Fish Hatchery Management
(Reproductive biology – natural reproduction – spawning induction – hatchery operations and management)

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Contents of this lecture

• Aquatic organisms (fact sheet)
• Modes of fish reproduction
• Naturally collected fry/broodstock
• Sexual maturation and broodstock management
• Fish hatcheries and hatchery technologies
• Nursing
• Conclusion
Aquatic organisms (fish) Introductory fact Sheet

• Cold Blooded Animals with the exception of a known species (Great white shark)
• Highly fecund animals compared to other animal groups even for low-fecund fish species
• Highly diversified group (finfish, crustaceans, molluscs, …)
• Living environments determine living fish species and their mode of reproducing (cold water, warm water, freshwater, marine water)
• Vary significantly in regard to the mode of their reproduction
Fish fecundity

Notes:
Fecundity of fish species with large eggs (e.g. salmonids) is lower than fishes with small eggs.

Fecundity of a fish is inversely related to the degree of parental care it exhibits (e.g. mouth brooders).

Generally, mouth breeders like Nile tilapia have low fecundities compared to substrate spawners such as *Tilapia zillii*.

<table>
<thead>
<tr>
<th>Comments</th>
<th>Species</th>
<th>Relative fecundity estimates (no. eggs/kg of female)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>African catfish</td>
<td>80,000</td>
</tr>
<tr>
<td></td>
<td>Common carp</td>
<td>150,000</td>
</tr>
<tr>
<td></td>
<td>Grass carp</td>
<td>80,000</td>
</tr>
<tr>
<td></td>
<td>Silver carp</td>
<td>160,000</td>
</tr>
<tr>
<td>Maternal care</td>
<td>Nile tilapia</td>
<td>2000 – 4000</td>
</tr>
<tr>
<td></td>
<td>Striped bass</td>
<td>220,000</td>
</tr>
<tr>
<td>Large eggs</td>
<td>Rainbow trout</td>
<td>2,200</td>
</tr>
<tr>
<td>Catadromous fish</td>
<td>European eels</td>
<td>1.8 – 3.0 million</td>
</tr>
<tr>
<td></td>
<td>Black tiger shrimp</td>
<td>1.5 – 2.2 million</td>
</tr>
</tbody>
</table>
## Modes of fish reproduction

### Egg layers - examples

- **Substrate spawners**
- **Oviparous**
- **Prawn carrying eggs**
- **Mouth brooders**

### Egg retainers

- **Ovoviviparous**
  - Each embryo develops in its own egg in female’s body until hatch. Embryos depend on their yolks.

### Live bearers (female or male)

- **When male seahorse gives birth**
- **mother retains the eggs and nourishes the embryos till they are born**
Egg layers and parental care

No parental care: fish freely lay their eggs and sperm and then abandon the eggs (e.g. Atlantic herring, tilapia zillii)

Modes of parental care:
• Nesting and guarding: (e.g. Nile tilapia, channel catfish)
• Fanning egg masses (e.g. channel catfish males)
• Mouth incubation: (e.g. Nile tilapia females – Banggai cardinal males)
• Guard young after hatching (e.g. bowfins males)

Passive care & special arrangements: (depending on species):
• Hiding eggs
• Eggs have oil droplets that help them float
• Some bottom-dwelling fishes produce eggs that sink
• Laying sticky eggs to attach to various objects (e.g. common carp)
Parental care

- Spawning nest (tilapia)
- Holding fry (Copa female)
- Fanning egg mass (channel catfish male)
- Mouth incubation (Nile tilapia)
- Taking fry in (Haplochromine cichlids)
Organism and spawning runs & last stops

Salmon
Rivers (last stop)
anadromous

5000 – 6000 km trip

Eels
Sargasso Sea (last stop)
catadromous

Mullet
(no last stop)
catadromous
Collection of broodstock/fry from nature is done in case of:
Naturally available/abundant (milkfish – mullet)
No hatcheries
Reproductive cycle is not closed (eels)
Limited hatchery facilities
Economic reasons
Human activities (over fishing)  
Pollution (mass/selective effects)  
Political conflicts (sturgeon & shared stocks)  
Construction of dams (block migration)
Old hatchery practices
Setting the stage (Common carp) – Dubisch pond

The Dubisch Pond has a raised center area that is still covered by water.

