GENERAL TOPICS:

1. Introduction
2. Sampling of eggs and larvae
3. Development of eggs
4. Development of larvae
5. Identification of eggs and larvae
6. Ontogeny and phylogeny
7. Pictures!
1. INTRODUCTION

The early-life history of fishes, or the egg and larval stages of fishes, is a fascinating subject, and its importance has been recognized by scientists for more than 140 years. The range of developmental patterns is broad, and the morphological diversity of fish eggs and larvae matches, and in some cases exceeds, that seen in adult fishes.
However, the early development or ontogeny of most fish species is not known or has not been described. In fact, it has been estimated that of all fish species worldwide the eggs of only 4% and the larvae of only 10% are known. In the Eastern North Pacific, the eggs of approximately 10% and the larvae of about 44% of the species are relatively well known.
Fish eggs and larvae are considered part of the “plankton” (from the Greek meaning wanderer) meaning that they cannot swim against currents. However, some larval fish have been shown to swim vertically in the water column to take advantage of different currents.

Larval fish eat a variety of things: phytoplanton, algae, copepods, larvaceans, and other fish.
Fish eggs and larvae differ anatomically, physiologically, behaviorally, and ecologically from the adults that they eventually become, and so studies aimed at examining these early stages must be done to get a complete picture of the biology of fishes.
In addition, information about the early-life history stages of **commercially important** fish species is closely tied to proper management of these fisheries. An understanding of the early stages of **non-commercial fishes** is equally important because they belong to the same ecosystem and interact extensively with commercial fishes.
2. **SAMPLING OF EGGS AND LARVAE**

The *collection* or *sampling* of fish eggs and larvae help to provide a number of things about fish species, populations, and communities. First, we can determine the species present in a given area and in a given time of the year. By sampling at different times of the year and over several years, we learn whether the species present change *seasonally* or from year-to-year because of changes in the physical environment.
Sampling can also be used to determine the **geographic distribution** of eggs and larvae. This is important because the distribution of eggs and larvae is often not the same as that of adults, especially in places where currents transport **freely floating** eggs and larvae.

Figure courtesy
Katie Shulzitski
Currents affecting transport of bluefish larvae (Pomatomus saltatrix) in North Atlantic Ocean.
Especially for species that lay **pelagic eggs**, sampling can help to determine the **spawning area** of the adults. By knowing the developmental stage of the eggs and something about the water **currents** in the area, we can trace the eggs back to the location of the spawning area. For example, this has been done to determine the location of the spawning area of **walleye pollock** (*Theragra chalcogramma*) in Shelikof Strait, Alaska.
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Sampling can also be used to study **larval ecology**. Egg and larval collections have been used in studies of starvation, predation, disease, competition, and the condition of the physical environment (e.g., effects of storms, water temperature, and pollution).

In addition, quantitative samples of eggs and larvae can be used to make relatively accurate estimates of the number of spawning adults, or the spawning biomass, in the population. Collections of eggs and larvae are also frequently used in **taxonomic** and **phylogenetic** studies.
A number of different methods are used by researchers to collect **planktonic** (pelagic) fish eggs and larvae. Eggs are usually collected by **vertical egg tows** in which a net is lowered to 70 meters and then retrieved at a constant rate. Larvae are usually collected in **oblique net tows** in which the net is lowered to a particular depth and then pulled back to the boat as the boat moves forward. Some collecting gear employ multiple nets with each net collecting at a specific depth range. This allows us to determine how the larvae are distributed vertically in the water column.
Another method used to collect larvae is the **neuston tow**, sampling just the upper 10 cm of the water. Once the nets are back on board the boat, they are washed down with **formalin** and the samples are sorted. The eggs collected are then preserved and stored in 3-5% formalin. Eggs are never stored in **ethanol** because it makes them cloudy so that the embryos are not visible. Larvae are first placed in 3-5% formalin and then later transferred to 70% ethanol.
There are several considerations that must be addressed when collecting fish eggs and larvae. **Extrusion** from the net, or the loss of organisms after capture, can be a serious problem. Collectors can limit the amount of extrusion by considering what **mesh size** to use and the **speed** of the tow.
Collectors also need to consider how large a volume of water needs to be sampled in order to collect rare taxa or taxa with patchy distributions. If particular species are being targeted, collectors need to know whether the eggs and larvae are found only in special habitats such as near the bottom, near the surface, or around structure.

One problem associated with collection is unique to larvae: because larvae can swim (though not very quickly), avoidance of the sampling gear is possible. The ability of larvae to do this is a function of several factors: the degree of sensory development of the larvae, their size and speed, and the size and speed of the net being used to collect them.
In recent years, **Models** have been used to look population size, location and connectivity.
3. DEVELOPMENT OF EGGS

There has been a great deal of confusion over the years about the best way to define the developmental stages of eggs and larvae. This is because there is an incredible amount of variation in the pattern of early development among fishes. The most commonly used definitions are shown in the table below.
Terminology of early life history stages.
The development of fish eggs is usually divided into **three basic stages**:

**Early:** Fertilization to blastopore closure

**Middle:** Blastopore closure to embryo tail-bud free of yolk

**Late:** Embryo tail-bud free of yolk to hatching
However a complete description of the eggs of a particular species is often divided into more than three stages; in some cases, many more. For example, the development of English sole (*Parophrys vetulus*) eggs is divided into 15 stages, as shown below:
4. DEVELOPMENT OF LARVAE

