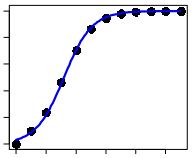
Fisheries Reproductive Biology

Presented by Nikolai Klibansky





Outline

- I. Introduction
- II. Diversity of Reproductive Biology in Fishes
- III. Organizing Diversity: Breeding Systems
- IV. Fisheries Reproductive Biology
  - -Major ideas
  - -The Nitty Gritty
  - -Methodologies

Defining some terms

- fish reproductive biology
  - biology
  - physiology
  - ecology

Defining some terms

- Fish reproductive biology
- Fisheries reproductive biology

Fish RB: Diversity

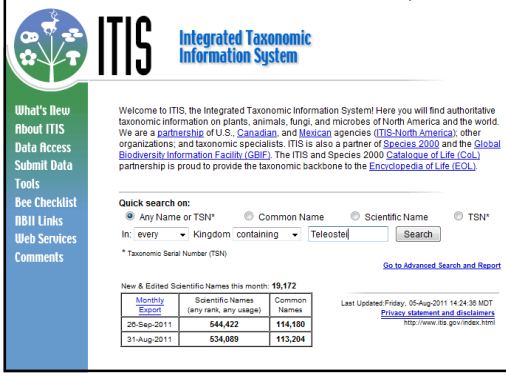
Pink anemonefish
(*Amphiprion perideraion*)

Port Jackson shark
(*Heterodontus portusjacksoni*)

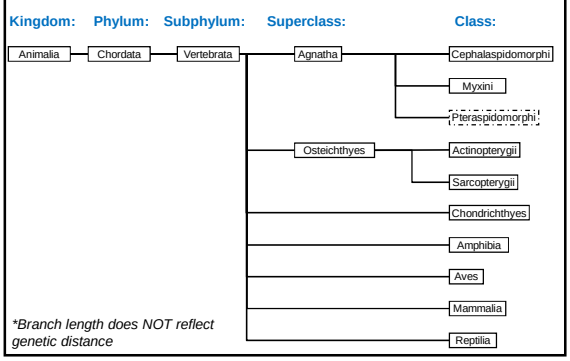
California grunion,
Leuresthes tenuis

Anglerfish
(*Linophryne indica*)

Fish RB: Taxonomy



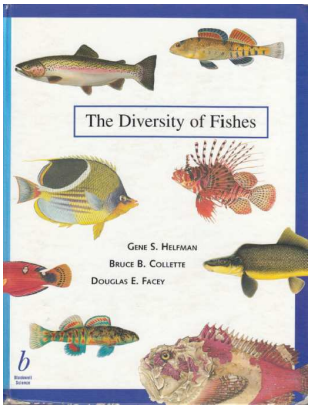
Fish RB: Taxonomy*



Branch length does NOT reflect genetic distance

Fish RB Diversity

MAIN SOURCE:
Helfman, G.S., Colette, B.B., and Facey, D.E. 1997. The Diversity of Fishes. Blackwell Science, Malden, MA.



Superclass Agnatha

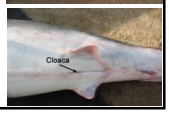
- Class Cephalaspidomorphi (lampreys)
  - RB relatively well understood
  - Gonochoristic
  - Semelparous
  - Anadromous (migrate up to 1000km!)
  - Make nests
  - Spawn many small demersal eggs

Superclass Agnatha

- Class Myxini (hagfishes)
  - RB poorly understood
  - Apparently gonochoristic
  - External fertilization
  - Few, large, unique, demersal eggs
  - Eggs incubate for about 2 months

Class Chondrichthyes

- Subclass Elasmobranchii (sharks, skates, and rays)
  - RB fairly diverse within group
  - Typically late maturity (sharks, 6-18 years)
  - Gonochoristic
  - Sexual dimorphism
    - Males with claspers, females without
    - Dentition and skin thickness due to spawning behavior
  - Internal fertilization
  - Shark gestation period averages 9-12 mo.