This area is covered with a spawning medium such as trimmed grass (eggs stick to).

Selected pairs of broodstock spawn on the raised section.

Immediately after spawning, water is drained down to allow taking breeders out from deep water.

The pond is filled again. The eggs hatch as they grow to adequate size, they are collected for further nursing.

Dubisch ponds are typically 120 to 300 m² in surface and have an average depth of 30 – 60 cm.

The relative shallowness and small area of the pond allow the water to warm quickly after filling.

The shallow depth encourages the emergent grass which act as a substrate.
Hatchery Broodstock

- Sources (wild – farm or hatchery)
- Domesticated versus wild

**To be covered in the lecture on genetics**
- Efficiency under different environments (G x E)
- Genetic bottlenecks
- Number of spawns
- Understanding the effective breeding number $N_e$
Broodstock from the wild

Why? and when?

For First time ever

For stock enhancement programs (release) (Fish for natural systems are not the same fish for aquaculture)

Does not mature in captivity (until now)

Limitation in hatchery facilities (cannot handle the whole operation)

Economic reasons

BUT: Less Reliable & not economical in some cases (shrimp – Iran)

Cannot perform breeding programs
Broodstock *(From other hatcheries or farms)*

More reliable
More domesticated (for aquaculture)
Possible application of breeding programs
Possible conditioning for extended spawning seasons
Better understanding of broodstock history
(depending on the availability/quality of book keeping system)
Broodstock Maintenance

Overwintering and species

- Tilapia (Egypt)
- Whiteleg shrimp (Peru)
  Credit: Victor Hugo
- Seabream – seabass (Italy)
- Indian shrimp (Iran)

Insulation capacity

- A smart tilapia overwintering system in Egypt (fish can go in and out depending on outside temperature)
  Credit: Samart Detsathit (Thailand)
- A highly controlled tilapia overwintering system
  Japan
  Credit: Samart Detsathit (Thailand)
Overfeeding with carbohydrate rich or fatty diet should **be avoided**

The visceral fat in Indian carps and grass carp affected ovary development and impaired their response to artificial reproduction practices.

Placing fish in weedy habitats helped them to shed visceral fat allowing fish to spawn.

Mixing artificial feed of marine broodstock with squids/snail is believed needed.
Broodstock – ponds/tanks

Ponds
Sufficient number of broodstock ponds will help avoid too many fishing and so reduce stress and possible decline in the potency of fish
Good match between outdoor ponds and indoor facility should be secured
A recovery pond for spent females is a must
Depending on hatchery plan, a pond for common carp may be considered (donor to pituitary gland)

Why common carp?

Tanks
Neither tank material nor paint should carry any harm to broodfish
Water flow should be adequate to fish biomass (not excessive)
Design should allow self-cleaning
Tanks are either covered or enough free board should be secured
Air supply from oil-free air pumps
## Hatchery Management – Water

### Quantity

**For freshwater hatchery**
- Ponds of 5-ha require 40-50 l/second of water

**For marine hatchery**
- Pumping capacity/h 50% of water volume

### Quality

- Hatchery water should be:
  - Low in turbidity
  - High in DO
  - Low in CO₂
  - **Extremely low** in hydrogen sulfide (*if any*)
  - Not super-saturation with nitrogen or other gases
  - **Salinity (level & range)**: close to optimum
  - **Temperature**: close to optimum with minimum fluctuation
  - **Heavy metals**: case by case
We need to consider:
What could be accepted in a farm may not be tolerated in a hatchery
Copper and Zinc are damaging elements (no copper pipes, no zinc containers)
Hatchery management
Started complex (Cases)

1980 – Abbassa (common carp)

1982 – Sète/France (seabass, seabream)
Hatchery management
Turned easier- more towards natural systems

