

I. Deep Sea Fishes

II. Nocturnal-Diurnal Changeover (Twilight)



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

Deep Sea Fishes

<http://www.youtube.com/watch?v=dFholu4VKms>



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!)

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

Deep Sea

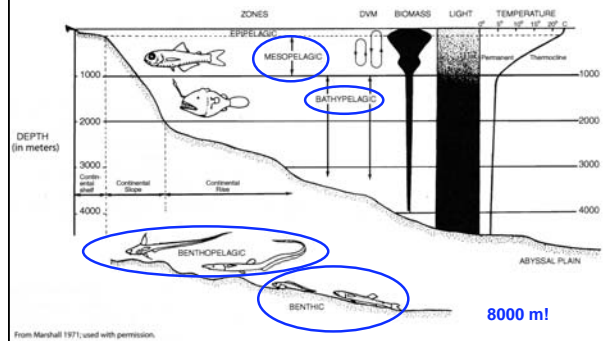
- Primary production via photosynthesis occurs only in epipelagic (euphotic) zone
- where does the base of the food chain come from in the deep sea?

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/in²)
 - surface = 1 atm
 - 10 m = 2 atm
 - 200 m = 21 atm
 - 1000 m = 101 atm
 - 8000 m = 801 atm (12,000 lb/in²)
- presents challenges for using gas bladder
 - solutions:
 - close gas bladder duct ("secondary physoclistous")
 - longer rete mirabile
 - 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

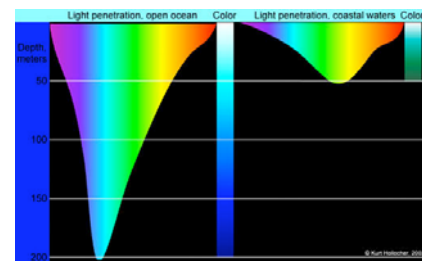
- low & constant in deep areas (2-5° C in bathypelagic region)
- up to 20° C difference for vertical migrators

Consequences:

- species are 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
10-20° C	Myctophids; Stomiidae
5-10	Sternoptychids; pale <i>Cyclothone</i>
2-4	Ceratioid anglers; dark <i>Cyclothone</i>

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 (used 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...
 - go long periods without food
 - obtain any food available

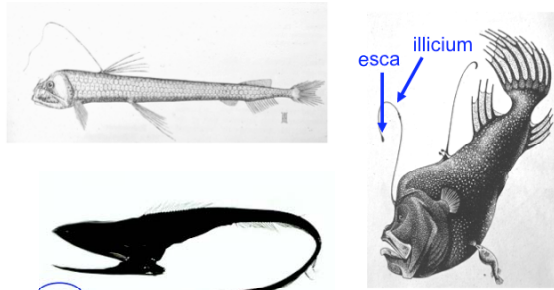
Adaptations:

- dagger-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 m³ (a football in a darkened stadium)

sexual dimorphism related to mate finding...

Males:

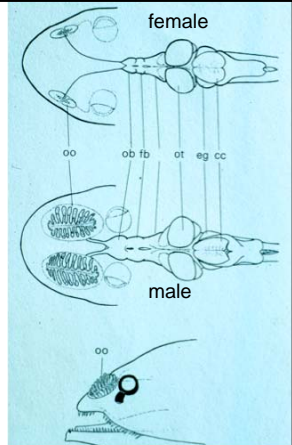
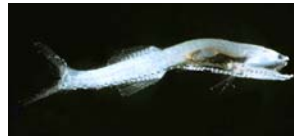
- small
- large olfactory organs
- red muscle
- highly developed eyes
- high lipid reserves

Females:

- large
- small olfactory organs
- white muscle
- poorly developed eyes
- 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)
 - Anguilliformes (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 (Ophididae; Bythitidae)
 - Lophiiformes (Ceratiidae)
- Acanthopterygii
 - Stephanoberyciformes (Melamphidae; Stephanoberycidae; Cetomimidae)
 - Beryciformes (Anoplogastridae)
 - Perciformes (Chiasmodontidae)

Benthal (Bethopelagic & Benthic) (~1000 species)