Class Chondrichthyes

- Subclass Elasmobranchii (sharks, skates, and rays)
  - 40% of elasmobranchs, including all skates, are oviparous (egg laying). Eggs fairly large with hard outer case attach to substrate.
  - 70% of sharks and all rays bear live young
    - Ovoviviparity- embryos in uterus with yolk sacs
    - Oophagy - embryos feed on eggs in uterus
    - Embryophagy- embryos feed on other embryos!!!
    - Placental viviparity - embryos in uterus with yolk sacs, which then attach to uterine wall to form a yolk sac placenta

Class Chondrichthyes

- Subclass Holocephali (chimaeras)
  - RB poorly understood
  - Gonochoristic
  - Separate anal and urogenital openings
  - Sexual dimorphism
    - Males with pair of claspers
    - Sometimes a 3rd clasper (tentaculum) on the head!
  - Internal fertilization
  - Lay relatively large leathery eggs

egg

Superclass Osteichthyes

- Class Sarcopterygii (lobe-finned fishes)
  - Subclass Coelacanthimorpha (Coelacanths; 1 species)
    - RB poorly understood
    - Gonochoristic
    - Male may be able to use cloaca as copulatory organ
    - Internal fertilization
    - Viviparous, lecithotrophic, live-bearers
    - Few (5-26) large (8.5-9cm) eggs
    - Clutch weight up to 12% of mother's weight
    - Gestation may be >1 year

Superclass Osteichthyes

- Class Sarcopterygii (lobe-finned fishes)
  - Subclass Dipnoi (lungfishes; 5 species)
    - Gonochoristic
    - Oviparous
    - South American species
      - lays eggs in burrows guarded by males
      - Sexual dimorphic- nest-guarding males help oxygenate eggs in burrows using vascularized fin filaments
    - Australian species
      - pair spawn
      - Deposit 50-100 eggs per spawn
      - No nest guarding
      - No larval stage

Superclass Osteichthyes

- Class Actinopterygii
  - Subclass Chondrostei
    - Order Acipenseriformes
      - Acipenseridae (sturgeons)
        - » Gonochoristic
        - » Late maturity (5-30yrs)
        - » Spawn every 3 to 5 years
        - » Oviparous
        - » GSI up to 25%
        - » Many small demersal eggs

Superclass Osteichthyes

- Class Actinopterygii
  - Subclass Chondrostei
    - Order Acipenseriformes
      - Polyodontidae (paddlefishes)
        - » Gonochoristic
        - » Late maturity (7-12yrs)
        - » Females mature later
        - » Oviparous
        - » Large GSI
        - » Many small demersal eggs on gravel bottoms

Superclass Osteichthyes

- Class Actinopterygii
  - Subclass Chondrostei
    - Order Polypteriformes (bichirs and reedfish)
      - RB poorly documented
      - Gonochoristic
      - Males compete for mates
      - Sexual dimorphism of anal fins
      - Male uses anal fins to improve fertilization rate during spawning then scatters eggs by thrashing with tail
      - Demersal eggs adhere to substrate
      - No parental care

Superclass Osteichthyes

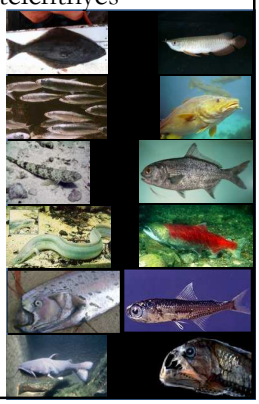
- Class Actinopterygii
  - Subclass Neopterygii
    - Order Amiiformes (the bowfin, *Amia calva*)
      - Gonochoristic
      - Mature by age 3
      - GSI 1.9-14.8% in females, 1.0% in males
      - Many (9-110 thousand) small, demersal eggs
      - Eggs laid in nest built by males
      - Males aggressively defend eggs and juveniles <100mm in length
      - Spawning activity may cause high mortality in males

Superclass Osteichthyes

- Class Actinopterygii
  - Subclass Neopterygii
    - Order Semionotiformes (gars)
      - Gonochoristic
      - Mature at 2-4 years
      - GSI 3-14% in females, 0.2-2.2% in males
      - Many (5000+) small (3.5mm) demersal eggs
      - Eggs are poisonous!!

