I. Deep Sea Fishes

II. Nocturnal-Diurnal Changeover (Twilight)

19 cm black swallower with 86 cm snake mackerel in its stomach

Deep Sea Fishes

Definition of open ocean habitats

Name	Depth
Epipelagic	0-200 m
Mesopelagic	200-1000 m
Bathypelagic	1000-4000 m
Abyssal	4000+ (up to 8000 m!)

Deep Sea

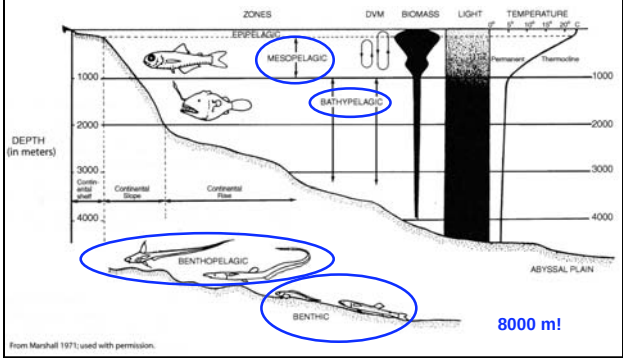
Largest habitat type on earth! (75% of ocean)

- **Primary production via photosynthesis occurs only in epipelagic (euphotic) zone**
  - where does the base of the food chain come from in the deep sea?

Types of Deep Sea Fishes

- **Mesopelagic**
- **Bathypelagic**

Benthal
- **Bethopelagic**
- **Benthic**



Types of Deep Sea Fishes

- **Mesopelagic** (~750 species)
- **Bathypelagic** (~200 species)
- **Benthal (Bethopelagic & Benthic)** (~1000 species)

Taxonomically diverse, but many common features:

- **photophores** (light emitting organs)
- **large mouths**
- **dagger-like teeth**
- **lures**
- **thin bones**
- **enlarged, tubular, or reduced eyes**

Why??

Convergent Evolution:

Organisms exposed to similar selective pressures are likely to evolve similar adaptations

Selective Pressures in the deep sea:

- pressure
- temperature
- light
- food
- space

Pressure

- every 10 m of depth adds 1 atm of pressure (14.7 lb/in^2)
  - surface = 1 atm
  - 10 m = 2 atm
  - 200 m = 21 atm
  - 1000 m = 101 atm
  - 8000 m = 801 atm (12,000 lb/in^2)
- presents challenges for using gas bladder
  - solutions:
    - close gas bladder duct ("secondary pysoclistous")
    - longer rete mirable
    - use lipids for buoyancy
    - reduce heavy tissues (bones & muscles)
    - eliminate gas bladder (benthal & bathypelagic)

zone	rete length (mm)
epipelagic	< 1 mm
mesopelagic	1-7 mm
bathypelagic	15-20 mm

Pressure (cont.)

- at great pressures, volume of water & protein molecules decreases

  -- affects rates of chemical reactions

solution:

- proteins that are less sensitive to effects of pressure (found in deep meso- and bathypelagic species)

Temperature

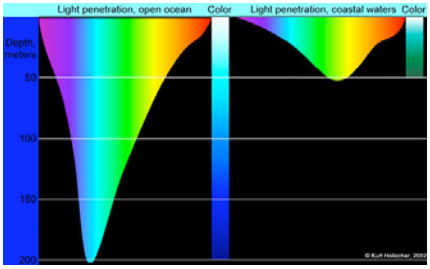
- low & constant in deep areas (2-5º C in bathypelagic region)
- up to 20º C difference for vertical migrators

Consequences:

- species usually found in specific temperatures regardless of latitude (i.e., different depths)
- vertical migrators have more DNA per cell, possibly for multiple enzyme systems for different temps.

temperature	fishes
10-20º C	Myctophids; Stomiidae
5-10	Sternoptychids; pale *Cyclothone*
2-4	Ceratioid anglers; dark *Cyclothone*

Light – the deep ocean is dim or dark



zone	
epipelagic	**euphotic**
mesopelagic	**twilight**
bathypelagic	**sunless**

Adaptations for low-light or no-light

Mesopelagic

- large eyes
- pure rod retinas (max sensitivity to blue-green)
- eye elongation (e.g., barrel eye)
- bioluminescence (5 superorders + Squaliformes)

