proposal was approved by NARP, and after a short delay for the summer of his oldest daughter, Dr. El-Gamal left his home in Cairo and was on his way.

While in Marion, Dr. El-Gamal will be conducting experiments on the genetics of tilapia, a fish native to Egypt that many experts feel has



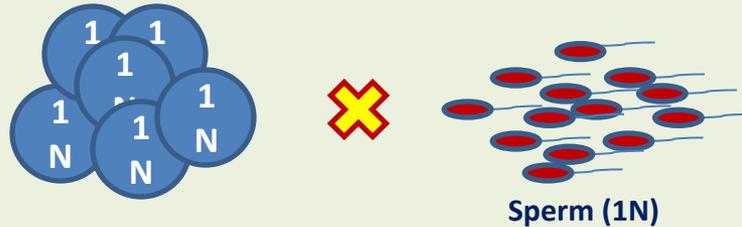
Dr. El-Gamal prepares pressure chamber used to treat eggs of tilapia.

### Tilapia Ploidy



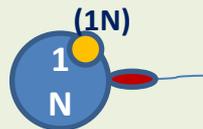
# Triploidy induction in fish

Preparing for fertilization between haploid gametes (1N) each



Fertilization

Second polar body (1N)



Apply the shock soon after fertilization

Resulted cell has 3 chromosomes from: ova, 2<sup>nd</sup> polar body (**retained**) and sperm



3-N fish



Without shock, second polar body is extruded and fallen and embryos with 2 chromosomes result

How soon the time of shocking depends on species and water temperature

Types, levels and durations of shock vary

# Triploidy (concerns and inspection protocol)

## Issues of concern

Environmental concerns call for the use of triploidy fish if needed based on their sterility

It is assumed that sterile fish (triploids) will not cause environmental damages compared to diploid fish

However, triploidy fish might out-compete their diploid counterparts in regard to food or the spawning grounds



## Inspection (example of triploid grass carp) – No chance for any mistake

Before grass triploid is licensed to leave the production facility, producers test their fish according to the protocol that has been set by USFWS :

Each fish must be individually blood tested by the producer using coulter counter to ensure it is triploid.

Afterward, a USFWS inspector visits the farm and randomly retests 120 fish from each prospective shipment.

If the 120 fish are triploid, a certificate is issued verifying that every fish in the prospective shipment is triploid.

If even one diploid is found during the inspection, no certificate is issued and every fish in the shipment must be individually retested by the producer.

Another 120 randomly selected fish must pass another USFWS inspection. If the inspection passes, and a certificate is issued, triploid grass carp may be shipped from the facility

