Aquatic Systems and Environmental Health

MARINE MAMMALS OF THE OCEANS

Solutions to difficult problems:

Living in water

Living around humans

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Topics

- Diversity of marine mammals
- Adaptations to marine lifestyle
- Threats to marine mammals

What are marine mammals?

- Air-breathing mammals that live in a marine and/or brackish environment for all or part of their lives.
- The marine mammal group includes: polar bears, sea otters, walruses, sea lions, seals, sirenians (manatees & dugongs) and cetaceans (whales and dolphins).

Partially vs. permanently aquatic marine mammals?

- Some of these still have a terrestrial body plan (e.g. polar bear and sea otter) adapted to take advantage of coastal habitat but allowing regress onto land.
- Conversely, cetaceans and sirenians are adapted for permanent residence in the water and are relatively helpless on land.

Exceptions exist for most things…

- The following information is a general guide to marine mammal life history. Marine mammals comprise a VERY diverse and highly adapted group. Exceptions exist for most things I will discuss…

Sea Otters

www.allposters.com

www.veer.com

Sea Otters

-Basic life history

-Near-shore waters from Japan, along Aleutian Islands, to California

-Benthic invertebrates, cephalopods, and fish

-IUCN Status: Endangered

-Appearance

-Densest fur of all mammals (100,000 hairs/cm²)

-Terrestrial body plan with minor modifications (e.g. webbed feet, flattened tail, etc.)

- Sexual dimorphism (males larger: 148cm, 45kg)

Polar bears

www.solcomhouse.com

Polar bears

-Basic life history

-Circumpolar distribution in North pole

-Ringed seals (other seals, walruses, belugas)

-IUCN Status: Vulnerable

-Appearance

-White, dense fur with long guard hairs

-Large, partially-webbed front paws

- Sexual dimorphism (males larger: 250cm, 800kg)

Walruses/Sea Lions

www.tundrabuggyweather.com

www.odt.co.nz

Walruses (1)/Sea Lions (15)

-Basic life history

-Sea lions: fish and invertebrates (neritic to oceanic, epipelagic to benthic); global (not in Mediterranean)

-Walruses: benthic invertebrates; circumpolar Arctic and subarctic distribution

-Appearance

-External pinnae (ear flaps)

-Thick fur (sea lions) with heavy subcutaneous fat layer

-Modified forelimbs (swim with forelimbs)

Forelimbs lengthened and paddle-shaped

-Teeth reflect lifestyle (e.g. generic all-purpose teeth, molars for crushing, tusks for rooting)

-Sexual dimorphism (males larger)

Seals

www.innatmerrobay.com

www.seagrant.uaf.edu

Seals (Phocids)

-Basic life history

-Diet: krill, fish, invertebrates (neritic to oceanic, epipelagic to benthic)
-Range: worldwide distribution, pole to pole
-Habitat: Spend most time at sea. Some shallow water, some deep.
Haul out for mating and parturition
-IUCN Status: Least Concern (Crabeater seal) to extinct (Carribean monk seal)

-Appearance

-No external pinnae
-Thick fur with heavy subcutaneous fat layer
-Modified hind-limbs
-Limbs shortened, knees tucked in, swim with hind flippers
-Teeth reflect lifestyle (e.g. incisors of ice seals angled outward for carving ice holes)

Porpoises, Dolphins & Whales

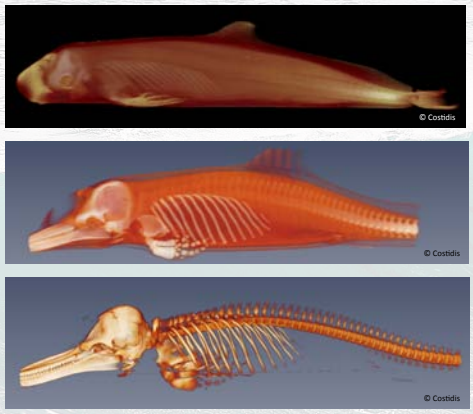
Porpoises, Dolphins, & Whales (Cetaceans)

