Food and Agriculture Organization of the United Nations

FAO/China Intensive Training Course on Tilapia Lake Virus (TiLV)

Sun Yat Sen University, Guangzhou, China

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Session 1

Junhong XIA

The biology and culture status worldwide of tilapia

Email: xiajunh3@mail.sysu.edu.cn; HP:13711013684

Outline

1. Biology of tilapia
2. Overview of commercial species and lines
3. Challenges facing in tilapia culture
4. Exercise on hand sexing of tilapia

PART 1

- Biology of tilapia

Common and scientific names

Tilapia is the common name for cichlids

Three Genera: more than 70 species identified

Oreochromis: maternal mouthbrooders

Sarotherodon: paternal and biparental mouthbrooders

Tilapia: substrate incubators

Commercial species:

Nile tilapia *Oreochromis niloticus*

Blue tilapia: *Oreochromis aureus*

Mozambique tilapia *Oreochromis mossambicus*

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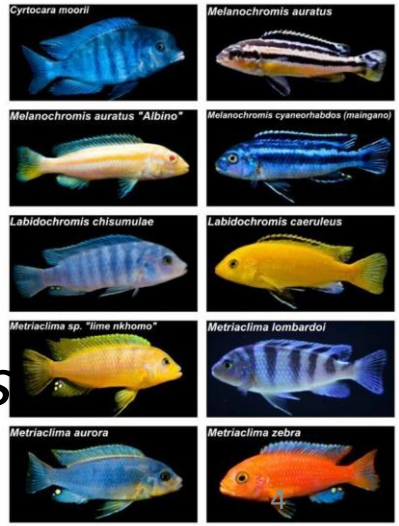


Mouth breeding species

- Parents carry the fertilized eggs and young fish in their mouths for several days after the yolk sac is absorbed

Geographic distribution and habitats

- endemic to Africa, Jordan, and Israel
- mainly freshwater fish and less commonly found living in brackish water
- inhabiting shallow streams, ponds, rivers and lakes



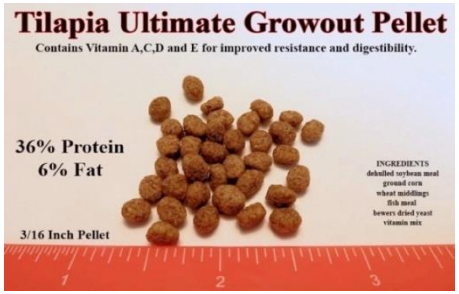

Feeds

- **Omnivorous**

Phytoplankton

Benthic algae

Insect larvae



Artificial feed

Tolerance to key water quality parameters

Salinity tolerance

Fish	Salinity Tolerance for Growth	Salinity Tolerance for Reproduction
Nile Tilapia	Grows well at salinities up to 15 ppt	Reproduce well at salinities up to 5-10 ppt
Blue Tilapia	Grows well at salinities up to 20 ppt	Reproduce well at salinities up to 5-10 ppt
Mozambique Tilapia	Grows well at salinities approaching seawater	Reproduce well at salinities up to 10-15 ppt

Tilapia spawning is best in lower salinities. The fry perform better at salinities less than 5 ppt.

Temperature tolerance

Tilapia Activity	Temperature Range
Feeding	Stops below 17° C
Harvesting	Stress and mortality from handling increases below 18° C
Reproduction	Best above 27° C, no reproduction below 20° C
Growth	Optimal from 28-29° C

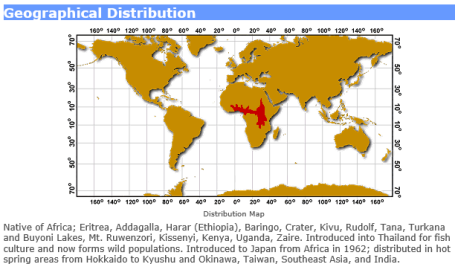
Temperature sensitivity

The blue tilapia has the greatest cold tolerance and dies 7 ° C

All other species of tilapia will die at a range 11 to 17 ° C

- Generally not in temperate climates due to their inability to survive in cold water

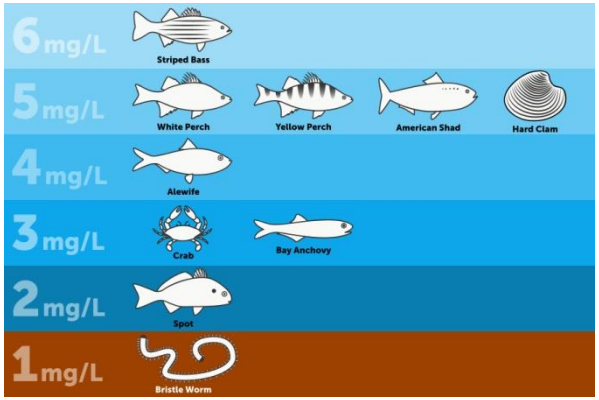
Native Range: Tropical and subtropical Africa, and Middle East.



Nile tilapia

Dissolved Oxygen

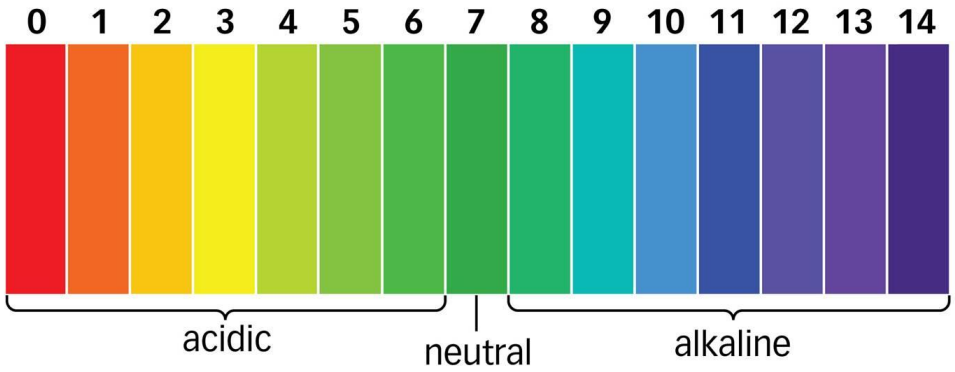
Tilapia are able to tolerate dissolved oxygen levels less than 0.3 mg/L, a level that would prove fatal to most other farmed fish.



how much oxygen the Bay's living creatures need to survive?

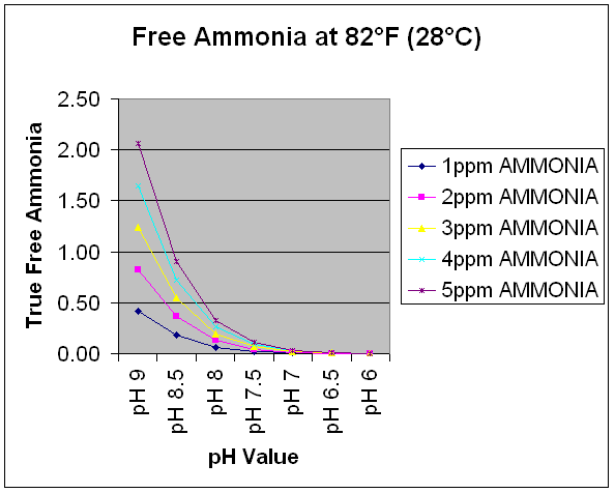
pH

Tilapia can survive in pH ranging from 5 to 10, but optimal pH is between 6 to 9.



Ammonia

Ammonia Level	Effect on Tilapia
0.08 mg/L or above	Depressed feeding
0.2 mg/L or above	Some mortality occurs
1 mg/L or above	Mortalities, particularly among fry and juveniles
2 mg/L or above	Massive mortality

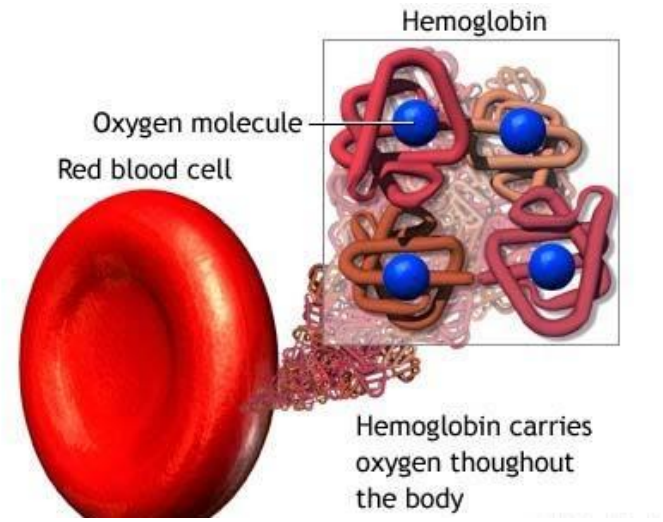


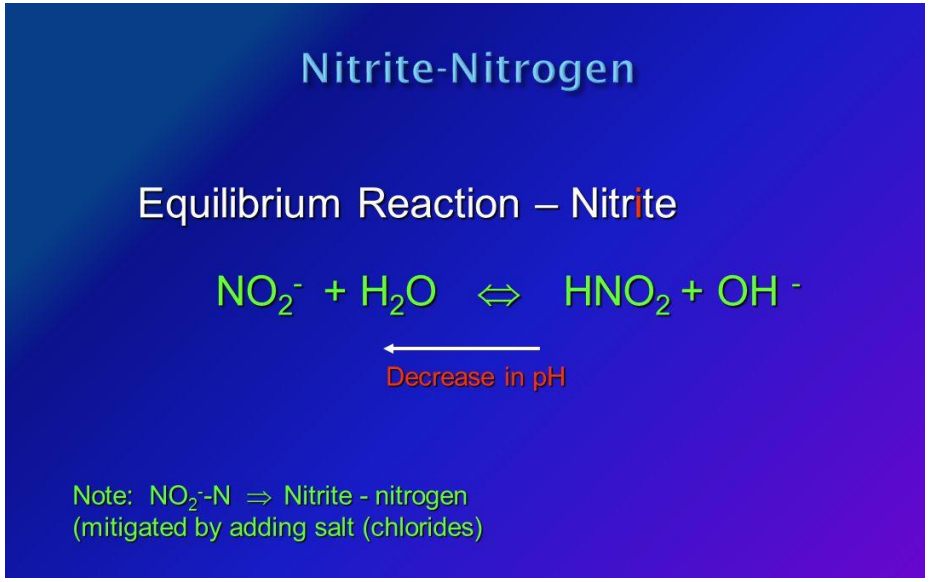
Low pH increases ammonium (NH4), while high pH would increases ammonia (NH3).

http://www.aquaworldaquarium.com/Articles/TonyGriffitts/Ammonia.htm

Nitrate

- For optimal cultivation, nitrate concentrations should be kept below 27 mg/L. To prevent nitrate problems in recirculating systems, chloride concentrations are often maintained at 100 to 150 mg/L chloride.