# Tetraploidy induction in fish

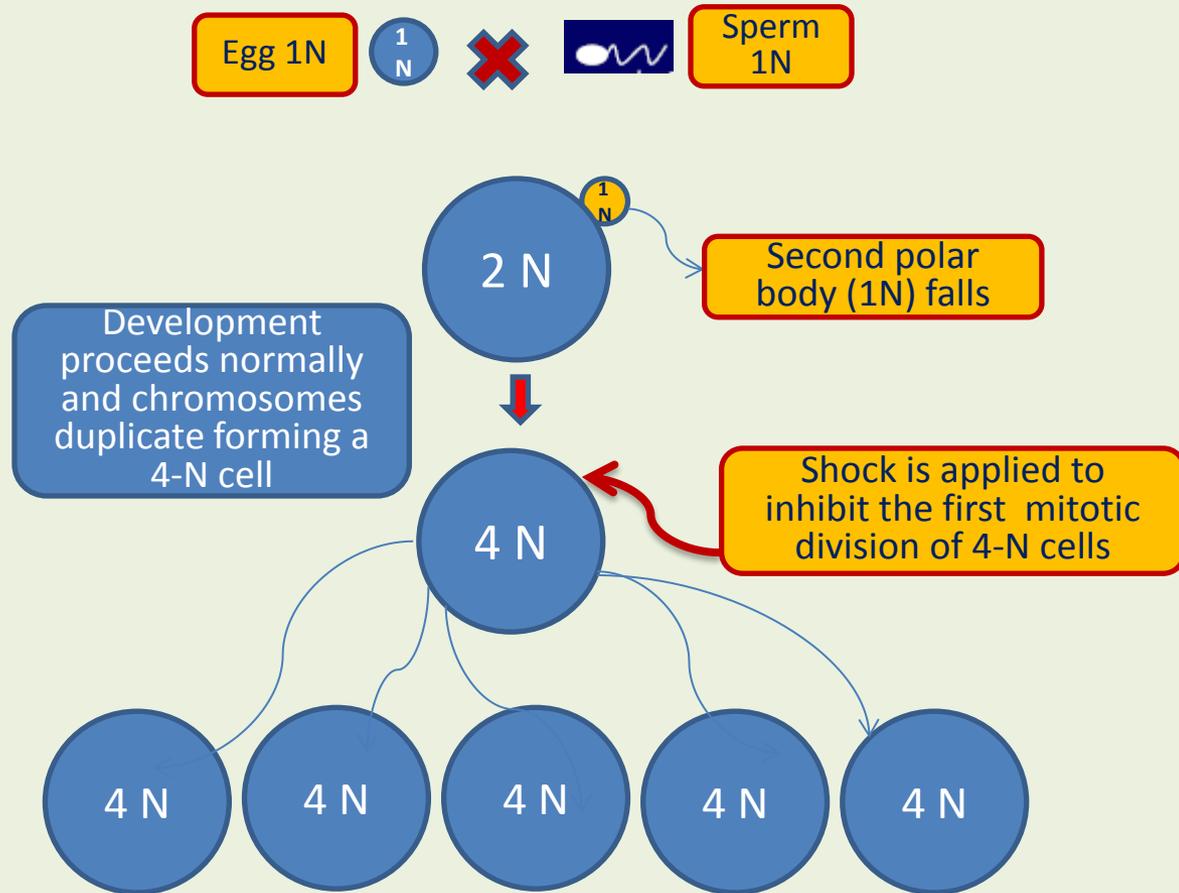
## Summary of the process:

No shock is applied after fertilization and so 2<sup>nd</sup> polar body is extruded and fallen (as normal) - embryos with 2 chromosomes result

Enough time should be allowed till cell chromosomes duplicate forming 4N

Shock is applied to inhibit the first mitotic division resulting in a 4N cells that divides normally afterwards producing tetraploid fish

Shock could be heat shock, cold shock, pressure or use of specific chemicals; timings, levels and durations of treatments vary



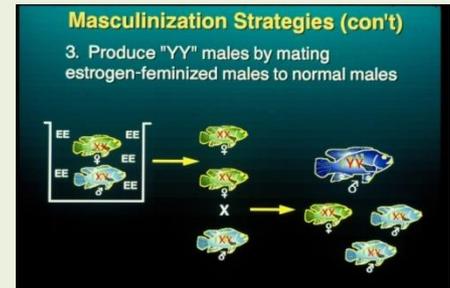
# More chromosomal manipulation

## YY tilapia super male

- Sex chromosome of Nile tilapia is (XX) for female and (XY) for male
- Normal mating produces 50% of each sex
- Using estrogen for 28 days during the larval phase, will end by phenotypic **all-female** fry
- 50% of these “feminized fry” are genetic females (XX) and 50% are genetic males (XY)

### XX females are **identified** and discarded

- Reversed females (XY) when individually paired with normal males (XY), 25% of offspring will be super male (YY)
- Super males are marked and kept. When YY super males mate with normal female XX, the result is XY males



Progeny testing  
is required  
(**squash  
technique**) to  
identify genetic  
make-ups of  
females

# Advanced genetic technologies

## **Gynogenesis:**

Used for the production of off-springs having its genetic make-up only from mother. This is achieved through the use of irradiated sperm using UV which destroys its DNA but still activates the ova development.

## **Androgenesis:**

Used for the production of off-springs having its genetic make-up only from father upon the fertilization of irradiated ova using UV which destroys its DNA by normal sperm.