Open spawning system
Marine hatchery - Cyprus

Egg collection system
Marine hatchery - Kuwait

Hapa system
Tilapia hatchery - Egypt
• Gonads develop to a certain stage and remain dormant
• Further development will be triggered as suitable conditions exist producing ready to spawn
• Triggering factors include favored light & temperature, salinity, flood conditions, presence aquatic plants, presence of opposite sex
• Dormant stage continues if environmental changes are not too strong
• If environmental conditions get worse, the absorption of eggs takes place
# Sexual maturity scale

<table>
<thead>
<tr>
<th>Total spawners (8-point scale)</th>
<th>Partial spawners (5-point scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virgin</td>
<td>Immature</td>
</tr>
<tr>
<td>Maturing virgin</td>
<td>Maturing virgin</td>
</tr>
<tr>
<td>Developing</td>
<td>Ripening</td>
</tr>
<tr>
<td>Developed</td>
<td>Ripe</td>
</tr>
<tr>
<td>Gravid</td>
<td>Spent</td>
</tr>
<tr>
<td>Spawning</td>
<td></td>
</tr>
<tr>
<td>Spent</td>
<td></td>
</tr>
<tr>
<td>Resting</td>
<td></td>
</tr>
</tbody>
</table>

Source: Manual FAO, of fisheries, Part 2
Broodstock sorting
Sorting (based on gonad development)

**Females:**
- Ripest (ready to spawn)
- Promising
- Not different from males (discard)

**Males:**
- Ready
- Unready (discard)
Sexing and stage of Maturation

Roughness of the dorsal surface of pectoral fins for the male of grass carp

Can be easy
Sexing and stage of maturation

May not be possible or may require additional work

Sea urchin – sex is only known after they shed their gametes

Fish in the spawning run/grounds must be sexually mature

Laparoscopy (surgical procedure) is used to determine the sex and stage of maturation in sturgeon

Egg sampling a common practice with many marine fish species
Hatchery technologies

Chosen reproduction methodology is based on:

• Fish species & reproduction requirements
• Available hatchery facilities
• Economics

Fish spawning could be classified as:

Natural: Tilapia, common carp, African catfish
Some artificial: Tilapia, some marine species, shrimp, others
Artificial: Chinese carps, common carp, some marine species, African catfish, others

Why there is no artificial spawning for tilapia on commercial scale?
Natural Spawning

Our responsibility:
Choose the ready broodstock
Furnish the required facilities & environments
Watch for the spawning

Fish responsibility:
Get the work done
Artificial Spawning

Even the spawning is artificial, biological parameters still control

A broodstock must be ready in order to respond to induction practices
Pituitary gland

- First use was in 1934 in Brazil
- Should be taken from sexually mature male or female
- Will be more effective when taken just prior to the spawning season
- One kg of common carp has a pituitary weighs 3 mg dry weight (usually used by count and not by weight)
Artificial Spawning (related to hormonal/other substances injection/)

- Hormones used for induced spawning do not produce eggs or sperm (gametes)
- Hormones only trigger the release of fully developed gametes
- Fish must not only be sexually mature but also in the advanced stage of sexual development before induced spawning will be successful
- Sources of hormones could be the pituitary gland or other hormones (e.g. Human chorionic gonadotropin-HCG, Luteinizing Hormone Releasing Hormone - LHRH)
- HCG is a reliable marker of pregnancy in human
- Other substances rather than hormones may be used
Inserting other substances

Spawning induction of sea urchin

Potassium chloride injection and/or Acetylcholine injection have been used successfully to induce sea urchin spawning

Sea urchin, Loxechinus albus

Photo credit: Rodrigo Rivera González (Chile)
Administration of hormones & fish

**IF:**
Fish are selected properly **and**
Hormones are administered at the right time with the proper dose

Ovulation is expected

**Full Spawners or Batch Spawners?**
Specific hormonal induction & eyestalk ablation in marine shrimp

Commercially adopted in the early 1970s

Eye stalk ablation removes x organ along with its contents of “Gonad Inhibiting Hormones”

Ablated shrimp has to be when hard-shelled, or in pre-molt stage

Final ovarian development/spawning within 3-10 days

Hopefully one eye stalk only

Source of diagrams: FAO, shrimp hatchery, design, operation and management
## Ripening period & temperature