- **Adaptation to a very wide range of conditions**

  high salinities, high temperatures, high ammonia concentrations, and low oxygen levels

Tolerant of high stocking density

Exotic and invasive species

100 OF THE WORLD'S WORST INVASIVE ALIEN SPECIES

MICRO-ORGANISM

avian malaria	*(Plasmodium relictum)*
banana bunchy top virus	*(Banana bunchy top virus)*
rinderpest virus	*(Rinderpest virus)*

MACRO-FUNGI

chestnut blight	*(Cryphonectria parasitica)*
crayfish plague	*(Aphanomyces astaci)*
Dutch elm disease	*(Ophiostoma ulmi)*
frog chytrid fungus	*(Batrachochytrium dendrobatidis)*
phytophthora root rot	*(Phytophthora cinnamomi)*

AQUATIC PLANT

caulerpa seaweed	*(Caulerpa taxifolia)*
common cord-grass	*(Spartina anglica)*
wakame seaweed	*(Undaria pinnatifida)*
water hyacinth	*(Eichhornia crassipes)*

LAND PLANT

African tulip tree	*(Spathodea campanulata)*
black wattle	*(Acacia mearnsii)*
Brazilian pepper tree	*(Schinus terebinthifolius)*
cogon grass	*(Imperata cylindrica)*
cluster pine	*(Pinus pinaster)*
erect pricklypear	*(Opuntia stricta)*
fire tree	*(Myrica faya)*
giant reed	*(Arundo donax)*
gorse	*(Ulex europaeus)*
hiptage	*(Hiptage benghalensis)*
Japanese knotweed	*(Fallopia japonica)*
Kahili ginger	*(Hedychium gardnerianum)*
Koster's curse	*(Clidemia hirta)*
kudzu	*(Pueraria montana var. lobata)*
lantana	*(Lantana camara)*
leafy spurge	*(Euphorbia esula)*
leucaena	*(Leucaena leucocephala)*
melaleuca	*(Melaleuca quinquenervia)*
mesquite	*(Prosopis glandulosa)*
miconia	*(Miconia calvescens)*
mile-a-minute weed	*(Mikania micrantha)*
mimosa	*(Mimosa pigra)*
privet	*(Ligustrum robustum)*
pumpwood	*(Cecropia peltata)*
purple loosestrife	*(Lythrum salicaria)*
quinine tree	*(Cinchona pubescens)*
shoebutton ardisia	*(Ardisia elliptica)*

LAND PLANT (CONTINUED)

Siam weed	*(Chromolaena odorata)*
strawberry guava	*(Psidium cattleianum)*
tamarisk	*(Tamarix ramosissima)*
wedelia	*(Sphagneticola trilobata)*
yellow Himalayan raspberry	*(Rubus ellipticus)*

AQUATIC INVERTEBRATE

Chinese mitten crab	*(Eriocheir sinensis)*
comb jelly	*(Mnemiopsis leidyi)*
fish hook flea	*(Cercopagis pengoi)*
golden apple snail	*(Pomacea canaliculata)*
green crab	*(Carcinus maenas)*
marine clam	*(Potamocorbula amurensis)*
Mediterranean mussel	*(Mytilus galloprovincialis)*
Northern Pacific seastar	*(Asterias amurensis)*
zebra mussel	*(Dreissena polymorpha)*

LAND INVERTEBRATE

Argentine ant	*(Linepithema humile)*
Asian longhorned beetle	*(Anoplophora glabripennis)*
Asian tiger mosquito	*(Aedes albopictus)*
big-headed ant	*(Pheidole megacephala)*
common malaria mosquito	*(Anopheles quadrimaculatus)*
common wasp	*(Vespula vulgaris)*
crazy ant	*(Anoplolepis gracilipes)*
cypress aphid	*(Cinara cupressi)*
flatworm	*(Platydemus manokwari)*
Formosan subterranean termite	*(Coptotermes formosanus shiraki)*
giant African snail	*(Achatina fulica)*
gypsy moth	*(Lymantria dispar)*
khapra beetle	*(Trogoderma granarium)*
little fire ant	*(Wasmannia auropunctata)*
red imported fire ant	*(Solenopsis invicta)*
rosy wolf snail	*(Euglandina rosea)*
sweet potato whitefly	*(Bemisia tabaci)*

AMPHIBIAN

bullfrog	*(Rana catesbeiana)*
cane toad	*(Bufo marinus)*
Caribbean tree frog	*(Eleutherodactylus coqui)*

FISH

brown trout	*(Salmo trutta)*
carp	*(Cyprinus carpio)*
large-mouth bass	*(Micropterus salmoides)*

FISH (CONTINUED)

Mozambique tilapia	*(Oreochromis mossambicus)*
Nile perch	*(Lates niloticus)*
rainbow trout	*(Oncorhynchus mykiss)*
walking catfish	*(Clarias batrachus)*
Western mosquito fish	*(Gambusia affinis)*

BIRD

Indian myna bird	*(Acridotheres tristis)*
red-vented bulbul	*(Pycnonotus cafer)*
starling	*(Sturnus vulgaris)*

REPTILE

brown tree snake	*(Boiga irregularis)*
red-eared slider	*(Trachemys scripta)*

MAMMAL

brushtail possum	*(Trichosurus vulpecula)*
domestic cat	*(Felis catus)*
goat	*(Capra hircus)*
grey squirrel	*(Sciurus carolinensis)*
macaque monkey	*(Macaca fascicularis)*
mouse	*(Mus musculus)*
nutria	*(Myocastor coypus)*
pig	*(Sus scrofa)*
rabbit	*(Oryctolagus cuniculus)*
red deer	*(Cervus elaphus)*
red fox	*(Vulpes vulpes)*
ship rat	*(Rattus rattus)*
small Indian mongoose	*(Herpestes javanicus)*
stoat	*(Mustela erminea)*

Species were selected for the list using two criteria: their serious impact on biological diversity and/or human activities, and their illustration of important issues of biological invasion. To ensure a wide variety of examples, only one species from each genus was selected. **Absence from the list does not imply that a species poses a lesser threat.**

Development of the *100 of the World's Worst Invasive Alien Species* list has been made possible by the support of the Fondation d'Entreprise TOTAL (1998 - 2000).

For further information on these and other invasive alien species consult The *Global Invasive Species Database*:

www.issg.org/database

- **Tilapia are on the IUCN's 100 of the World's Worst Alien Invasive Species list**

Fish species in the IUCN list

FISH	
brown trout	*(Salmo trutta)*
carp	*(Cyprinus carpio)*
large-mouth bass	*(Micropterus salmoides)*
Mozambique tilapia	*(Oreochromis mossambicus)*
Nile perch	*(Lates niloticus)*
rainbow trout	*(Oncorhynchus mykiss)*
walking catfish	*(Clarias batrachus)*
Western mosquito fish	*(Gambusia affinis)*