Bathypelagic

- small eyes (for photophore detection)
- free neuromasts
- use of other senses (e.g., olfaction)

Overall:

-- more sensitive eyes (15-30 x more than humans)

-- can detect light deeper than human eyes

Food

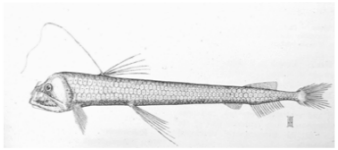
- Food is scarce, patchy, and unpredictable in the deep sea
- must be able to…
  1. go long periods without food
  2. obtain any food available

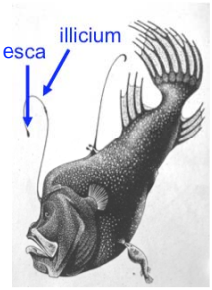
Adaptations:

- daggar-like teeth
- huge mouths
- huge stomachs
- pectoral girdle free from skull in some species
- lures

fangtooth (Anoplogastridae)

Lures





Going long periods without food:
adaptations for energy conservation in deep sea fishes

- low metabolism
- bone loss and reduction
- loss of scales
- reduction in musculature

Space

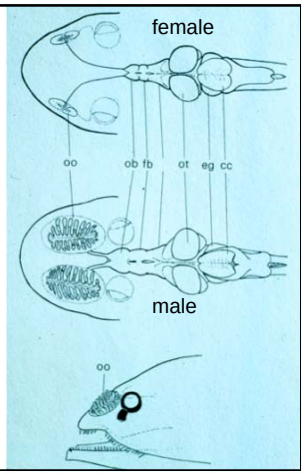
- the deep ocean is vast & densities of fishes are extremely low
  - -- hard to find food & mates
  - -- e.g., 1 female ceratioid anglerfish per 800,000 m^3 (a football in a darkened stadium)

sexual dimorphism related to mate finding…

Males:	Females:
• small	• large
• large olfactory organs	• small olfactory organs
• red muscle	• white muscle
• highly developed eyes	• poorly developed eyes
• high lipid reserves	• low lipid reserves

- also protandrous sex change in *Cyclothone*
- simultaneous hermaphroditism in some groups

Male *Cyclothone* have highly developed olfactory abilities



Taxa of Deep Sea Fishes

Mesopelagic (~750 species)
(superorders, orders, & families)

- Elopomorpha
  - – Notacanthiformes (Notacanthidae)
  - – Anguiliformes (Nemichthyidae; Synaphobranchidae)
- Protacanthopterygii
  - – Argentiformes (Microstomatidae; Opisthoproctidae; Alepocephalidae; Platytroctidae)
- Stenopterygii
  - – Stomiiformes (Gonostomatidae; Sternoptychidae; Stomiidae)
- Cyclosquamata
  - – Aulopiformes (Giganturidae; Synodontidae; Paralepididae; Evermannellidae; Alepisauridae)
- Scopelomorpha
  - – Myctophiformes (Myctophidae; Neoscopelidae)
- Lampriomorpha
  - – Lampriformes (Stylephoridae)
- Acanthopterygii
  - – Stephanoberyciformes (Mirapinnidae)
  - – Perciformes (Chiasmodontidae; Gempylidae)

Bathypelagic (~200 species)

- Elopomorpha
  - Anguiliformes (Nemichthyidae; Serrivomeridae; Saccopharyngidae; Eurypharyngidae)
- Protacanthopterygii
  - Argentiformes (Alepocephalidae)
- Stenopterygii
  - Stomiiformes (Gonostomatidae)
- Paracanthopterygii
  - Gadiformes (Melanonidae; Macrouridae)
  - Ophidiiformes (Ophidiidae; Bythitidae)
  - Lophiiformes (Ceratiidae)
- Acanthopterygii
  - Stephanoberyciformes (Melamphaidae; Stephanoberycidae; Cetomimidae)
  - Beryciformes (Anoplogastridae)
  - Perciformes (Chiasmodontidae)

Benthal (Bethopelagic & Benthic) (~1000 species)