### Common carp

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Ripening time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 - 16</td>
<td>24 - 26</td>
</tr>
<tr>
<td>18 - 19</td>
<td>15 - 16</td>
</tr>
<tr>
<td>22 - 23</td>
<td>12 - 15</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>28</td>
<td>08</td>
</tr>
</tbody>
</table>

### African catfish

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Ripening time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>30</td>
<td>07</td>
</tr>
</tbody>
</table>

Source: FAO: Manual on seed production of African catfish (Clarias gariepinus)

Ripening period (time between final hormonal dose and ovulation/stripping)
Ovulation

- Time of ovulation need to be watched
- Indicator fish may tell
- If eggs were not stripped at the appropriate time they turn overripe
- Over-ripe eggs do not fertilize
- Time between final injection and ovulation is ripening time (hour-grade)
Ovulation & stripping

Eggs are flowing freely/un-interrupted

African catfish

Colossoma sp.

Mekong Giant Catfish

Rainbow trout

Credit: Wanna Thawinwan (Thailand)

Credit: TROUTLODGE (USA)
Fertilization

After the completion of fertilization, (dry or wet method), fertilized eggs (embryos) should be incubated till hatching.

Done through:
- Direct use of live males
- Use of sacrificed male testes (African catfish)
- Preserved milt

Good quality milt = High rate of fertilization

One male or more?

Genetic consideration

Preserving milt
Artificial insemination
(Whiteleg shrimp, *Litopenaeus vannamei*)

- Artificial inseminating is done when the mating between selected individuals is targeted.
- Female shrimp should have full ovarian development; males should have full and healthy spermatophores.
- Spermatophores are manually ejected until it slips out of the genital pore.
- Spermatophores are placed/secured anterior and posterior to the thelycum of the ripe female.
- Females are placed in spawning tanks in seawater with optimum salinity 25-36 g/l and temperature (26° - 30°).
- Spawning usually occurs within 1 to 24 hours after the insemination.

Photo credit: Ahmed Shaheen (Egypt)
Incubation — duration & facilities

**Affected by:**
- Species
- Type of eggs
- Environmental conditions

**Key environmental factors are:**
- temperature and light

In general, incubation period could be as short as few days for some species or as long as several months for other species.
### Incubation period (examples)

#### Selective warm water species

**Source:** FAO

<table>
<thead>
<tr>
<th>Species</th>
<th>Incubation temperature (°C)</th>
<th>Optimum</th>
<th>Days/hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common carp</td>
<td>20 - 22</td>
<td>3.5 - 4 d</td>
<td></td>
</tr>
<tr>
<td>Grass carp</td>
<td>22 - 25</td>
<td>1 - 1.5 d</td>
<td></td>
</tr>
<tr>
<td>Catla</td>
<td>24 - 30</td>
<td>14 - 20 h</td>
<td></td>
</tr>
<tr>
<td>Asian catfish</td>
<td>28 - 29</td>
<td>23 - 25 h</td>
<td></td>
</tr>
<tr>
<td><em>Pangasius sutchi</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nile tilapia</td>
<td>28</td>
<td>4 d</td>
<td></td>
</tr>
<tr>
<td><em>Clarias macrocephalus</em></td>
<td>26 - 30</td>
<td>18 - 20 h</td>
<td></td>
</tr>
<tr>
<td>Cachama <em>Colossoma oculus</em></td>
<td>25 - 26</td>
<td>18 - 19 h</td>
<td></td>
</tr>
</tbody>
</table>

#### Incubation & temperature

**Source:** Earl Leitritz, trout & salmon culture

<table>
<thead>
<tr>
<th>Temp °C</th>
<th>Incubation period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainbow trout</td>
</tr>
<tr>
<td>1.7</td>
<td>156</td>
</tr>
<tr>
<td>4.4</td>
<td>80</td>
</tr>
<tr>
<td>7.2</td>
<td>48</td>
</tr>
<tr>
<td>10.0</td>
<td>41</td>
</tr>
<tr>
<td>12.8</td>
<td>24</td>
</tr>
<tr>
<td>15.6</td>
<td>19</td>
</tr>
<tr>
<td>24.0</td>
<td>5 - 6</td>
</tr>
<tr>
<td>28.0</td>
<td>4</td>
</tr>
<tr>
<td>30.0</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: the optimum thermal range for reproduction falls **within** survival range.
Types of fish eggs in relation to: incubation or treatment