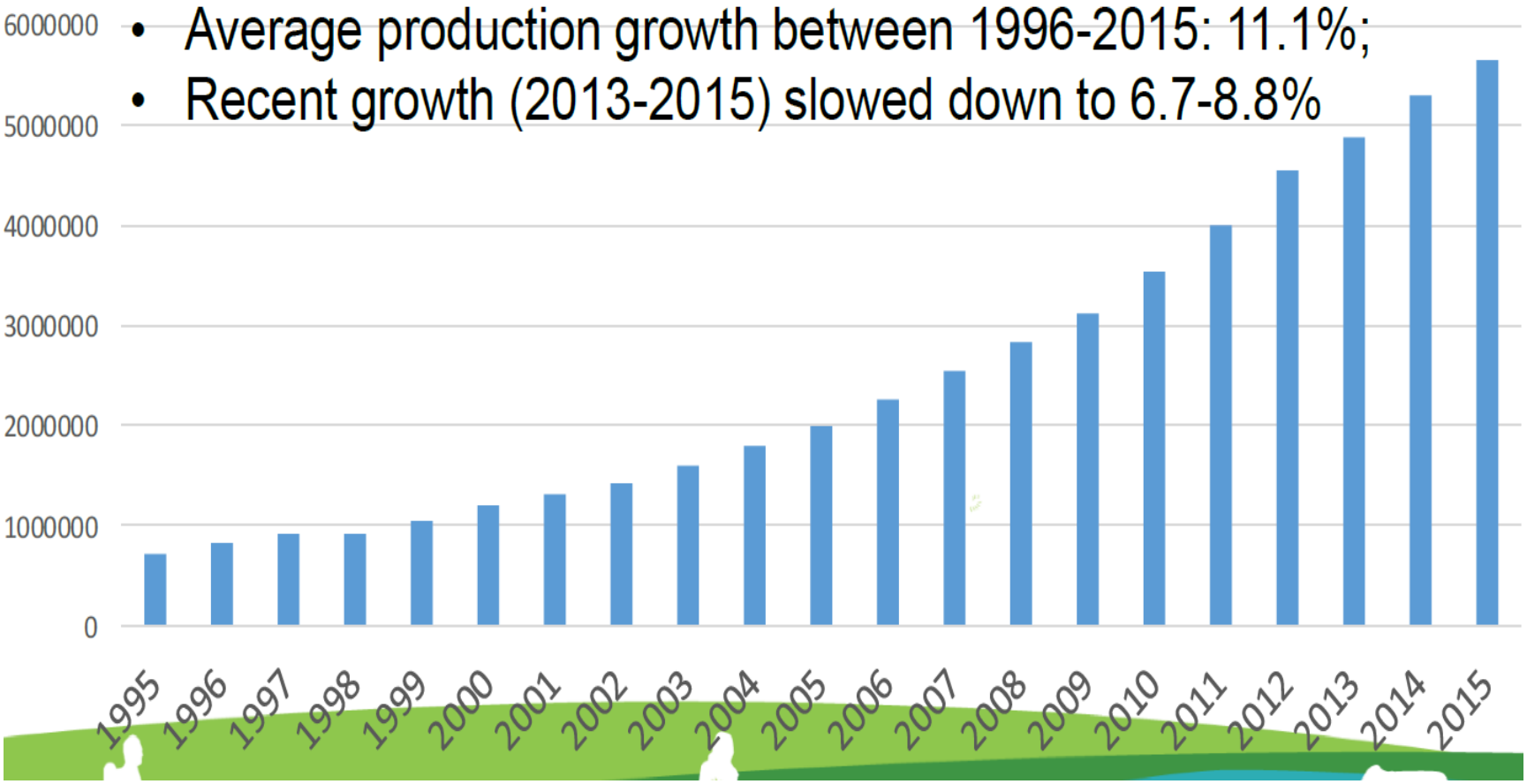
Fast-growing

Tilapia Growth and Feeding Rates

Month	Start Weight (g)	End Weight (g)	Growth Rate g/day	Feeding Rate (% weight)
1	1	5	0.2	15 - 10
2	5	20	0.5	10 - 7
3	20	50	1.0	7 - 4
4	50	100	1.5	4 - 3.5
5	100	165	2.0	3.5 - 2.5
6	165	250	2.5	2.5 - 1.5
7	250	350	3.0	1.5 - 1.25
8	350	475	4.0	1.25 - 1.0
9	475	625	5.0	1.0

Starting with one gram fry at month one, fingerlings would be starting at month two or three.
Growth is approximate and is based on 84°F water temperature.

Trend of cultured tilapia production



Aquaculture production and trade trends: carp, tilapia and shrimps. Weimin Miao, FAO RAP

Top 10 tilapia producers in 2015

Country/region		Production (1000 tonnes)
China	31%	1,779.5
Indonesia	20%	1,120.4
Egypt	15%	875.5
Bangladesh		324.3
Viet Nam		283.0
Philippines		261.2
Brazil		219.4
Thailand		177.6
Taiwan PoC		70.5
Colombia		61.1

Aquaculture production and trade trends: carp, tilapia and shrimps. Weimin Miao, FAO RAP

World fishery production

II World fishery production
Production halieutique mondiale
Producción pesquera mundial

Estimated value by groups of species
Estimation de la valeur par groupes d'espèces
Estimación del valor por grupos de especies

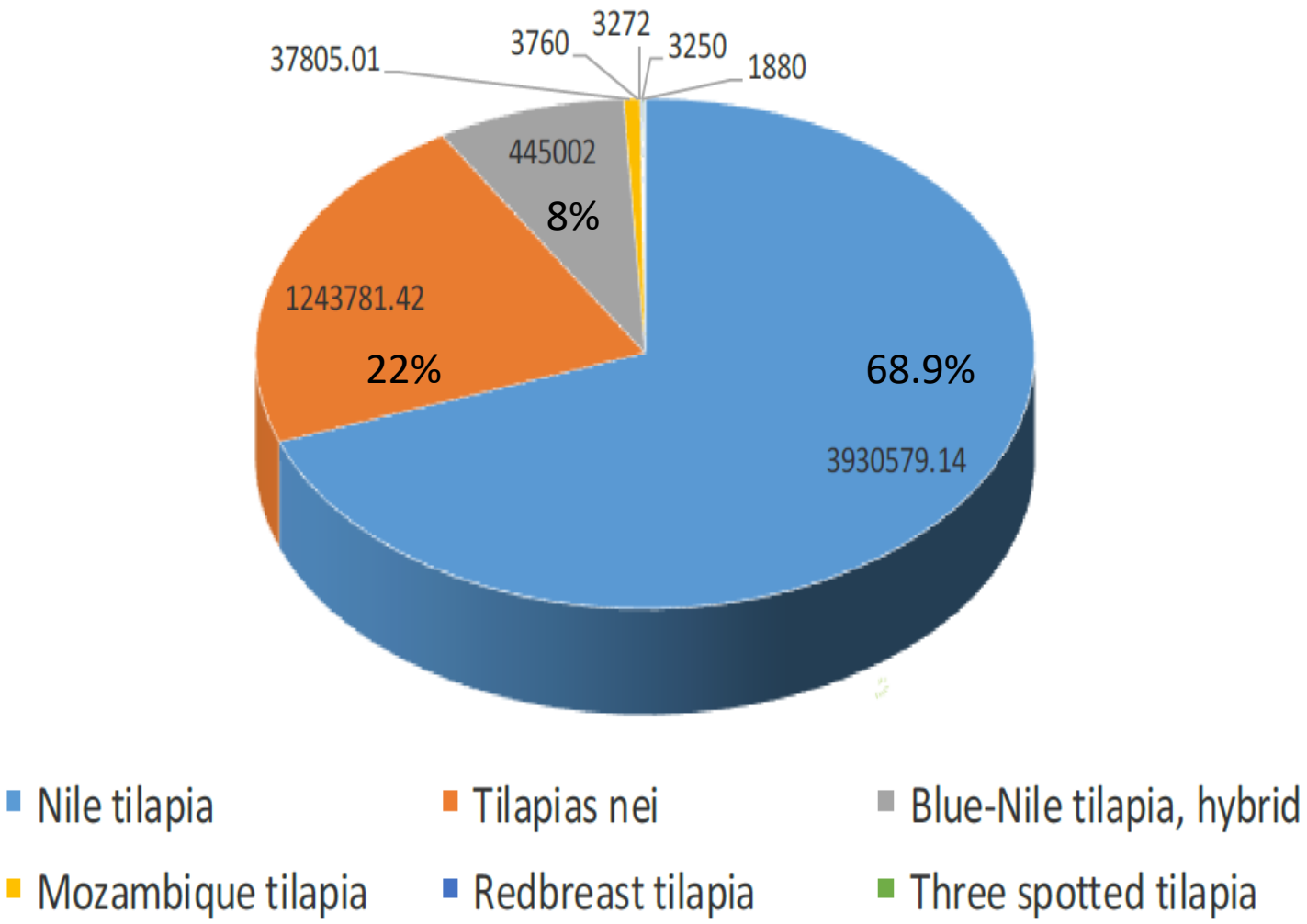
Species group Groupe d'espèces Grupo de especies			2009	2010	2011	2012	2013	2014	2015
Carps, barbels and other cyprinids	Capture fisheries	1 000 t	998	1 330	1 235	1 519	1 456	1 560	1 524
Carpes, barbeaux et autres cyprinidés	Pêches de capture	*US$/t*	*985*	*990*	*995*	*990*	*985*	*1 000*	*990*
Carpas, barbos y otros ciprínidos	Pesca de captura	US$ mill	983	1 317	1 229	1 504	1 434	1 560	1 509
	Aquaculture	1 000 t	22 180	23 316	23 981	25 392	26 901	28 229	29 121
	Aquaculture	*US$/t*	*1 325*	*1 403*	*1 429*	*1 454*	*1 454*	*1 443*	*1 406*
	Acuicultura	US$ mill	29 392	32 719	34 276	36 917	39 114	40 744	40 946
Tilapias and other cichlids	Capture fisheries	1 000 t	760	773	780	706	697	722	709
Tilapias et autres cichlidés	Pêches de capture	*US$/t*	*1 020*	*1 040*	*1 050*	*1 060*	*1 050*	*1 040*	*1 020*
Tilapias y otros cíclidos	Pesca de captura	US$ mill	775	804	819	748	731	750	724
	Aquaculture	1 000 t	3 109	3 541	3 997	4 563	4 885	5 316	5 671
	Aquaculture	*US$/t*	*1 599*	*1 642*	*1 690*	*1 701*	*1 712*	*1 666*	*1 570*
	Acuicultura	US$ mill	4 969	5 814	6 754	7 763	8 365	8 857	8 901
Miscellaneous freshwater fishes	Capture fisheries	1 000 t	7 192	7 498	7 399	7 631	7 785	7 779	7 915
Poissons d'eau douce divers	Pêches de capture	*US$/t*	*630*	*640*	*660*	*662*	*650*	*660*	*640*
Peces de agua dulce diversos	Pesca de captura	US$ mill	4 531	4 799	4 883	5 051	5 060	5 134	5 065

A big value fish

PART 2

- **Overview of the commercial species and lines**

Cultured tilapia production by species in 2015



Aquaculture production and trade trends: carp, tilapia and shrimps. Weimin Miao, FAO RAP