-Basic life history

-Range: All oceans and some rivers
-Diet: Fish, invertebrates, mammals
-Status: Species of special concern-Critically endangered-Extinct

-Appearance

-No fur (rostral hairs at birth). Smooth skin
-No hind limbs (pelvic vestiges); delicate pectoral flippers
-Dorsal blowholes (telescoping of skull bones)
-Porpoises
Small bodies
Spade-shaped teeth
-Odontocetes
Toothed whales: dolphins, beaked whales, narwhals, river dolphins, etc.
Hunters (fish, squid, etc.)
-Mysticetes
Baleen whales: gray, blue, fin, humpback, right, etc.
Grazers (fish, krill, plankton, etc.)



Sirenians

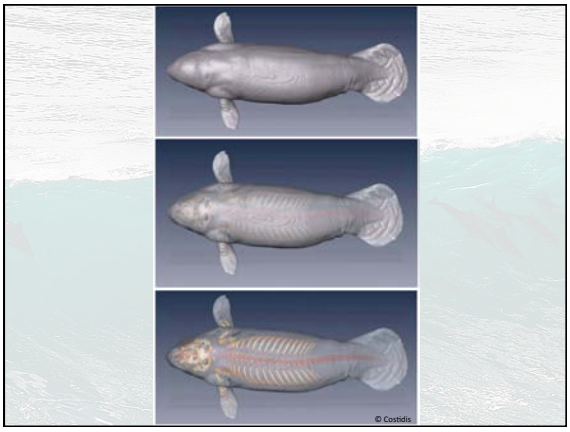
Sirenians

-Basic life history

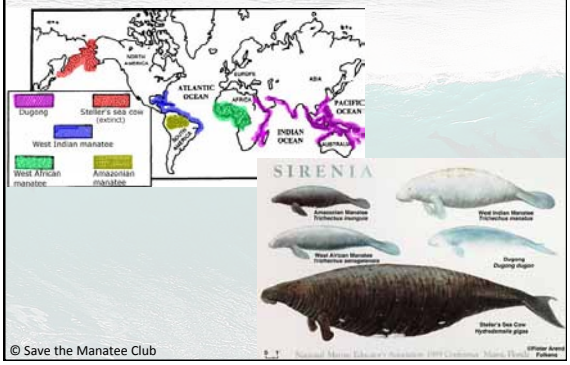
-Herbivorous (opportunistic carnivores)
-Tropical and subtropical (manatees: coastal, dugongs: oceanic)
-Status: Vulnerable

-Appearance

-No fur (body hairs present)
-No hind limbs; Strong pectoral flippers
-Manatees: Broad paddle (fluke) for propulsion
-Dugongs: two whale-like paddles
-Variable rostral deflection reflects different feeding habits



Sirenians



© Save the Manatee Club

Living in Oceans

Physiological Challenges

We often take for granted some of the enormous challenges that marine mammals cope with on a regular basis.

- How to conserve water in a desert (saline environment)?
- How to escape the cold when you live in it?
- How to move through water efficiently?
- How to avoid suffocating? Pray are down, air is up!
- How to find pray or mate?
  - Oceans cover 72% of earth's surface
  - Ocean volume: 1.3-1.4 billion cubic kilometers
  - Average depth: ~3,700 meters
  - Dysphotic zone starts at 100m
- How to deal with deep sea pressures?

Living in water (Energetics)

–Water retention

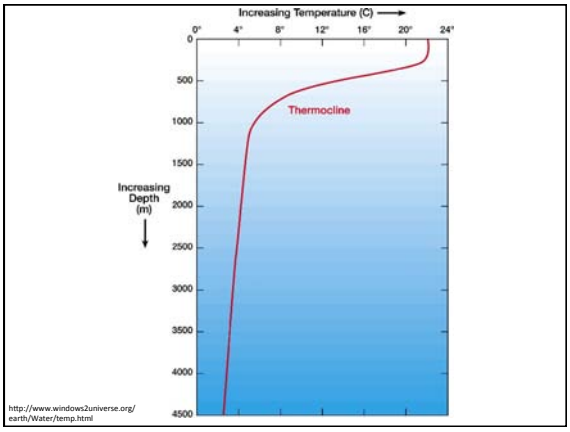
Marine mammals essentially live in a dessert. The saline environment provides constant osmotic pressures driving water out of the body. The body must therefore resist these forces (e.g. impermeable skin, renal ultrafiltration/urine hyperconcentration, etc.)

