Reproduction

Reading: Chapter 9 (9.3)
- Fecundity
- Reproductive potential
- Maturity
- Sex ratio
- examples

Reproduction

- 96% of marine fish have pelagic eggs/larvae
- Fecundity from a few to millions of eggs per year
- Variation in maturity schedules:
  - Some fish born mature (dwarf perch)
  - Some mature in first year (anchovy, silversides)
  - Some mature many years after hatching (sturgeon)

Fecundity and maturity schedules have profound effects on stock dynamics and response to harvest

Reproduction

- Gonads (testes and ovaries) have long inactive periods
- Spawning occurs when fully developed gametes are released
- Spawning often takes place in particular habitats at particular times
- Stimulus may be internal (endogenous) or external (exogenous)
Fecundity

- Total count of ova in both ovaries
- Increases with age/size in teleost fishes
- Related to a power of length or weight

\[ F = aL^b \]

after ln transformation:

\[ \ln F = \ln a + b\ln L \]

---

![Diagram of life cycle stages](image)

Figure 3.44 A generalized life history triangle for marine species; not all species have geographically separate spawning and nursery areas.
Fecundity

True fecundity
– total number of eggs produced

Functional fecundity
– actual production of viable oocytes

Fecundity

Functional fecundity vs. True fecundity

Differences due to:
– incomplete spawning
– atresia (degeneration)
– resorption of oocytes

Fecundity

Total spawners vs. Batch spawners

Total spawners release 1 batch of eggs per breeding season (e.g., brown trout)

Batch spawners release multiple batches of eggs per breeding season (e.g., Atlantic cod)
Fecundity

Batch spawners can be either **determinate** or **indeterminate** spawners

**determinate**
- all eggs to be spawned are present as oocytes in ovary prior to spawning

**indeterminate**
- eggs to be spawned are not all present as oocytes in ovary prior to spawning (some develop later)

Fecundity

**determinate** vs. **indeterminate** spawners

**Implications** for fecundity estimation?

**indeterminate spawners**:
- Counts of eggs do not indicate annual fecundity
  - Continuous new batches (size distribution)
  - Protracted season
  - Need to calculate Batch Fecundity X # of batches
- Keep in mind, spawning in multiple batches does not necessarily indicate indeterminate status!
Fecundity
Estimation Methods

A sub-sample of the ovary is used to extrapolate to total egg counts. This avoids total counts but introduces error.

- How representative is the sample?
  - sub-sample location
  - egg size variability
  - egg quality variability

Fecundity
Assumptions

Using population fecundity as a measure of reproductive potential assumes:

- constant annual sex ratio
- no annual variation in egg #-fish size relationship
- no annual variation in age/size at maturity
- egg # is a function of fish size independent of age
- no annual variation in proportion of eggs retained by the female during spawning
Fecundity
density-dependence

- At high population densities females can retain eggs
- At low densities females may become more fecund
- Each are examples of density-dependent compensatory responses

Fecundity
density-dependence

- At low population densities, females may also retain eggs if proper stimulus is absent
- This is an example of a density dependent response, but it is depensatory
- A decrease in reproductive success at low population density is an example of an Allee effect

Queen conch in the Caribbean
Maturity

- Maturity schedules are generally age- and size-dependent
- Determined by classifying ovaries into developmental stages
  - Macroscopic examination of morphology, color, size, presence of visible oocytes
  - Microscopic (histologic) examination of gonadal tissue for presence of secondary oocytes and postovulatory follicles
Maturity

gonadosomatic indices

- GSI used to track reproductive seasonality
- Assumes ovary size increases with egg development due to increases in egg size
- Function of gonad mass (GM) relative to total body mass (TM)

\[
GSI = 100 \times \left( \frac{GM}{TM} \right)
\]
Figure 3.47 Gonad indices for the giant clam Tridacna crocea. The vertical bars indicate ±1 standard deviation (adapted from Shelley & Southgate 1988).

Common flatfish off Ireland coast
Maturity
length at maturity

- Length ($L_m$) or age ($T_m$) at maturity is length/age when 50% of population is mature
  - Estimate % mature in each size class
  - Fit a logistic curve (binomial response)
    \[ P = \frac{1}{1 + e^{r(L - L_{mat})}} \]
  - Or when linearized:
    \[ \ln \left( \frac{(1 - P)}{P} \right) = rL_{mat} - rL \]
    with: \[ b = -r \]
    \[ a = rL_{mat} \] so $L_{mat} = a/r$
Maturity life histories

- Maturity schedules are species-specific
- Density-dependence may cause advance or delay
- Semelparity vs. Iteroparity
- Hermaphroditism
  - Protogyny-female 1st vs. Protandry-male 1st
- Sex ratios
  - females usually modeled
  - important if spawning biomass is needed, or if males are limiting to reproductive success
  - distinguishing sexes externally often difficult