Commercial species

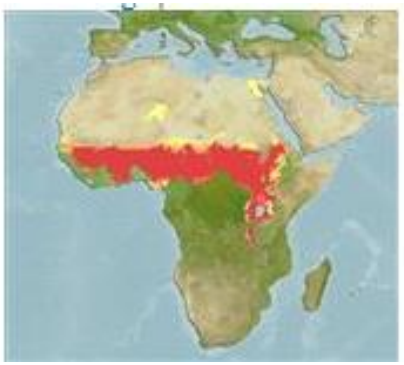
Nile tilapia *Oreochromis niloticus*

Mozambique tilapia *Oreochromis mossambicus*

Blue tilapia *Oreochromis aureus*

Oreochromis is the genus of greatest aquacultural importance

Nile tilapia

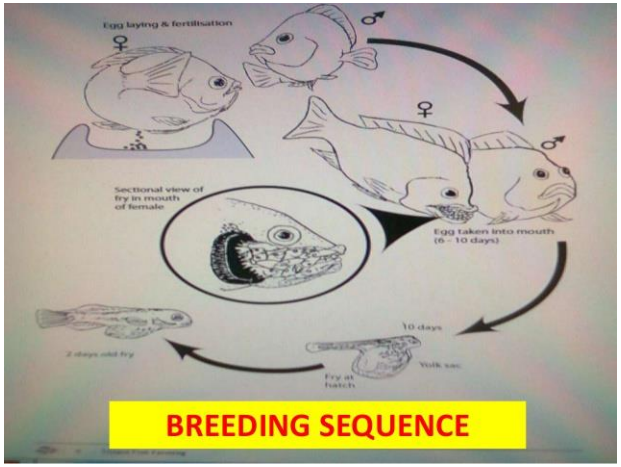


Biology

1. Occur in a wide variety of freshwater habitats like rivers, lakes, sewage canals and irrigation channels

2. Does not do well in pure salt water, but is able to survive in brackish water

Life cycle



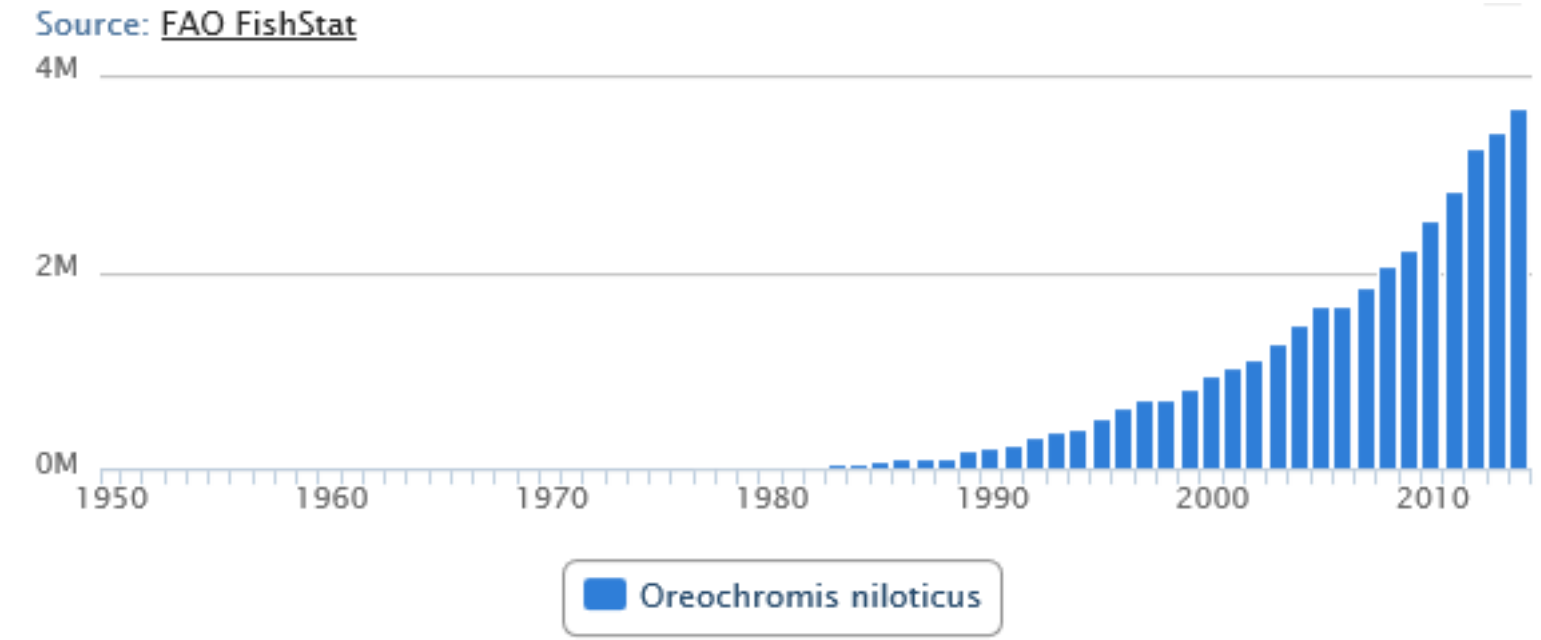
- Sexual maturity is reached at 3-6 months depending on temperature
- Reproduction occurs only when temperatures are over 20° C.
- Several yearly spawnings every 30 days
- A single male probably fertilises the eggs of more than one female
- Female carries eggs in her mouth

Temperature range

Table 1. Classification of growth and reproduction of the Nile tilapia in relation to temperature.

CLASS	TEMPERATURE REGIME	INTERPRETATION
1	t=<14°C	Unable to grow and reproduce
2	Intermediate	Growth and reproduction discontinuous
3	t>=22°C for 12 months	Continuous growth; reproduction possible throughout the year

Global aquaculture production



Local Names

English : Nile mouthbrooder , Nile tilapia .

More than 70% of these farmed fish are Nile tilapia-derived lines

Blue tilapia

Environment: Freshwater; brackish
Tropical; 8° C - 30° C

Distribution: Africa and Eurasia

Feeds on phytoplankton and small quantities of zooplankton

Maternal mouthbrooder

Sexual maturity in ponds reached at age of 5-6 months

Economic traits

- **1.Cold tolerant, occurring at temperatures ranging from 8-30°C**

  Cold tolerant tilapia new lines

- **2. Generating genetically male tilapia hybrids by interspecific hybridization**

- **Hybrid tilapia by crossing *O. niloticus* (xx ♀) and *O. aureus* (zz ♂).**

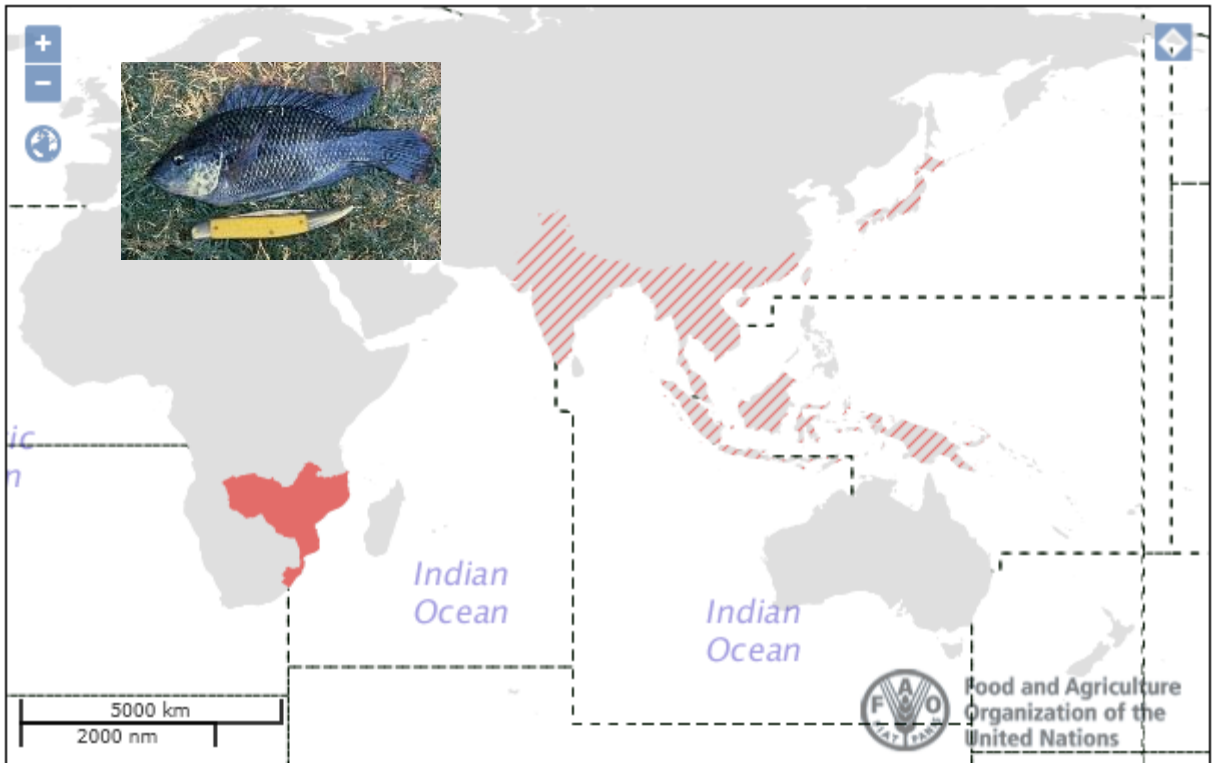
Grow rapidly (20 and 70% higher body weight than its female and male parent, respectively)

Resistant to disease (Wang et al. 1989).

High male rate: obtained 52% to nearly 100%males in such pair crosses (Pruginin et al. 1975)

Low male rates have been the result of using impure/contaminated stocks of one or both species.

Mozambique tilapia

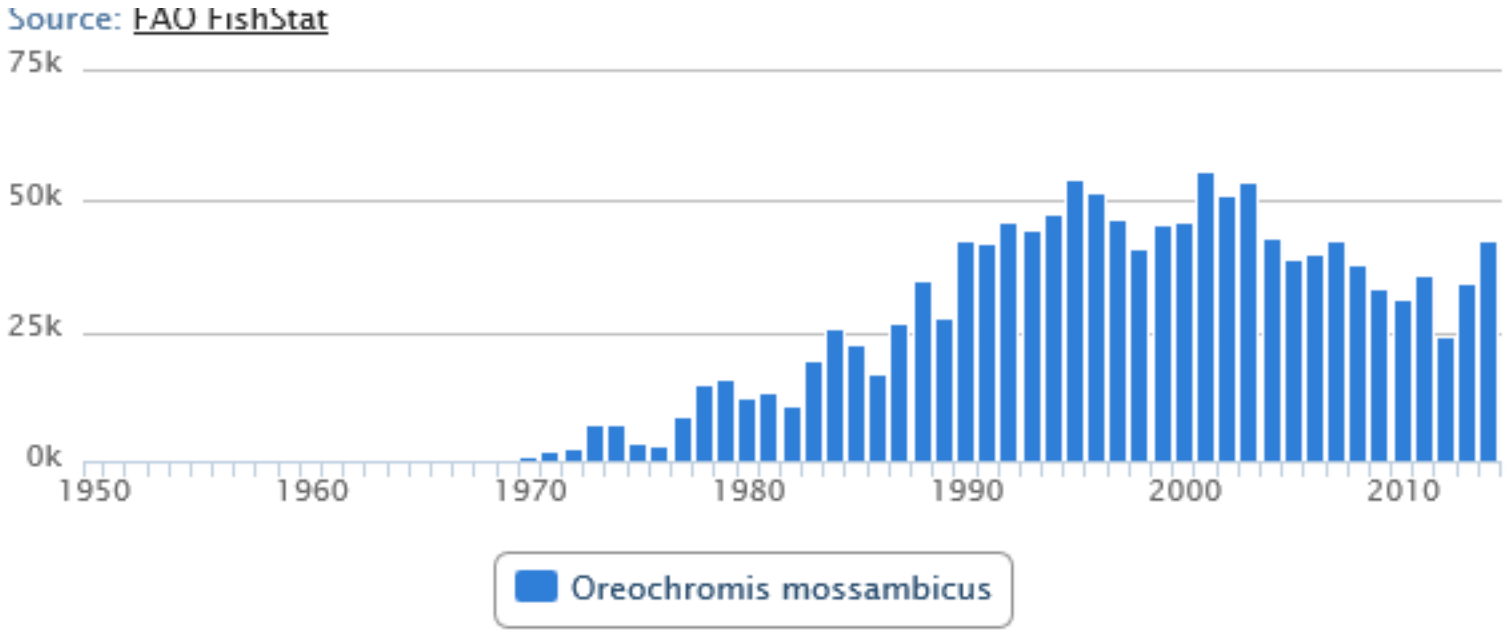


Geographical distribution

Biology

- Freshwater; brackish;saltwater
- Tropical; Extended temperature range 8-42 ° C, natural temperature range 17-35 ° C
- Maternal mouthbrooder
- Reaches sexual maturity may at an age of just over 2 months
- Known to tolerate full strength seawater (Green 1997)