As indicated in the table of developmental terminology given above, the development of fish larvae is also generally divided into three stages:

**Pre-flexion:** Absorption of yolk sac to start of notochord flexion

**Flexion:** Start of notochord flexion to completion of notochord flexion

**Post-flexion:** Completion of notochord flexion to start of metamorphosis
There are also transitional stages between eggs and larvae and between larvae and juveniles. The larval development of the horse mackerel (*Trachurus trachurus*) is a good example of larval development in general.
5. IDENTIFICATION OF EGGS AND LARVAE
The identification of fish eggs and larvae is not an easy task. The specimens are small, fragile, and usually look very different from the adults. And to complicate matters even more, eggs and larvae can change dramatically in appearance as they develop.

*Loweina rara*, Myctophidae
Rosaura rotunda (family Giganturidae)

Curfin sole (Pleuronichthys decurrens)

Longfin halfbeak (Hemiramphus saltator)

Swordfish (Xiphias gladius)

Ocean sunfish (Mola mola)
However, there are many characters that are useful for identifying fish eggs and larvae. For fish eggs, the following characters are often used: **shape**, **size**, **chorion texture** (embryonic tissue layer), size and number of **oil globules**, size of **perivitelline space**, and **embryonic characters** (late stage only).
For fish larvae, useful characters for identification can be divided into five categories:

**Morphology:** Shape and length of gut, pigmentation (melanophores)

**Meristics** (things you can count): Myomeres (muscle bands that run along the length of a fish), fin spines and rays, vertebrate

**Specialized larval characters:** Elaborate spines, especially on head, stalked eyes, trailing guts, enlarged fin folds, etc.

**Osteology:** timing of bone and cartilage development

**Genetics:** DNA of unknown larvae matched to DNA of known adults
There are **two main approaches** to identifying unknown eggs and larvae:

The first approach is called the **serial method**. This method uses adult characters to identify juveniles and progressively links them to smaller specimens through a continuous sequence of shared or similar characters.

Using this method, a developmental series is assembled of identified specimens from the largest to the smallest. A complete developmental series usually has between 50 and 100 specimens. This approach can be used to identify both eggs and larvae.
Bigeye squaretail (*Tetragonurus atlanticus*)
A second approach involves the use of **aquaculture methods** to raise collected specimens of unknown eggs or larvae until they can be identified, or to spawn adults of a species for which the eggs or larvae are unknown and raise the offspring. These methods are usually only used in cases where the **serial method** has not been successful.
A third method is to take DNA samples and run a genetic analysis. The sample is usually taken by sampling an eye. But this is expensive, difficult to do and sometimes ruins the fish. It can only really be done if have many and can sacrifice one.
6. ONTOGENY AND PHYLOGENY

Though not used nearly as often as adult morphology or molecular characters, **ontogeny** provides an excellent suite of characters for the study of phylogenetic relationships. This is particularly true for larvae. All of the characters used to identify larvae can potentially be used to construct **phylogenetic trees**. Early-life history characters can sometimes even resolve phylogenetic problems that cannot be figured out by using character sets based on adult morphology.
There are many examples of how **ontogeny** can be used to determine phylogenetic relationships. One good example is the **leptocephalus larvae** of the orders **Anguilliformes** (eels) and **Elopiformes** (tarpon and ladyfishes).
Similarly, there are no adult characters that support the hypothesis that the order **Atheriniformes** (silversides, rainbowfishes, etc.) is a natural group. However, there are several larval characters: the preanal length is short (approximately 1/3 of body length), there is a single row of melanophores on the dorsal margin of the body, and fin rays are not visible at hatching.

California Flyingfish  Boeseman’s rainbowfish  Mediterranean sand smelt
Odontesthes debueni  
(family Atherinidae)

Iso hawaiensis  
(family Isonidae)

Bedotia geayi  
(family Bedotiidae)
The family *Myctophidae* (lanternfishes) is divided into two tribes. This division is well supported by adult characters. It has also been found that these two tribes can be distinguished during the larval stage by the **shape of the eye**: one tribe has round eyes and the other has narrow, elliptical eyes.

![Adult Myctophid](image)
The superfamily Argentinoidea is composed of four families: the Argentinidae (herring smelts), Microstomatidae, Bathylagidae (deep-sea smelts), and Opisthoproctidae (barreleyes). As adults, they don't look particularly similar:
However, there are two excellent ontogenetic characters that define this group. First, the **chorion** has distinctive pustules on the inner surface. Second, the **dorsal and anal fins** form in the fin-fold away from the body, connected to the trunk by what are called hyaline strands.

*Images of fish species with labeled names and family information.*
Although this second character is an excellent one for recognizing the common descent of the superfamily Argentinoidea, it is also a good example of **convergent evolution** because this character also exists in two other relatively unrelated families, Myctophidae (lanternfishes) and Icosteidae (the ragfish).

*Icosteus aenigmaticus*
(family Icosteidae)
Batfish, Ogcocephalidae
Telescopefish, Giganturidae
Mahi Mahi, Coryphaenaenid
Look-down, *Selene vomer*
Squirrelfish, Holocentridae
Flatfish