Mass (Channel catfish)

Large Eggs (salmon)

Sticky eggs (carps) Tannin is used to dissolve the adhesive material

Loose Eggs (tilapia)
Incubators in relation to types of eggs

- **Tilapia**
  - Simple and efficient incubator
  - Credit: Grace Charway (Ghana)

- **African catfish**

- **Channel catfish**

- **Black catfish**
  - Large size incubator for highly fecund fish
  - Credit: Claudia Gravina (Uruguay)
Chinese-system incubators

Incubating tanks are circular with outer and inner chambers. The inner chamber is adequately screened to allow only water to pass through. These tanks have outlets through which hatchlings pass through into the larval tanks. Water speed and direction assures favorable circulation and protection of incubated.
Embryonic Developments
Never mix different ages during incubation

Tilapia

Green eggs

Freshwater prawn

A colored tub for each stage
Credit: Muhammad Iqbal (Pakistan)
If eggs are heavily infected with fungus and other batches could be obtained:

Discard the bad batches.
Embryonic Development

- Stable temperature is very important during incubation
- Proper hygienic condition of the system is influenced by the quality of fertilized eggs
Incubation/temperature

It is much safer to incubate at highest safe temperature
(refer to an earlier table)
Hatchery Products (good or bad)
Replacing hatchery broodstock

Facts:
Young broodstock produce more eggs/g (relative fecundity), with shorter spawning intervals & much easier to handle. Replacing old broodstock by younger ones is often recommended.

No Fixed Rule

Replacing oldest age group  OR  Annually change 33%  OR  All-in & all-out

Compensating the missing sex & correcting the skewed sex ratio (in changing sex species – e.g. gilthead seabream: males change into females)
Early nursing (environment – feeding)

Water temperature is the most important single factor
Temperature range is acceptable; severe fluctuation should be avoided. (some species cannot tolerate temperature fluctuation that exceeds 0.5° C/day (seabass, seabream)
Light regime is critical for some species

No matter where a larvae stays or moves Its food should be there

The onset of the first larval feeding is a crucial step in the young fish life as starvation is a major cause of larval mortality
Management & species

While management may apply to almost all species

Because in biology nothing is exact

Modification in hatchery operations may take place according to species

Some steps may be omitted, others may be added

In brief, study your species
When facility begins by incubation

Incubating the fertilized eggs of sturgeon hybrids in Uruguay
Credit: Alejandro Perretta

Incubating the fertilized eggs of all-female of rainbow trout
Credit: Troutlodge (USA)

A carrying-egg female of freshwater prawn
Management and scale of production
Usually apply to large hatcheries

Abbassa – 15 million fry/year

Aswan
Management and scale of production

*Should* also apply to small hatcheries

- 8-million tilapia fry
- 2-million tilapia fry
Extending the spawning season

- Manipulating of photoperiod and temperature are the key factors for extending the spawning season outside the natural season
- The technique is in practice for several fish species
- This allows the production of seeds according to marketing and/or farming needs

Green houses help to produce tilapia at the time suitable to farms (Egypt)

Chilling, heating and light manipulation are used in marine hatcheries (Italy)
Enhancing Hatchery Efficiency
Multi-species – multi-sizes - quality

- Sea Bass
- Sea bream
- Soles
- Shrimp

Multi-species concept applies to freshwater hatchers
Production of different sizes of the same species is possible if economically visible

Screening for disease causing agents
Vaccination
Conclusion

• Hatcheries are not farms in regard to management and specific targets
• Quality of hatchery products is often seen on the farms
• For production economics, proper hatchery facility never means over-equipped hatchery
• Hatcheries are the place of genetics applications
• In the planning process, target species, possible additional species and hatchery products (e.g. fry, fingerlings, fertilized eggs), should be clearly defined
• Any change/improvement in the biological application has to be economically justified or **Drop the idea**
• Competition, economics, quality control are issues to be considered in order for the hatchery activity to remain sustainable