Global aquaculture production



Year 2014: 42363 tonnes

Commercial lines

- Genetically Improved Farmed Tilapia (GIFT) and GIFT –derived lines

Faster-growing strains of Nile tilapia

The GIFT project operated from 1988 to 1997

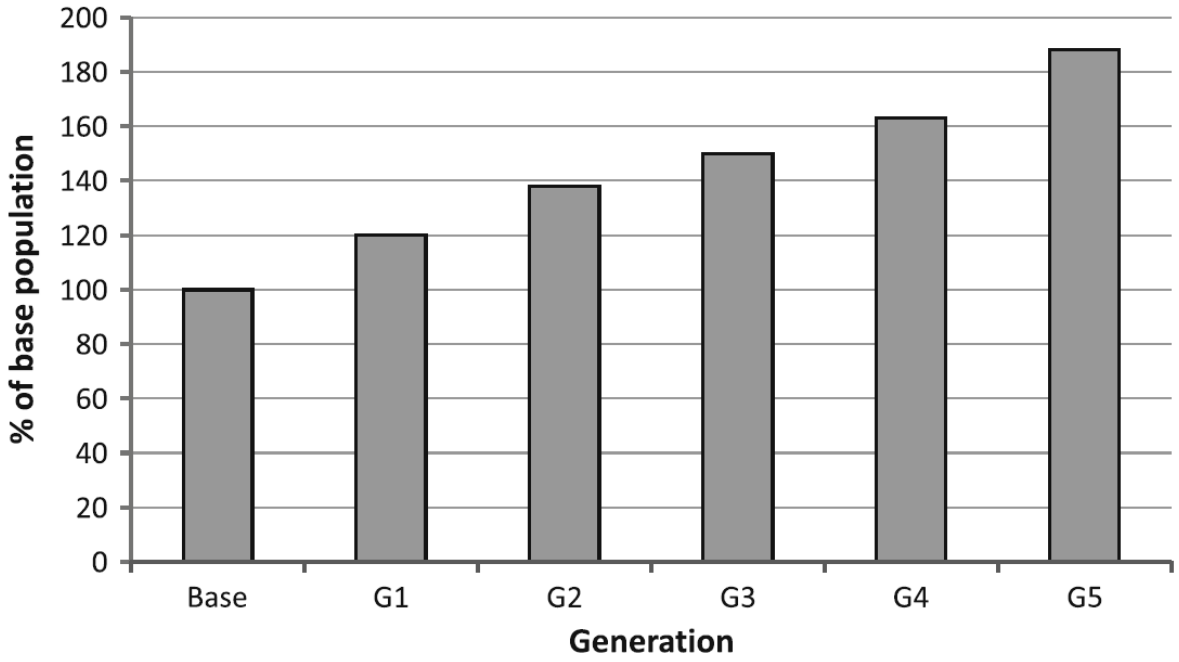


Fig. 3.3 Selection response in the GIFT project for increased body weight at harvest, measured as the percentage of the base population mean. For each generation, the response is calculated by comparing progeny of selected parents and progeny of parents with average breeding values. Reproduced from Bentsen et al. (2003) by permission of Elsevier

In 2008, WorldFish reported that GIFT had achieved a genetic gain in live weight of at least 64 per cent in the nine generations since the base population was established.

The most farmed tilapia lines in the world

- Currently, More than 100 countries now farm tilapia

- For example, In the Philippines, 70% of farmed tilapia is either GIFT strain or of GIFT- derived origin reported by Asian Development Bank

Red tilapia

- Genetic mutants selected from tilapia species

Taiwanese red tilapia: a cross between a mutant reddish-orange female *O. mossambicus* and a normal male *O. niloticus* in 1960s (Galman and Avtalion 1983)

Florida red tilapia strain: a normal colored *O. hornorum* female crossed with a red-gold male *O. mossambicus* in the 1970s (Behrends *et al*., 1982)

Israel red tilapia strain: red Nile tilapia originating from Egypt crossed with wild-type Blue tilapia (Hulata *et al*. 1995)

Other red tilapia strains are likely to have been developed but published information on their origins is unavailable

Disadvantage

1. Selection of a best strain for culture difficult

The genetic makeup of most red tilapia is unknown. All 3 original stains have been crossed with other red tilapia of unknown origin or with wild-type *Oreochromis sp.*

2. Low survival of juvenile red tilapia hybrids

Average survival of red tilapia was 51 % compared to 91 % for nile tilapia.

Reason: bird predation on the easily seen red fish

Advantage

1. Consumers will often pay a higher price/kg for red tilapia than for a Nile tilapia of equivalent weight

Consumers relate the red color to a number of marine fishes with similar coloration and high market value.

2. Red tilapia is preferred for culture in saltwater and less Off-flavor taste.

Red tilapia with Mozambique tilapia heritage can be cultured in full strength seawater.

Nile tilapia can be adapted to 25 to 30 g/l saltwater but growth is inhibited in salinities above 15 g/l (Popma and Lovshin 1996)

Muddy Off-flavor is more prevalent in tilapia raised in freshwater than in saltwater.

PART 3

- **Challenges in tilapia culture**

1. How to produce all-male fingerlings for growout?

Why1: Sexual dimorphism in growth rates and male tilapia grow faster than females.

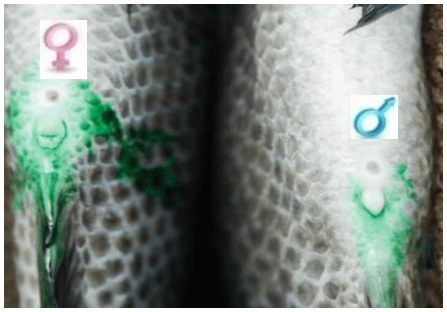
Why2: Avoid of uncontrolled reproduction

excessive recruitment of fingerlings, competition for food, and stunting of the original stock

Commercially applicable techniques used to produce monosex fingerlings

- **Hand sexing**

  labor intensive



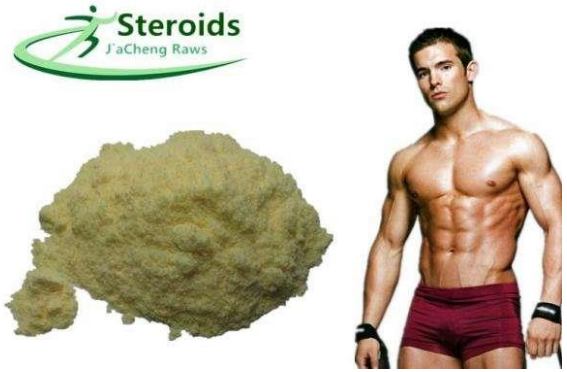
- **Interspecific hybridization**

  vigilance is required to maintain broodstock

Sex reversal with male steroids

Concerns

- pose a health risk to workers
- affect consumer acceptance of the fish
- hormone residues may damage water quality and biodiversity
- treated with steroids is not approved by FDA and is illegal to sell as foodfish in the U. S.



2.Environmental stressors

- **Adaptation to a very wide range of conditions**

  high salinity, high temperatures, high ammonia concentrations, and low oxygen levels

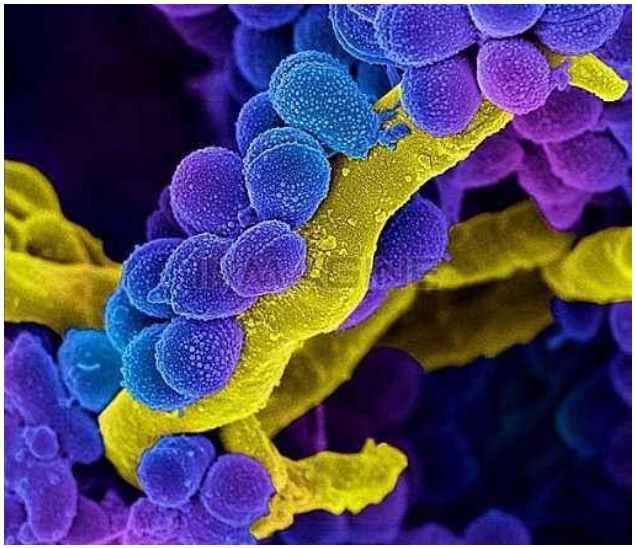
Tolerant of high stocking density

Cold temperature cause losses of tilapia in Guangxi, China (2016/1/27)

Disease-resistant fish?

Specific Pathogens

- *Streptococcus*
- *Aeromonas*
- *Trichodina*
- *Columnaris*
- *Tilapia Iridovirus*
- Tilapia lake virus
- ……



Disease impacts the production of tilapia worldwide!