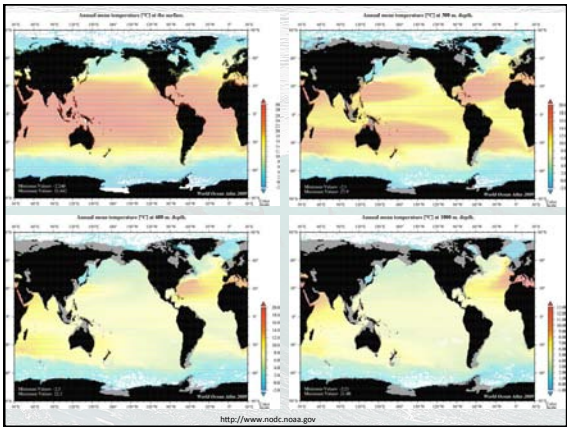
Living in water (Energetics)

–Temperature/Thermoregulation

Water draws heat away from the body 25 times faster than air

- » **$H' = (SA)C(T_b - T_a)$** where H' = conductive heat loss, SA = surface area, C = thermal conductance, T_b = body temperature, and T_a = ambient temperature
- » Blubber (e.g. whales), subdermal fat (e.g. manatees), or fur (e.g. sea otter) for insulation; Increased insulation = Decreased C
- » Reduction of external protuberances; Decreased SA = Decreased H'
- » Elevated metabolic rate (e.g. dolphins); Increased MR = Increased T_b
- » How does an animal designed to conserve heat, get rid of heat when it is exercising? Vascular modifications.





Living in water (Movement)

- Locomotion (Prey capture/predator avoidance/energetically efficient swimming)

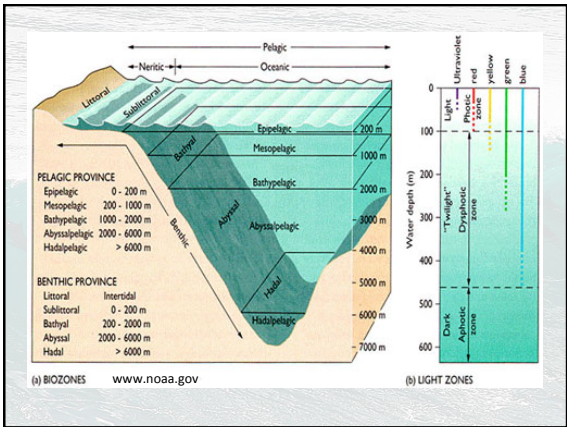
  Viscous (D_v) and pressure (D_p) drag forces (e.g. Reynold's number) necessitate reduced SA:V and streamlining
  - » Loss of external protuberances = Decreased SA (e.g. loss of hindlimbs and external ears) (D_v)
  - » Fusiform (spindle-shaped) body (D_p)
  - » Axial locomotion (vs. appendicular) (D_v & D_p)
  - » Shedding/sloughing of skin (D_v)
  - » Lateral stabilization (e.g. dorsal fin)
  - » Telescoping of the skull (D_p)

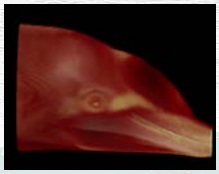
Living in Water (Oxygen)

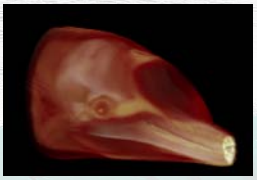
- Breath holding is imperative
  - » Increased oxygen stores (e.g. myoglobin, blood volume, hemoglobin binding affinity, etc.)
    - 2X muscle and blood O2 stores of humans (Reynolds & Rommel)
  - » Vascular control (e.g. shunting and compartmentalization of oxygen and metabolites, bradycardia, etc.)
  - » Reduced oxygen utilization (e.g. hypometabolic state, peripheral vasoconstriction, etc.)
  - » Other modifications (e.g. missing intrinsic blood clotting factors, elevated LDH, etc.)