- Elopomorpha
  - Notacanthiformes (Notacanthidae; Halosauridae)
  - Anguiliformes (Synaphobranchidae)
- Cyclosquamata
  - Aulopiformes (Chloropthalmidae; Ipnopidae)
- Paracanthopterygii
  - Gadiformes (Merluccidae; Moridae; Macrouridae)
  - Ophidiiformes (Ophididae; Bythitidae; Aphyonidae)
  - Lophiiformes (Ogcocephalidae)
- Acanthopterygii
  - Beryciformes (Caproidae)
  - Scorpaeniformes (Liparidae)
  - Perciformes (Zoarcidae; Bathydaconidae)

Mesopelagic Fishes

Elopomorpha
Anguiliformes, Nemichthyidae (snipe eels)

PROTACANTHOPTERYGII
Argentifomres, Opisthoproctidae (barrel eye)

Tubular eyes for light sensitivity and depth perception

PROTACANTHOPTERYGII
Argentiformes, Microstomatidae

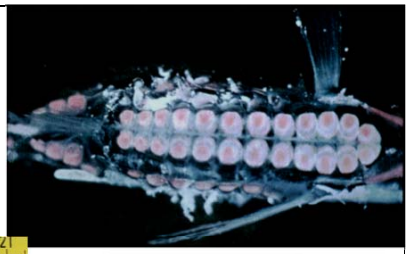
Bathylagus

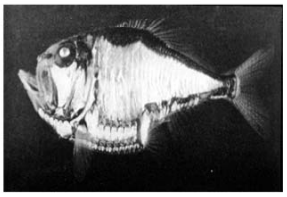
large eyes

STENOPTERYGII
(all deep sea)
Stomiiformes
Stomiidae
(barbeled dragonfishes)

STENOPTERYGII
• Sternoptychidae
(hatchetfishes)

Light Production:
• symbiotic bacteria
• luciferase





Bioluminescence has evolved in 5 Superorders & >500 spp.

(Protacanthopterygii, Stenopterygii, Scopelomorpha, Paracanthopterygii, Acanthopterygii + Squaliformes)

– Sex recognition

– Species recognition (like fireflies)

loosejaws (Stomiidae) may have their own private communication channel: produce and detect red light

CYCLOSQUAMATA
(cyclo = cycloid scales)

• almost entirely deep sea fishes

• up to 2 m

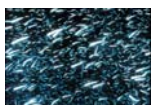
SCOPELOMORPHA
• all deep sea
• ctenoid scales

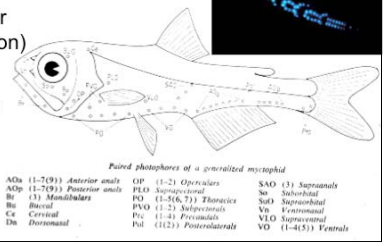
Myctophidae
(lanternfishes)

• diverse group >200 spp.

• deep scattering layer
(gas bladder reflection)

• taxonomy based on
photophore patterns

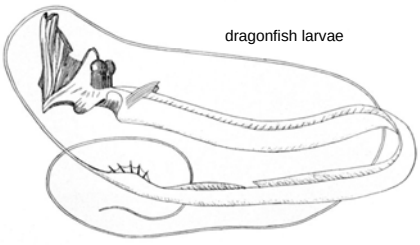




Paired photophores of a generalized myctophid

AOa (1–7(9)) Anterior anals
AOp (1–7(9)) Posterior anals
Br (3) Mandibulars
Bu Buccal
Ce Cervical
Dn Dorsonasal
OP (1–2) Opercular
PLO Supracleithral
PO (1–5(6,7)) Thoracics
PVO (1–2) Subpectorals
Pvl (1–4) Precaudals
Pol (1(2)) Posterolaterals
SAO (3) Supraanals
So Suborbital
SuO Supraorbital
Vn Ventronasal
VLO Supravental
VO (1–4(5)) Ventrals

Superorder Lampriomorpha “Strange Jaws”



• tube eyes

• 40 fold expansion of mouth volume during plankton feeding!