- **How to meet challenges in tilapia culture?**

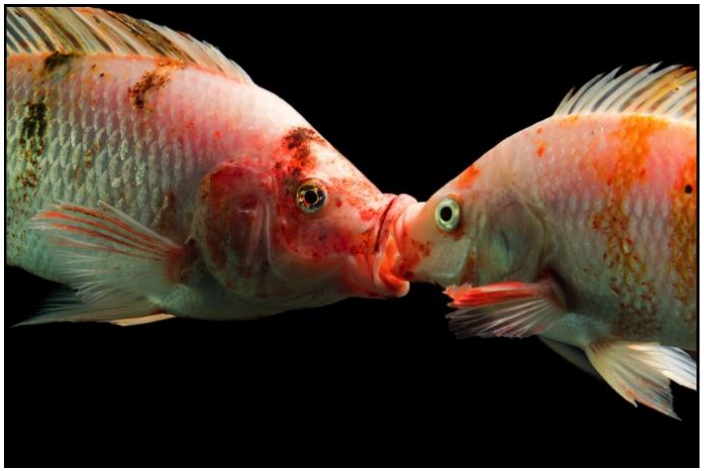
Opinions on breeding

Traditional genetic breeding

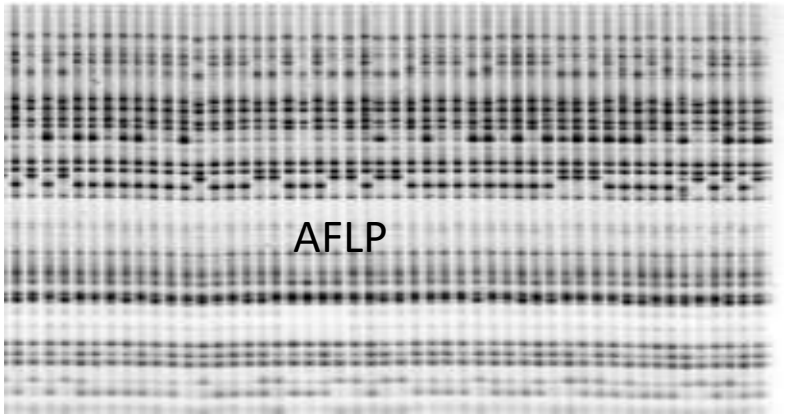
Cross-breeding

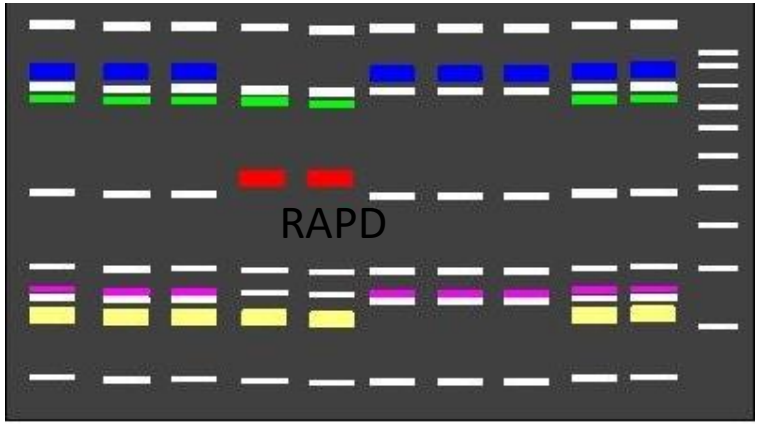
Genetic modification

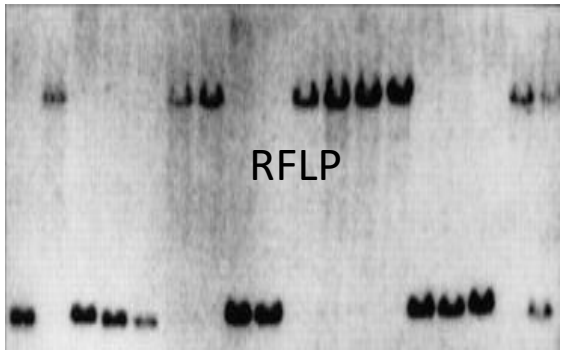
Marker-assisted Selection

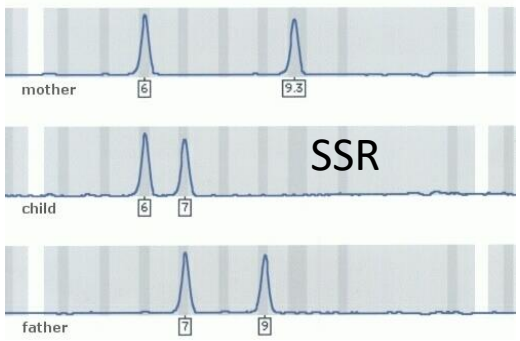


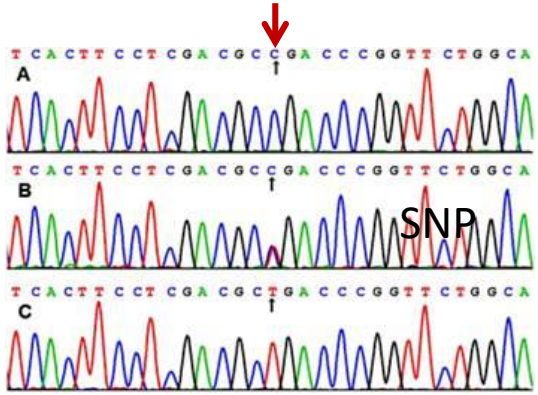
Molecular markers: genetic variation in DNA