- Elopomorpha
 - Notacanthiformes (Notacanthidae; Halosauridae)
 - Anguiliformes (Synphobranchidae)
- Cyclosquamata
 - Aulopiiformes (Chlorophthalmidae; Ipnopidae)
- Paracanthopterygii
 - Gadiformes (Merlucciidae; Moridae; Macrouridae)
 - Ophidiiformes (Ophididae; Bythitidae; Aphyonidae)
 - Lophiiformes (Ogocephalidae)
- Acanthopterygii
 - Beryciformes (Caproidae)
 - Scorpaeniformes (Liparidae)
 - Perciformes (Zoarcidae; Bathyaconidae)

Mesopelagic Fishes

Elopomorpha
Anguiliformes, Nemichthyidae (snipe eels)



PROTACANTHOPTERYGII
Argentiformes, Opisthoproctidae (barrel eye)



<http://www.youtube.com/watch?v=RM9o4VnFHJU>



Tubular eyes for light sensitivity and depth perception

PROTACANTHOPTERYGII
Argentiformes, Microstomatidae



Bathylagus
large eyes

STENOPTERYGII

(all deep sea)

Stomiiformes

Stomiidae

(barbeled dragonfishes)

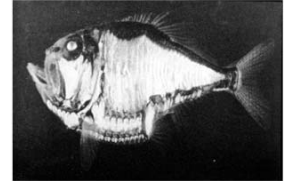


STENOPTERYGII

• 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

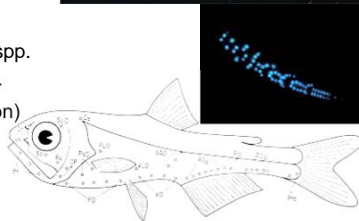
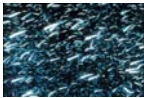


SCOPELOMORPHA

- all deep sea
- ctenoid scales

Myctophidae
(lanternfishes)

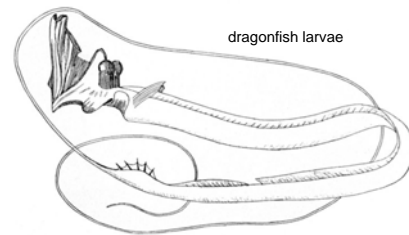
- diverse group >200 spp.
- deep scattering layer
(gas bladder reflection)
- taxonomy based on
photophore patterns



Paired photophores of a generalized myctophid

ADs (1-7/9) Anterior adials	DP (1-2) Dorsal photophores	SAO (3) Supranasal
ADp (1-7/9) Posterior adials	FD (1-2) Frontal dorsal	So Suborbital
Br (3) Branchiostegals	PD (1-5/6, 7) Pectoral dorsal	SOI Suborbital
Br (3) Branchiostegals	PVD (1-2) Pectoral ventral dorsal	Vp Ventrals
Cs Caudal	Pv (1-4) Pectoral ventral	VLO Ventrals lateral
Dn Dorsal	Pot (1/2) Postorbitals	VO (1-4/5) Ventrals

Superorder Lamprimorpha "Strange Jaws"



- tube eyes
- 40 fold expansion of mouth volume during plankton feeding!

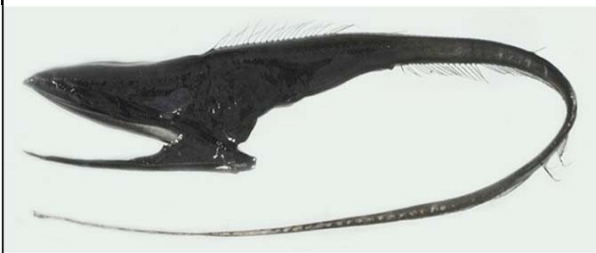
LAMPRIOMORPHA, Regalecidae



http://www.youtube.com/watch?v=...r2df_5S9M

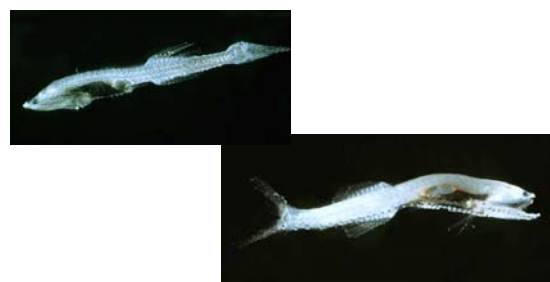
Bathypelagic Fishes

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)