LAMPRIOMORPHA, Regalecidae

Bathypelagic Fishes

Elopomorpha, Saccopharyngiformes (gulper eel)

- huge mouth
- no opercular bones, branchiostegal rays, scales, pelvic fins, ribs, gas bladder, etc.
- "Perhaps the most anatomically modified of all vertebrate species" - Joe Nelson

STENOPTERYGII, Gonostomatidae (bristlemouths)

- most abundant and widely distributed vertebrates on earth!
- representatives in both mesopelagic and bathypelagic

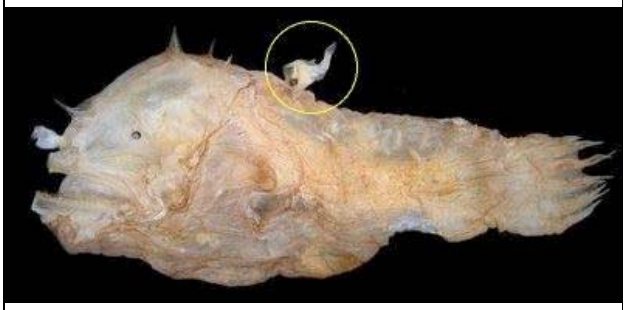
Paracanthopterygii, Gadiformes, Macrouridae (grenadiers/rattails)

Paracanthopterygii, Lophiiformes

Deep Sea Anglerfishes (Ceratioid Anglerfishes)

- Diverse group: 150+ spp.
- Lures
- What sex?

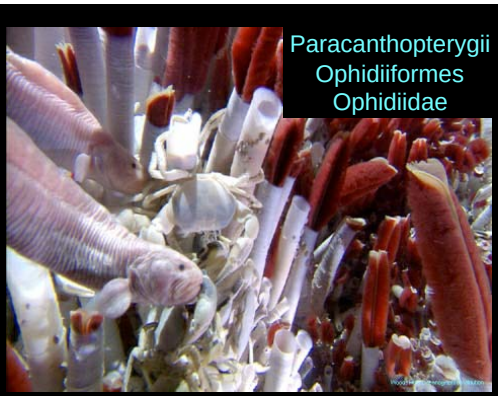
- males are small (males 2-4 cm max, females normally 10x longer than males, up to > 1 m long)
- neither sex matures until the male has attached



Benthopelagic and Benthic Fishes

Squaliformes (to 1000 m)
(prickly dogfish, *Oxynotus bruniensis*)

Cyclosquamata, Aulopiformes - tripodfishes (Ipnopidae)



Paracanthopterygii
Ophidiiformes
Ophidiidae

Deepest fish known is a cusk eel, *Abyssobrotula* (8370 m)

Acanthopterygii
Scorpaeniformes
fathead sculpins (Pyschrolutidae)

Acanthopterygii
Scorpaeniformes
snailfishes (Liparidae)

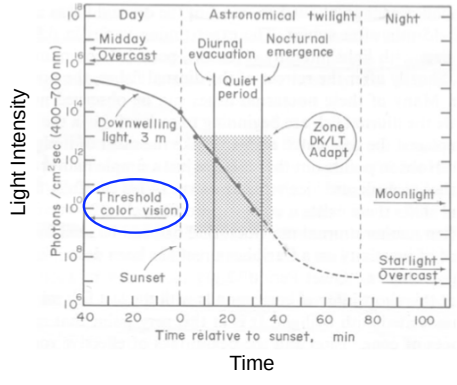
Acanthopterygii
Perciformes
Zoarcidae (eelpouts)

II. Light, Vision, & Ecology

Diel Variation in Fish Activity Periods

- **Diurnal** (day-active): 50-66% of fishes
- **Nocturnal** (night active): 25-33%
- **Crepuscular** (dawn and dusk): 10%

Diel light patterns are strong and predictable & cause strong temporal patterns in fish activity

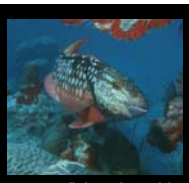


Coral reefs have the strongest patterns of diurnal-nocturnal changes in fish assemblage

- family-level patterns
  - most families are diurnal
  - key nocturnal families:
    - **Apogonidae**
    - **Holocentridae**
    - **Muraenidae**

Diurnal families

- Brightly colored
- Schooling or Territorial
- Herbivorous (all herbivores are diurnal)



Parrotfishes (Scaridae)

Damselfishes (Pomacentridae)

Rabbitfishes (Siganidae)

Surgeonfishes (Acanthuridae)

diurnal zooplanktivorous fishes

- huge stationary schools
- visual feeders on small plankton
- predator detection (many eyes)

anthias (Serranidae)

wrasses (Labridae)

Nocturnal Fishes

- ecological replacement sets for most diurnal groups

Zooplanktivores

Bigeyes (Priacanthidae)

Zooplanktivores (cont.)