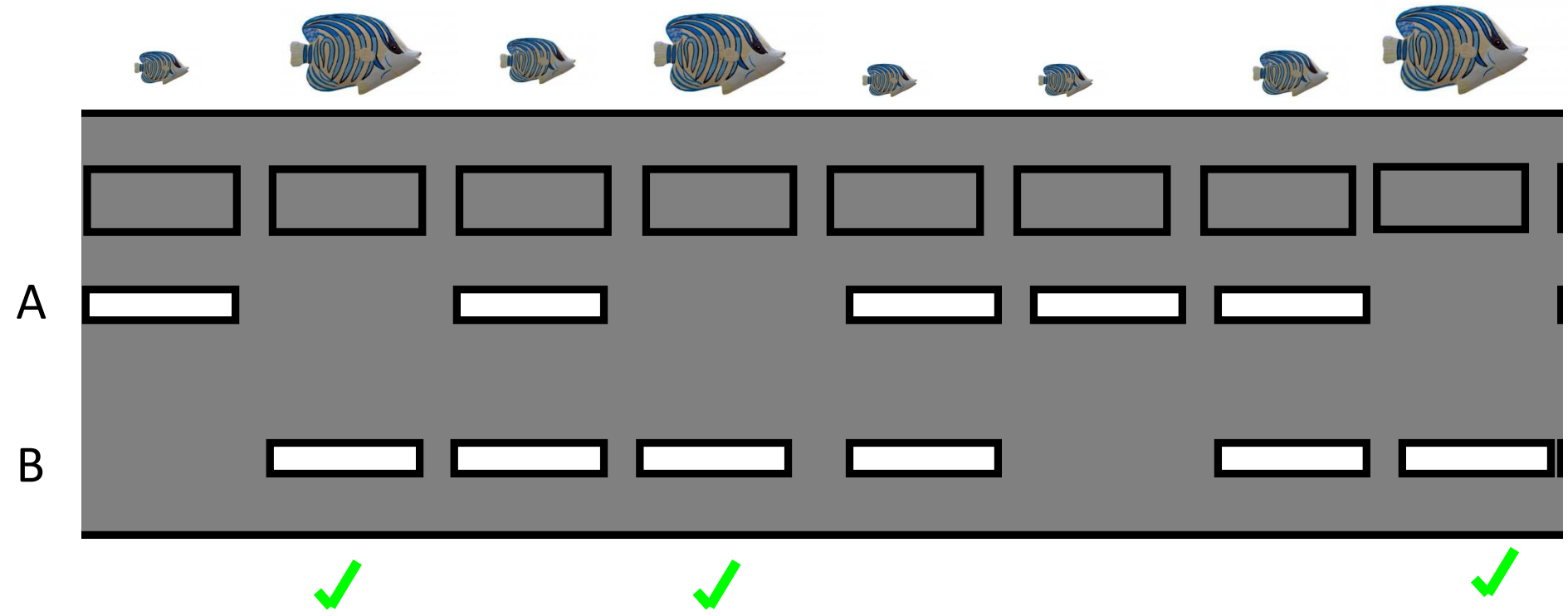










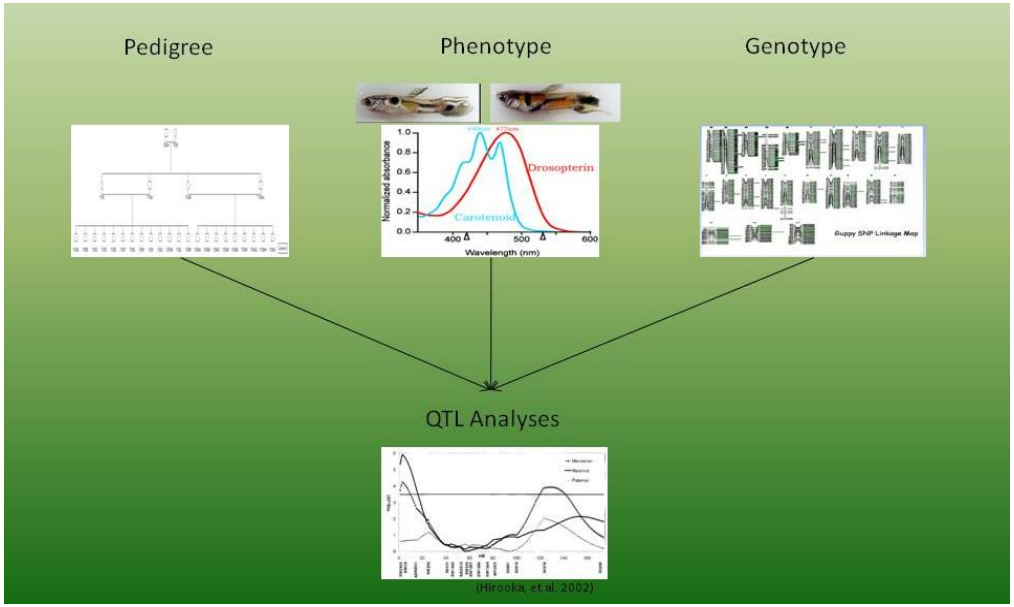


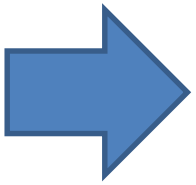
***Advantage**

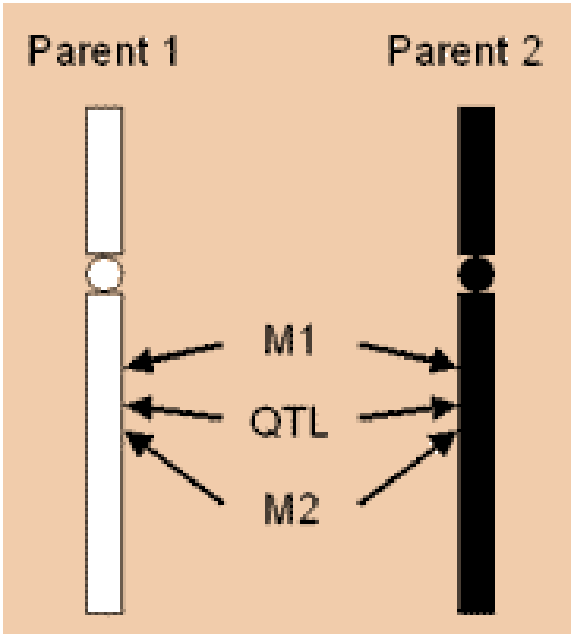
Less time

More efficient

Association of markers with economic traits



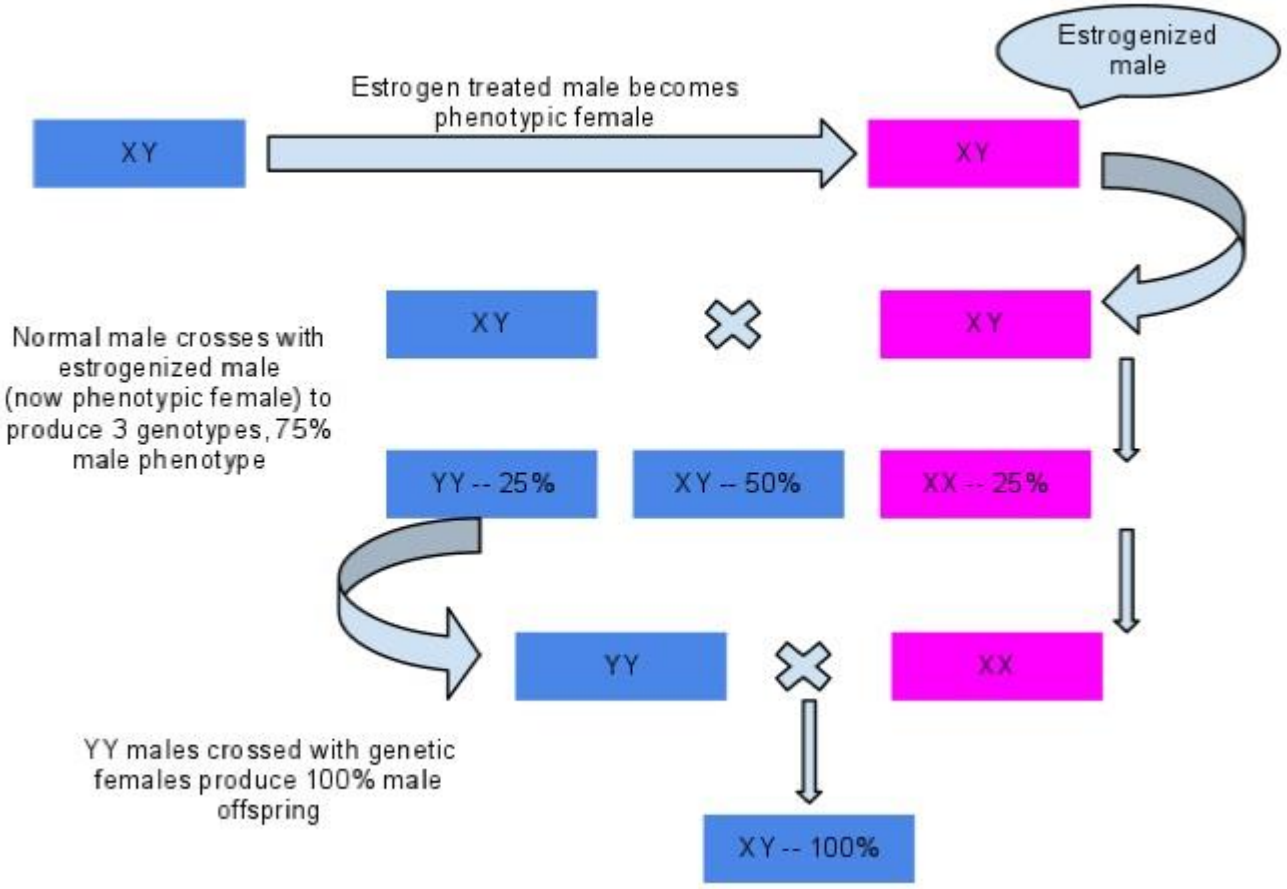




QTL mapping

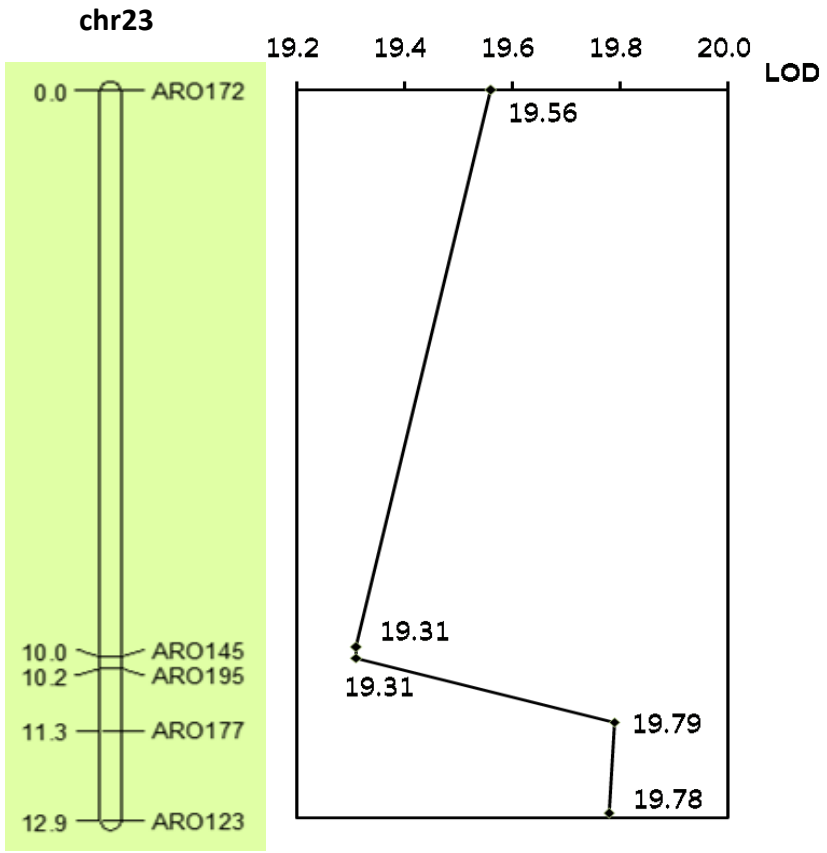
For example

MAS selection of YY supermale tilapia



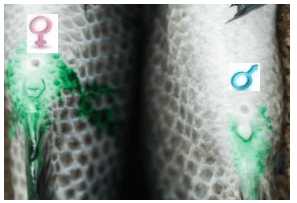
All male production using YY supermales

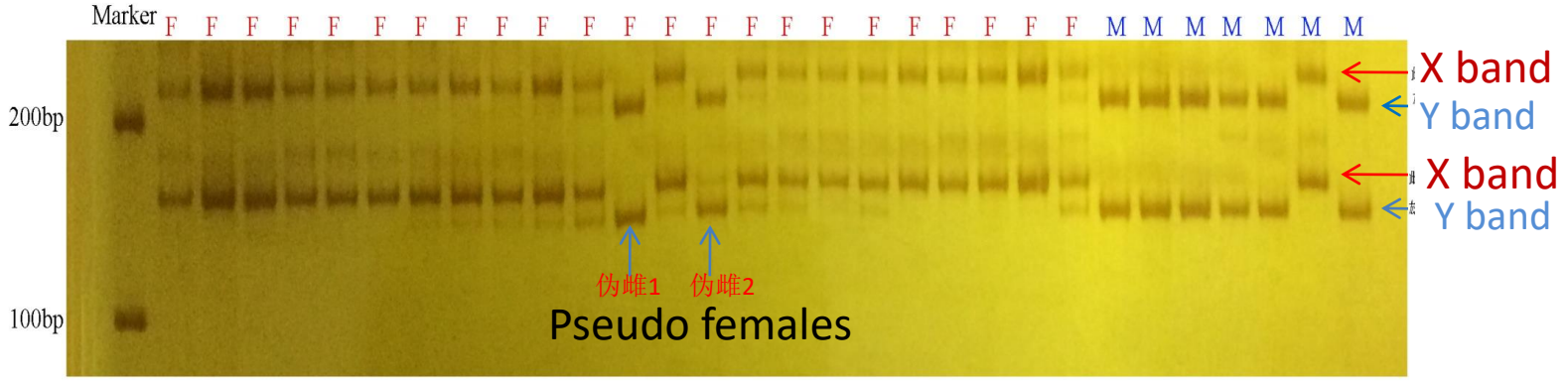
QTLs in 2 selection families



The accurate rate for linked markers are 84.7% and 90.6% in two families respectively.