Superclass Osteichthyes

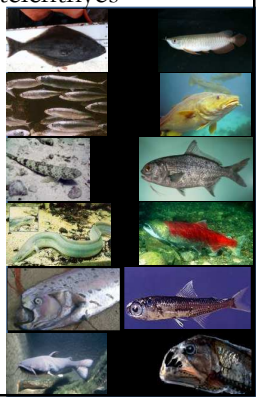
Class Actinopterygii
Subclass Neopterygii
Infraclass Teleostei (Teleosts)
12 Superorders
Acanthopterygii
Clupeomorpha
Cyclosquamata
Elopomorpha
Lampridiomorpha
Ostariophysi
Osteoglossomorpha
Paracanthopterygii
Polymixiomorpha
Protacanthopterygii
Scopelomorpha
Stenopterygii



Superclass Osteichthyes

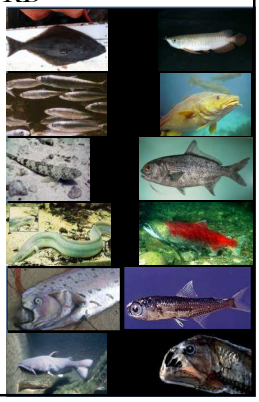
Class Actinopterygii
Subclass Neopterygii
Infraclass Teleostei (Teleosts)
39 Orders

Albuliformes
Anguilliformes
Ateleopodiformes
Atheriniformes
Aulopiformes
Batrachoidiformes
Beloniformes
Beryciformes
Characiformes
Clupeiformes
Ctenothrissiformes
Cypriniformes
Cyprinodontiformes
Elopiformes
Esociformes
Gadiformes
Gasterosteiformes
Gonorynchiformes
Gymnotiformes
Lampridiformes
Lophiiformes
Mugiliformes
Myctophiformes
Ophidiiformes
Osmeriformes
Osteoglossiformes
Perciformes
Percopsiformes
Pleuronectiformes
Polymixiiformes
Saccopharyngiformes
Salmoniformes
Scorpaeniformes
Siluriformes
Stephanoberyciformes
Stomiiformes
Synbranchiformes
Tetraodontiformes
Zeiformes



Teleost RB

- Contains most major fisheries species
- Most studied group
- Probably best studied separately
- RB hugely diverse!
- How do we organize this diversity?



Fish breeding systems (Wootton, 1990)

I. Number of breeding opportunities
   A. Semelparous – spawn once and die
   B. Iteroparous – spawn multiple times
II. Mating system
   A. Promiscuous – both sexes have multiple partners
   B. Polygamous – one or the other sex has multiple partners
   C. Monogamous – members of the opposite sex maintain pairs
III. Gender system
   A. Gonochoristic – separate sexes fixed at maturation
   B. Hermaphroditic – sex may change after maturation
      1. Simultaneous- both sexes in one individual
      2. Sequential – start as one sex then change to other sex
   C. Parthenogenetic – egg development without fertilization

Fish breeding systems (Wootton, 1990)

IV. Secondary sexual characteristics
   A. Monomorphic – both sexes look the same externally
   B. Dimorphic – sexes look different externally (at least sometimes)
V. Spawning site preparation
   A. No preparation – e.g. broadcast spawning
   B. Site prepared – e.g. nest building
VI. Place of fertilization
   A. External – outside the body
   B. Internal – inside the body (i.e. reproductive tract)
   C. Buccal – inside the mouth (e.g. some cichlids)

Fish breeding systems (Wootton, 1990)

VII. Parental care
   A. No parental care
   B. Male parental care
   C. Female parental care
   D. Biparental care – both parents give care
   E. Juvenile helpers – older siblings give care