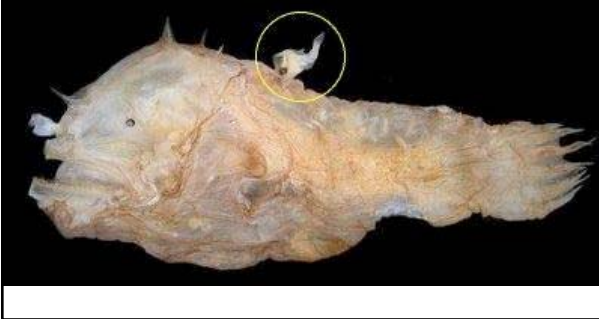
Paracanthopterygii, Lophiiformes

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*)



Hexanchiformes (to 1600 m)
(frilled shark, *Chlamydoselachus anguineus*)



<http://www.youtube.com/watch?v=qYH32gKMHuc>

Lamniformes (to 1300 m)
(goblin shark, *Mitsukurina owstoni*)

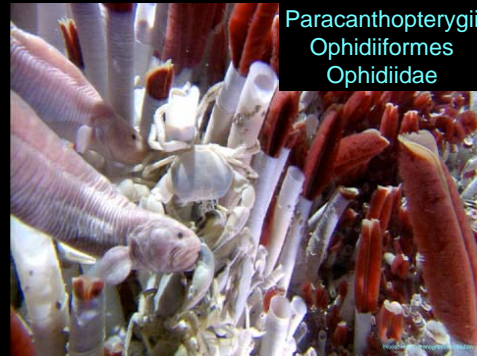


http://www.youtube.com/watch?v=eh_HUIJkRzU

Cyclosquamata, Aulopiformes - tripodfishes (Ipnopidae)



Paracanthopterygii
Ophidiiformes
Ophidiidae



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

Paracanthopterygii, Lophiiformes
Sea toads (Chaunacidae)

http://www.youtube.com/watch?v=Cl_MbvSUVTK

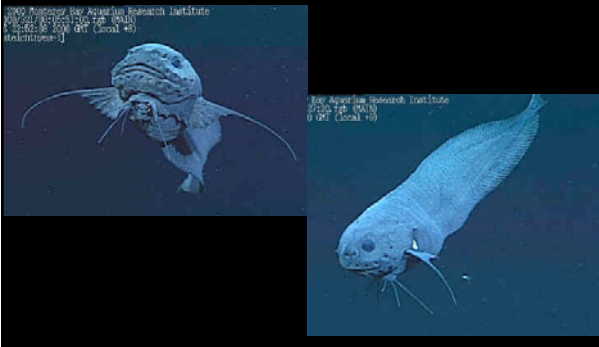


Acanthopterygii
Scorpaeniformes
fathead sculpins (Pyschrolutidae)



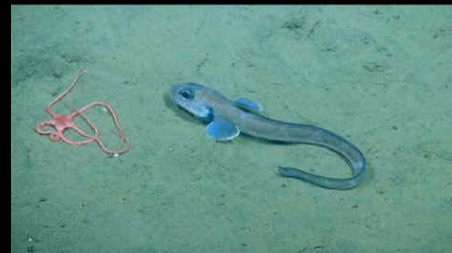
Acanthopterygii
Scorpaeniformes
snailfishes (Liparidae)

<http://www.youtube.com/watch?v=0mKotQs93Dc>



Acanthopterygii
Perciformes
Zoarcidae (eelpouts)