Results

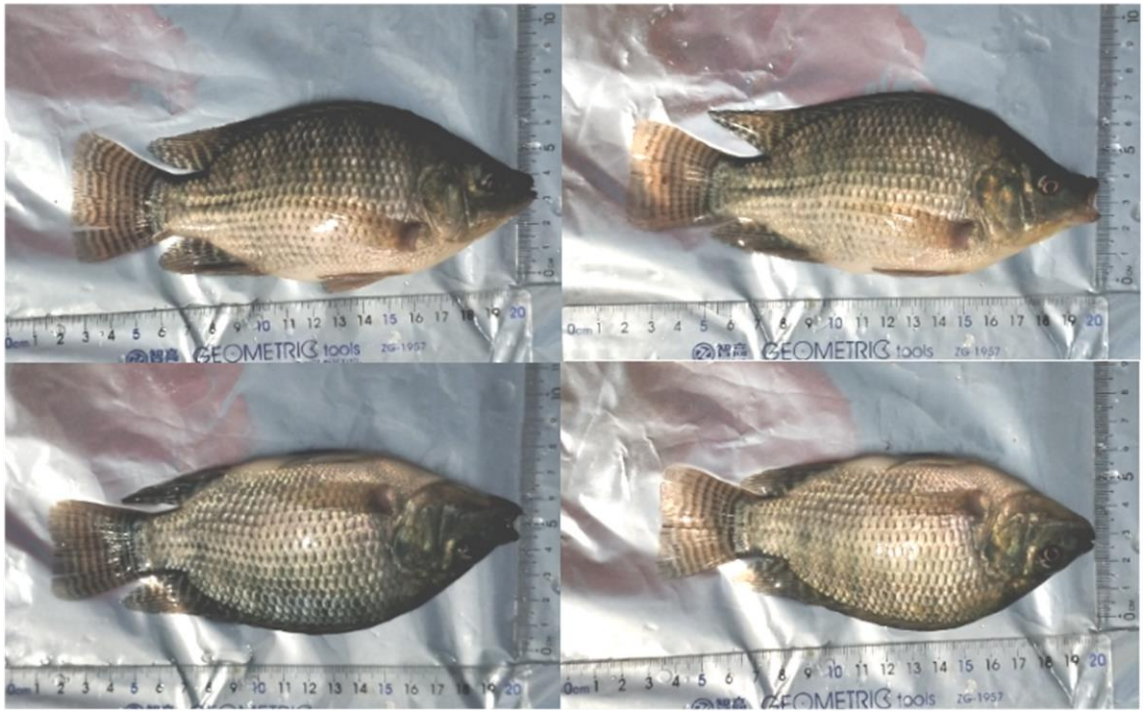




Screening of pseudo females (XY genotypes) using one marker

44 pseudo-females and >400 YY supermales

The male rate in the progeny population produced by crossing YY supermales with XX females



- **The rate is 99.6% (N = 914)**

PART 4 Exercise on hand sexing of tilapia

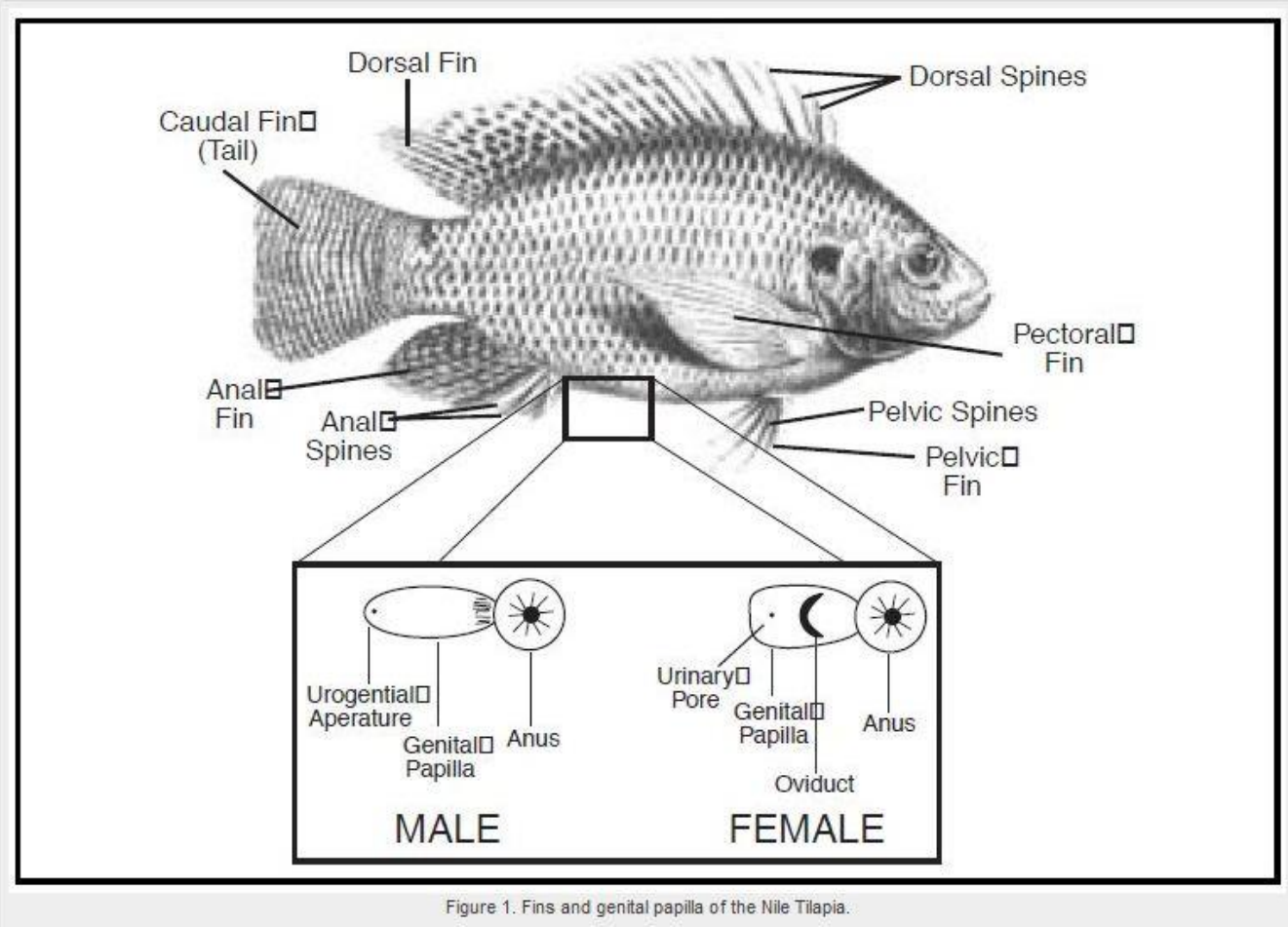
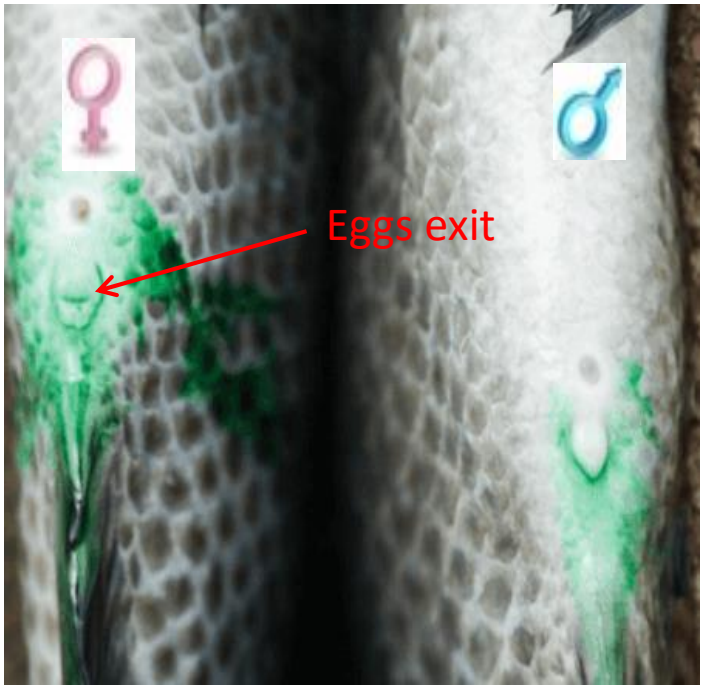
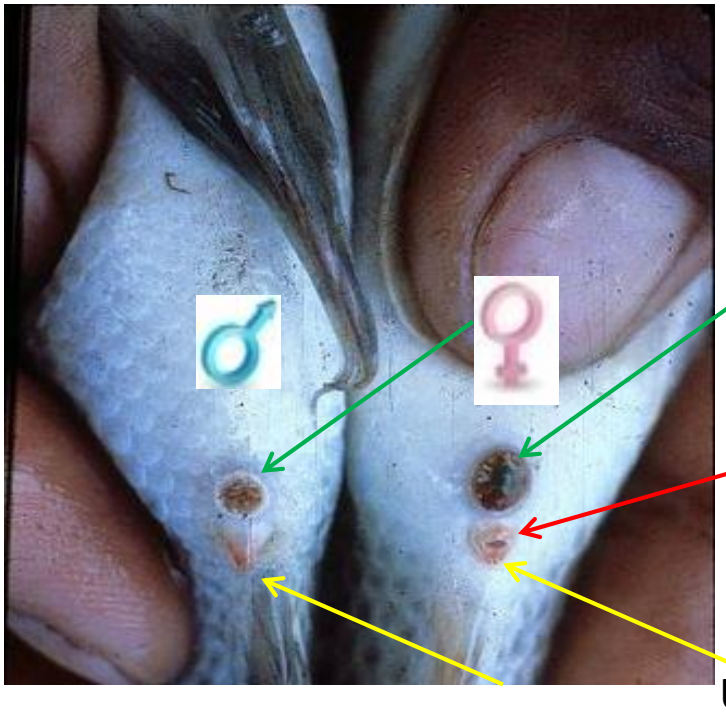


Figure 1. Fins and genital papilla of the Nile Tilapia.

Fins and genital papilla of the Nile Tilapia. (Credit: Tilapia: Life History and Biology by Thomas Popma and Michael Masser)

How to Sex Tilapia





Examining the genital papilla (located immediately behind the anus)
In males the genital papilla has only one opening (through which both milt and urine pass).
In females has two opening (the eggs exit through a separate oviduct and only urine passes through the urinary pore.)

Thanks