Fisheries RB

- How do we deal with all of this in fisheries science?
- Much of the above can be considered **basic** RB
  - Largely qualitative
  - Many aspects are critical
- When a new fishery begins, there may be a scramble for **basic** RB
- For major established fisheries species…
  - **basic** RB is usually well understood
  - breeding systems are often similar (more on that in a moment)
  - more advanced details are usually not
  - spatial and temporal variation complicates matters
  - much of the current work is on advanced RB
  - much of the needed information is very quantitative

Fisheries RB

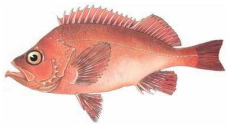
- "Normal" breeding system in marine fisheries species
  - I. Number of breeding opportunities
    Iteroparous
  - II. Mating system
    Could be any, but nobody really cares
  - III. Gender system
    Gonochoristic
  - IV. Secondary sexual characteristic
    Monomorphic
  - V. Spawning site preparation
    No preparation
  - VI. Place of fertilization
    External
  - VII. Parental care
    No parental care




Fisheries RB

- **BUT REMEMBER**: A lot of major fisheries species differ from the normal breeding system



Fisheries RB: Beyond the basics

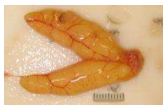
Major topic is fisheries reproductive biology

- Maturity
- Sex change
- Sex ratio
- Reproductive investment
- Egg characteristics
- Timing of spawning
- Spawning movements
- Spawning locations
- Variation in the above traits

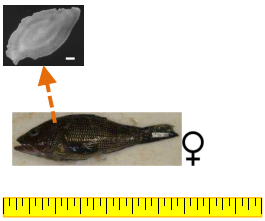
Fisheries RB: Beyond the basics

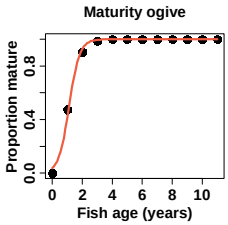
- Maturity
  - Age
  - Length

immature



mature

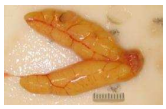




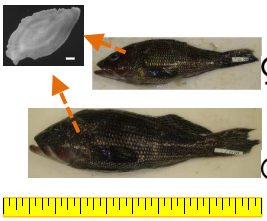
Fisheries RB: Beyond the basics

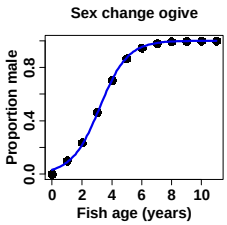
- Sex change
  - Age
  - Length

male



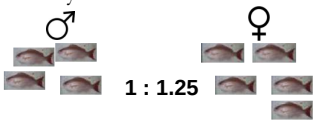
female





Fisheries RB: Beyond the basics

- Sex ratio
  - Current



1 : 1.25

  - Normal

gonochoristic

1 : 1

protogynous

1 : 1+

protandrous

1+ : 1

Fisheries RB: Beyond the basics

- Reproductive investment
  - Gonadosomatic index (GSI)
  - Fecundity

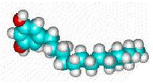
$$GSI = \frac{\text{gonad weight}}{\text{fish weight}} * 100$$

Fecundity = number of eggs

Fisheries RB: Beyond the basics

- Egg characteristics
  - Size
    - Diameter
    - Weight
  - Condition (quality)
    - Lipids
    - Other nutrients