Squirrelfishes (Holocentridae)

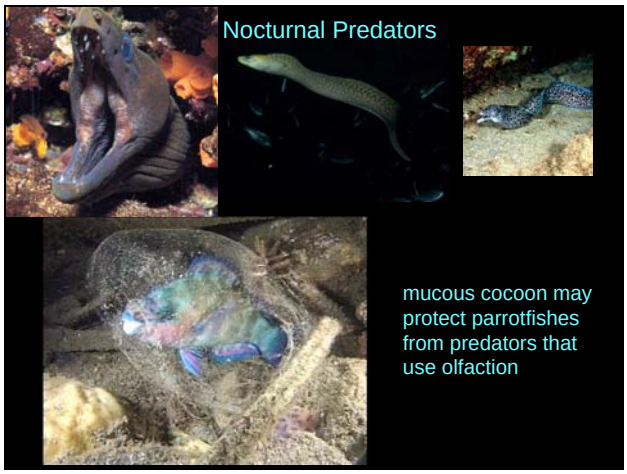
Why don't nocturnal fishes form large schools?

Zooplanktivores (cont.)

Cardinalfishes (Apogonidae)

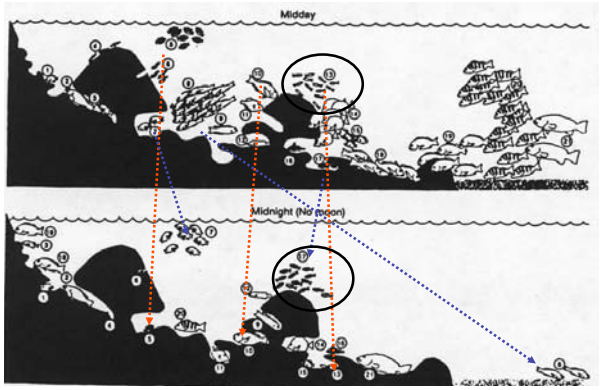
Haemulidae (Grunts)

- large daytime resting schools
- forage in sand and seagrass at night



Diurnal and Nocturnal Fishes-Summary

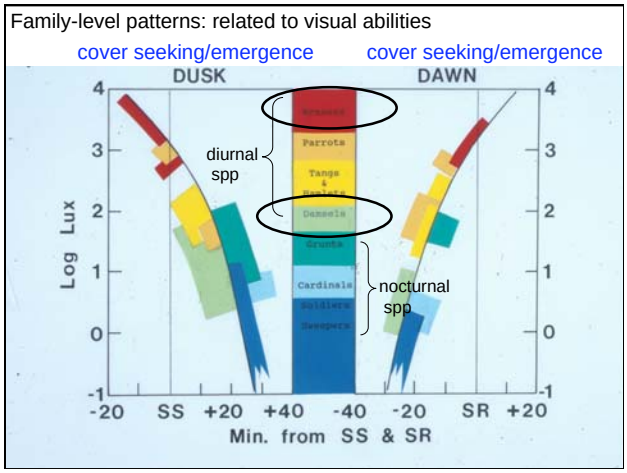
- more schooling in the day (both prey and predators)
- diurnal species more colorful
- no cleaner fishes or herbivores at night, but ecological replacement sets for other groups



Sequence of events on a coral reef at dusk:

1. migration of diurnal fishes (vertical or horizontal)
2. quiet period
3. shelter seeking (site fidelity)
4. emergence of nocturnal fishes

Family-level patterns: related to visual abilities



The quiet period (~15-30 min after sunset)

Nature's subtle signs of danger

Why is this a dangerous time to be in the water?

Diurnal Eyes
(many small cones)
- high light levels
- resolution
- motion detection
- color vision

Nocturnal Eyes
(rod dominated, few large cones)
- light capture