Living in water (Sensing)

- Sensing the surroundings
  - » Sight (diffraction, refraction, aphotic zones, etc. Sea lions/ dolphins vs. river dolphins/manatees)
    - Color vision (e.g. seals?) vs. monochromatic (e.g. manatees?)
  - » Hearing (localization: sound travels 5 times faster in water than in air; low frequency vs. high frequency)
  - » Feel (vibrations travel farther…manatee body hairs…river dolphins?)
  - » Smell (loss of olfactory bulb)







Dealing with the pressure

- Hydrostatic pressure increases by 1atm. every 10 meters.
  - Surface: 1atm
  - 10m: 2atm
  - 100m: 11atm
  - 1000m: 110atm (5,850lb/in^2)
    - Modern submarines have a crush depth of 600-700m.

Phocid Extreme Divers

- Elephant seals
  - 1,000-2,500ft (330-800m), 20-30 min.
  - Max 4,600ft (1,400m) (Southern elies)
- Hooded seals
  - 325-1,950 feet (100-600m), 15 min
  - Max 3,280ft (1,000m)

Cetacean Extreme Divers

- Sowerby's beaked whale
  - 28min dive, 4,920ft (1,500m)
- Sperm whale
  - 35min average dive to 1,312 ft (400m); max dive 3280ft (1,000m)
- Blainville's beaked whale
  - 20-45min, 1,600-3,300ft (500-1,000m); >54min and 4,600ft (1,400m) recorded
- Baird's beaked whale
  - 11-30min, Average 2,500-4,000ft (800-1,200m); maybe capable of 9,840ft (3,000m) and 67min
- Northern bottlenose whale (beaked whale)
  - Common depths 2,600-5,000ft, 10-60min; Likely capable of 2hr dive.

Info from www.nmfs.noaa.gov/pr

Other considerations

- Size helps with temperature but it has other implications:
- Action potential for myelenated axons: 10m/s to 120m/sec
- Action potential for unmyelinated axons: 5-25m/sec
- Conduction velocity increases with fiber diameter
- Capacitance is prop to diameter
- Resistance is inv prop to diameter
- Blue whale 33meters long (66 two way for reaction to a touch stimulus). Integrated spinal axons can reach 30meters. Peripheral nerves can be an additional few meters (e.g. afferent skin). Roundtrip can be even longer than 66meters. Therefore, depending on conduction speed, it could take anywhere from 1-6 seconds or more (adding synaptic transmission and temporal processing) to respond to a touch stimulus in the tail. Might blue whale be max size animal can grow and still be functional and responsive?

Living in Oceans

Environmental and Anthropogenic Challenges

Environmental Stressors & Threats to the Populations

- Prey availability (e.g. Orca switching to sea otters)
- Habitat depletion/ degradation
- Pollution (debris ingestion, entanglement, PCBs, oil, noise pollution)
- Vessel interactions (ship/ boat strikes, vessel traffic, ecotourism, noise/ harassment)
- Fishing interactions
- Hunting/poaching
- Harmful Algal Blooms (HABs: red tide, domoic acid, etc.)
- Meteorological influences (e.g. storms, tides, temperature, etc.)
- Disease (e.g. brucella, West Nile, toxoplasma, San Miguel Sea Lion virus, etc.)
- Predation

Marine debris and depredation

Plastic Ingestion

Entanglements

Fisheries Interaction/Bycatch

By-catch Data for Cetaceans

- Commercial Fisheries: Gill nets, Long-lines, crab/lobster pots, shrimp trawls…
  - Entanglement, depredation (hooking)
- Recreational fisheries
  - Entanglements and depredation (hooking)

Marine Mammal Bycatch U.S.