coho salmon egg



lipid molecule

Fisheries RB: Beyond the basics

- Timing of spawning
  - Seasonal

off season
in season
peak season

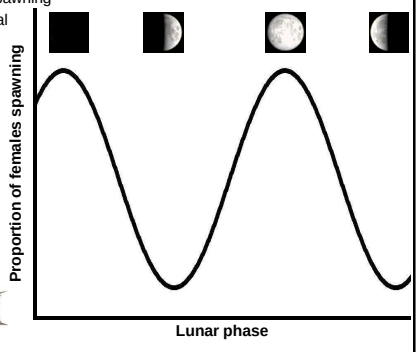
Acadian redfish

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Butterfish												
Cod												
Cusk												
Flounder, Am Plaice												
Flounder, Fourspot												
Flounder, Summer												
Flounder, Windowpane												
Flounder, Winter												
Flounder, Witch												
Flounder, Yellowtail												
Goosefish												
Haddock												
Hake, Red												
Hake, Silver												
Hake, White												
Herring, Atlantic												
Mackerel, Atlantic												
Pout, Ocean												
Pollock												
Redfish												
Sculpin, Longhorn												

NEFSC bottom trawl survey data

Fisheries RB: Beyond the basics

- Timing of spawning
  - Seasonal
  - Lunar

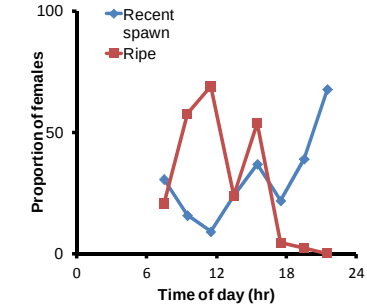


scamp

*Harris et al. 2002. Bull. Mar. Sci. **70(1)***

Fisheries RB: Beyond the basics

- Timing of spawning
  - Seasonal
  - Lunar
  - Diel (daily)

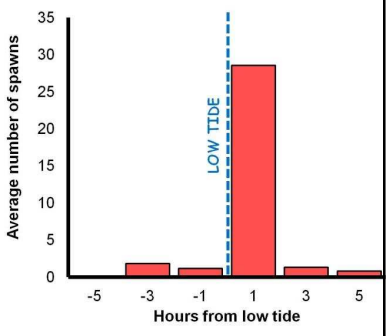


black sea bass

McGovern 2002 N. Am. J. Fish. Manage. 22(4)