Both approaches are used to produce highly inbred lines as required by some breeding programs

# Genetics in movies and imaginations

## Androgensis



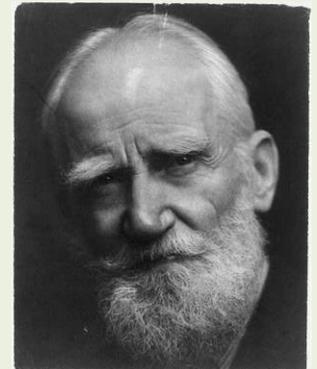
***The Boys from Brazil (1978)***

## Hybridization



**Sara Bernhardt:  
Imagine we had a  
child, and it had my  
looks and your  
brain**

**George Bernard  
Shaw:  
Yes, but imagine if  
it had your brain  
and my looks**



# Advanced genetic technologies

## Genetic engineering (gene transfer)

Fish are ideal organisms for genetic engineering programs because of:

- High fecundity
- Short generation (utilized for other purposes)
- External fertilization
- Large size ova

# Genetic Engineering

## Gene transfer

### Phases of application

Successful insertion of the gene

Expressing the transferred gene

Heritability of traits related to transferred genes

### Concerns:

Will remain at experimental stage for some time

Significant opposition

Biosafety is a must during all phases of the experimentation

# Genetically modified organism (s) (GMOs) – Genetic engineering organism

A living organism that inherited traits from another organism through the insertion of a gene from another organism using genetic engineering techniques.

Resulting organisms are always declared as GMOs according to biosafety regulations.

This technology has been used in several areas including plants, vaccines, foods, and medicine.

In relation to fish, genetic engineering research has commenced in several research institutes.

Fish with short generations could serve as an experimental animal whereas the outcomes may explain a phenomenon or could be applied to the target organisms with longer generations or could be extended to human (zebrafish and human muscular dystrophy).

# Fishery practices & genetics

Fishing practices especially over-fishing act as a selective agent and can favor some genotypes over others affecting the genetic structure of natural populations

Fish introductions in stock enhancement programs may contribute to changes in the genetic make-up of wild populations

**Examples**

# Fishery Practices & Genetics

## Examples (Atlantic cod, *Gadus morhua*)

### Atlantic cod (*Gadus morhua*)

On the Scotian shelf in the Northwest Atlantic, the sexual maturity of Atlantic cod declined from >5 years in the 1960s to <3 years in 1978 for both males and females.

Cod that matured at smaller size or younger age would have a selective advantage under heavy fishing pressure as the larger and older maturing cod would be captured before the onset of sexual maturity

### Using gillnets & whitefish

In heavily exploited populations of whitefish, *Coregonus clupeaformis* in Canadian lakes, fish matured at younger age and smaller size than fish from unexploited populations

Fishing practices in Lake George, Uganda are claimed to reduce the mean size of Nile tilapia (*Oreochromis niloticus*) from 900 g in 1950 to 400 g in 1970.

In the Arcto-Norwegian stocks, the majority of Atlantic cod, *Gadus morhua* fish matured at 8-10 years in the 1930s while matured at 6 years in the present. This decline has been attributed to a selective removal of late maturing cod from the population.

# Genetics in: Stock Enhancement Programs

There are genetic differences between hatchery produced stock and the wild population of the same species

Predator avoidance, fecundity, aggressiveness and homing are traits of importance to wild stocks while not that important to aquaculture

Noticeable problems may result from the mating of hatchery produced stocks with their wild counterparts

# Stock enhancement

## Mitigation of possible risks

For a species with a long spawning seasons, it is advised to use multiple spawnings to avoid selecting for particular period spawners

In order to reduce the possibility of domestication, seed produced in hatcheries should not be grown for the use as broodstock in stock enhancement programs. Instead, broodstock should be taken from wild –whenever possible- to maintain genetic diversity

Ideal enhancement programs are the ones that include breeding with no genetic changes; in other words preserving the inherent, undomesticated genotypes

Some international stock enhancement programs designate special hatcheries for stock enhancement (managed differently)

# Conclusion

The possibility of enhancing fish production through management has delayed the utilization of genetics due to cost and time required & **difficulty impression**

As aquaculture develops and challenges continue, it became obvious that husbandry practices **have limits** especially with issues of genetic nature (e.g. cold tolerance)

Artificial propagation in hatcheries represents a main step towards the application of genetics in aquaculture

Fish genetics programs are the responsibility of research institutes, while mass production takes place in hatcheries

The application of genetics that has been seen fancy in the past or in the present would be in application in the near future