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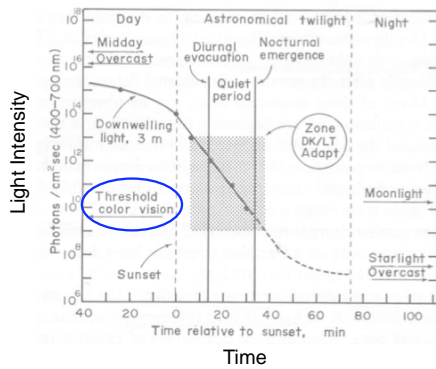


II. Light, Vision, & Ecology

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)



Damsel fishes (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



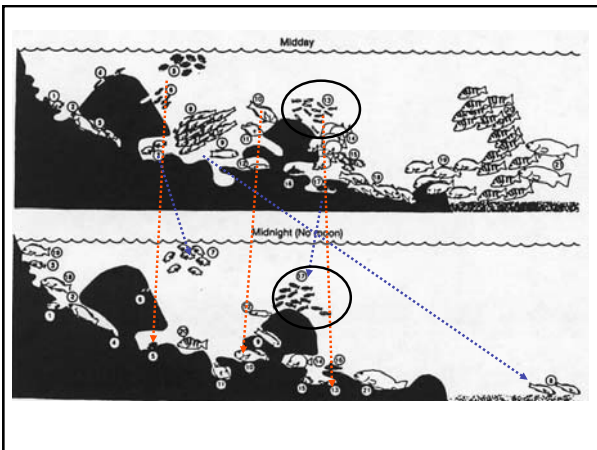
Nocturnal Predators



mucous cocoon may protect parrotfishes from predators that use olfaction

Diurnal and Nocturnal Fishes-Summary

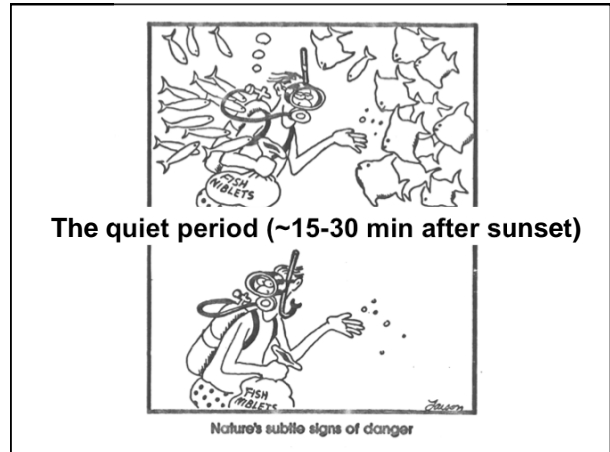
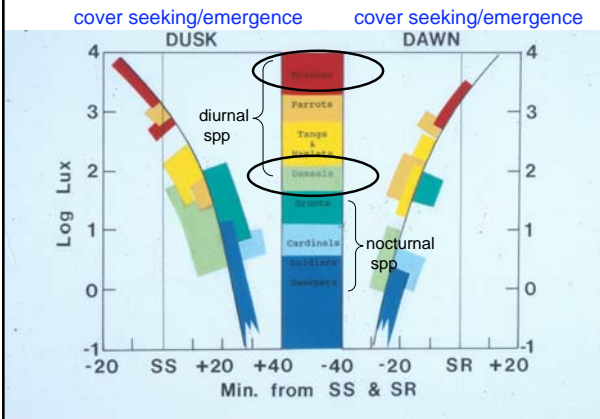
- more schooling in the day (both prey and predators)
- diurnal species more colorful
- no cleaner fishes or herbivores at night, but ecological replacement sets for other groups



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

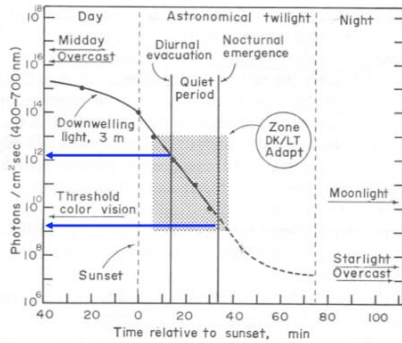


The quiet period (~15-30 min after sunset)

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



- Reaction distance of prey is shorter during twilight
- Predators have intermediate eyes
⇒ visual advantage at twilight!