Fisheries RB: Beyond the basics

- Timing of spawning
  - Seasonal
  - Lunar
  - Diel (daily)
  - Tidal

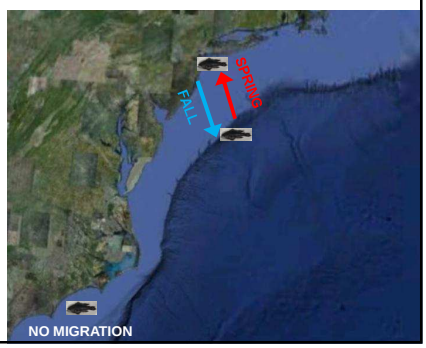


bullethead parrotfish

*Sancho et al. 2000. Mar. Ecol. Prog. Ser. **206***

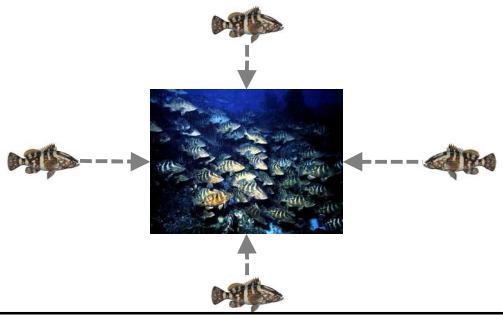
Fisheries RB: Beyond the basics

- Spawning movements
  - Migration



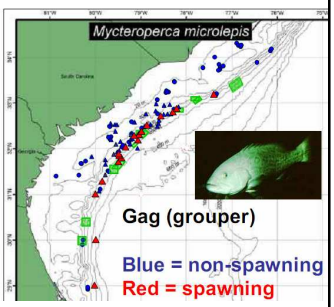
Fisheries RB: Beyond the basics

- Spawning movements
  - Migration
  - Aggregation



Fisheries RB: Beyond the basics

- Spawning location
  - Spawning areas

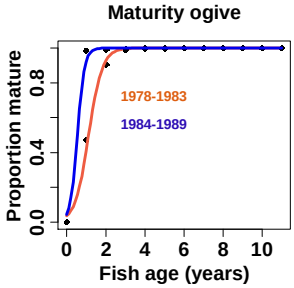


Fisheries RB: Beyond the basics

- Spawning location
  - Spawning areas
  - Offspring habitat


Fisheries RB: Beyond the basics

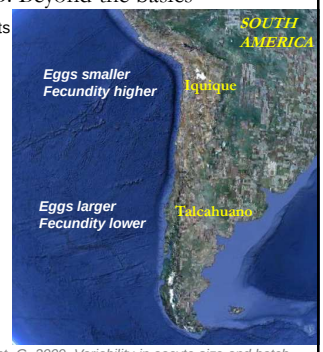
- Variation in the above traits
  - Temporal



Fisheries RB: Beyond the basics

- Variation in the above traits
  - Temporal
  - Spatial

Peruvian anchoveta (*Engraulis ringens*)



*Leal, E.M., Castro, L.R., and Claramunt, G. 2009. Variability in oocyte size and batch fecundity in anchoveta (Engraulis ringens, Jenyns 1842) from two spawning areas off the Chilean coast. Scientia Marina **73(1): 59-66.***

Fisheries RB: Beyond the basics

- Variation in the above traits
  - Temporal
  - Spatial
  - Demographic

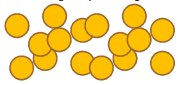
Atlantic cod
(*Gadus morhua*)

Small, first time spawners

-smaller eggs
-lower fecundity
-shorter spawning season

Larger, repeat spawners

-larger eggs
-higher fecundity
-longer spawning season



*Kjesbu, O.S., Solemdal, P., Bratland, P., and Fonn, M. 1996. Variation in annual egg production in individual captive Atlantic cod (Gadus morhua). Canadian Journal of Fisheries and Aquatic Sciences **53(3): 610-620.***

Fisheries RB: The nitty gritty

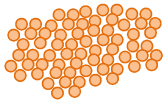
HOT topics in fisheries reproductive biology

- Spawning pattern
- Ovarian developmental organization
- Determinacy of oocyte recruitment
- Definitions of fecundity

Fisheries RB: The nitty gritty

- Spawning pattern

Total spawning



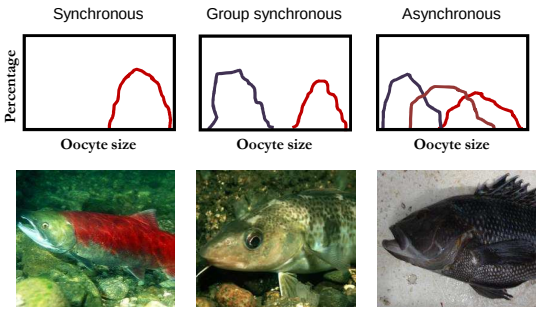
Batch spawning

All eggs are spawned at once

Eggs are spawned in batches over time

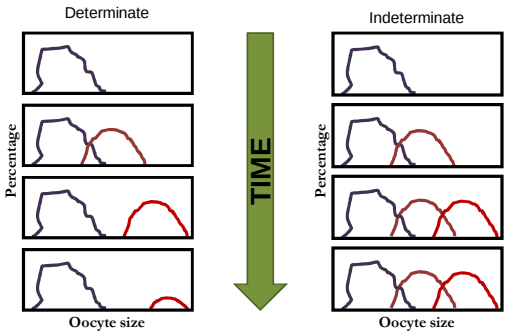
Fisheries RB: The nitty gritty

- Ovarian developmental organization



Fisheries RB: The nitty gritty

- Determinacy of oocyte recruitment



Fisheries RB: The nitty gritty

- Definitions of fecundity
  - Potential – number of oocytes present. MIGHT be spawned
  - Realized – number of eggs actually spawned
- When is potential fecundity ≠ realized fecundity?
  - Atresia – oocytes may be re-absorbed before becoming eggs
  - Down regulation