(Read *et al*., 2006)

- 1990
  - Cetaceans (N = 5025)
  - Pinnipeds (N = 1965)
  - Total (N = 6990)
- 1999
  - Cetaceans (N = 1782)
  - Pinnipeds (N = 2344)
  - Total (N = 4126)

Global Marine Mammal Bycatch

(Read *et al.* 2006)

- Gill net
  - 1990 (N = 649,154)
  - 1994 (N = 570,478)
- Trawl
  - 1990 (N = 3,719)
  - 1994 (N = 3,904)
- Other
  - 1990 (N = 3,717)
  - 1994 (N = 9,849)

"Workable solutions will likely need to be tailored to each fishery and cetacean bycatch species and will probably involve compromises by both industry and conservationists. They will entail combinations of technological developments, scientific discoveries, management enforcement actions, educational programs, cooperative studies, and economic and social reforms."

Jefferson, T.A. and Curry, B.E. 1994. A global review of porpoise (*Cetacea: Phocoenidae*) mortality in gillnets. *Biological Conservation*, (67)167-183.

Watercraft Mortality Data for *T.m.* & *E.g.*

- ~24% of Florida manatee deaths (Lightsey *et al*. 2006)
  - More deaths are due to impact than propeller injury (propeller guards not effective)
  - WC injuries are so common, they are used for photoID of manatees
  - Estimates that over 90% of FL manatee population has been struck at least once
- As many as 36% of North Atlantic Right Whale mortalities from 1970-1999 were caused by vessel collisions (Knowlton and Kraus, 2001).
  - Single greatest identified cause of death in NARWs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Acute vs. Chronic W/C Injuries

- It should be noted that sub-lethal injuries can also cause serious problems:
  - Chronic ailment/impairment
  - Delayed mortality
  - Reduced fecundity/reproductive success

U.S. National Oversight Agencies

- National Marine Fisheries (Dept. of Commerce)
  - All cetaceans
  - All phocids (seals) and otariids (sea lions)
- U.S. Fish and Wildlife Service (Dept. of Interior)
  - Florida manatees
  - Walruses
  - Sea Otters
  - Polar bears

Management/Conservation

- Marine Mammal Protection Act (1972)
  - All marine mammals
- Endangered Species Act (1973)

  21 Listed species
  - North Atlantic Right whale
  - Bowhead whale
  - Fin whale
  - Gray whale
  - Blue whale
  - Sperm whale
  - Monk seal (Mediterranean and Hawaiian)
  - Etc.
- International Whaling Commission
- Magnuson-Stevens Fishery Management and Conservation Act (1976)

Monitoring and Mitigation

- Stranding networks (mortality/disease monitoring)
- Take reduction plans and teams (strategic stocks)
- Gear modifications
- Outreach/education
- Fisheries observer program

Considerations (opinions…)

Due to the degree of influence we have had and continue to have on the environment, there are often times conflicting conservation goals (e.g. artificial warm water effluents for manatees cause thermal pollution that challenges fish spawning grounds)

Considerations (opinions…)

Any conservation plan is likely to be a temporary fix. We cannot expect through conservation programs to orchestrate a level of balance that nature achieved over millions of years.

The only meaningful long term preservation can happen through a change in mentality (e.g. reduce over-population) and life style (e.g. reduce over-consumption) on our part. The way to best conserve our environment may be to have as little impact (positive or negative) on it as possible.

Considerations (opinions…)

- Although most western cultures believe that harvesting of meat from dolphins and whales is a cruel practice, most of those cultures have adopted fishery regulations that allow a certain number of cetacean deaths (through bycatch) each year.

International Dolphin Conservation Program Act:

SEC. 2. PURPOSES AND FINDINGS

"The Congress finds that--

(1) the nations that fish for tuna in the eastern tropical Pacific Ocean have achieved significant reductions in dolphin mortality associated with the purse seine fishery from hundreds of thousands annually to fewer than 5,000 annually"

SEC. *4. AMMENDMENTS TO TITLE I*

Section 101(a)(2) (16 U.S.C.137 l(aX2))

"(iii) the total dolphin mortality limits, and perstock per-year dolphin mortality limits permitted for that nation's vessels under the International Dolphin Conservation Program do not exceed the limits determined for 1997, or for any year thereafter…"