FUNDAMENTALS OF FISH BIOLOGY
FT 273

Monday, 24 February 2014

Buoyancy, Thermal Regulation and Ion Balance www.thesca.org/serve

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FT 273 Fish Presentations

Poll initiated by Reid Brewer | 0 | 0 | less than a minute ago

Table view | Calendar view

	March 2015 Mon 30			April 2015 Mon 6			Mon 13			Mon 20								
0 of 19 invitees	7:00 PM	7:20 PM	7:40 PM	7:00 PM	7:20 PM	7:40 PM	7:00 PM	7:20 PM	7:40 PM	5:00 PM	5:20 PM	5:40 PM	6:00 PM	6:20 PM	6:40 PM	7:00 PM	7:20 PM	7:40 PM
reid.brewer																		

Cannot make it | Save

Comment

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WHY SHOULD I LISTEN TODAY?

SPECIFIC OBJECTIVES

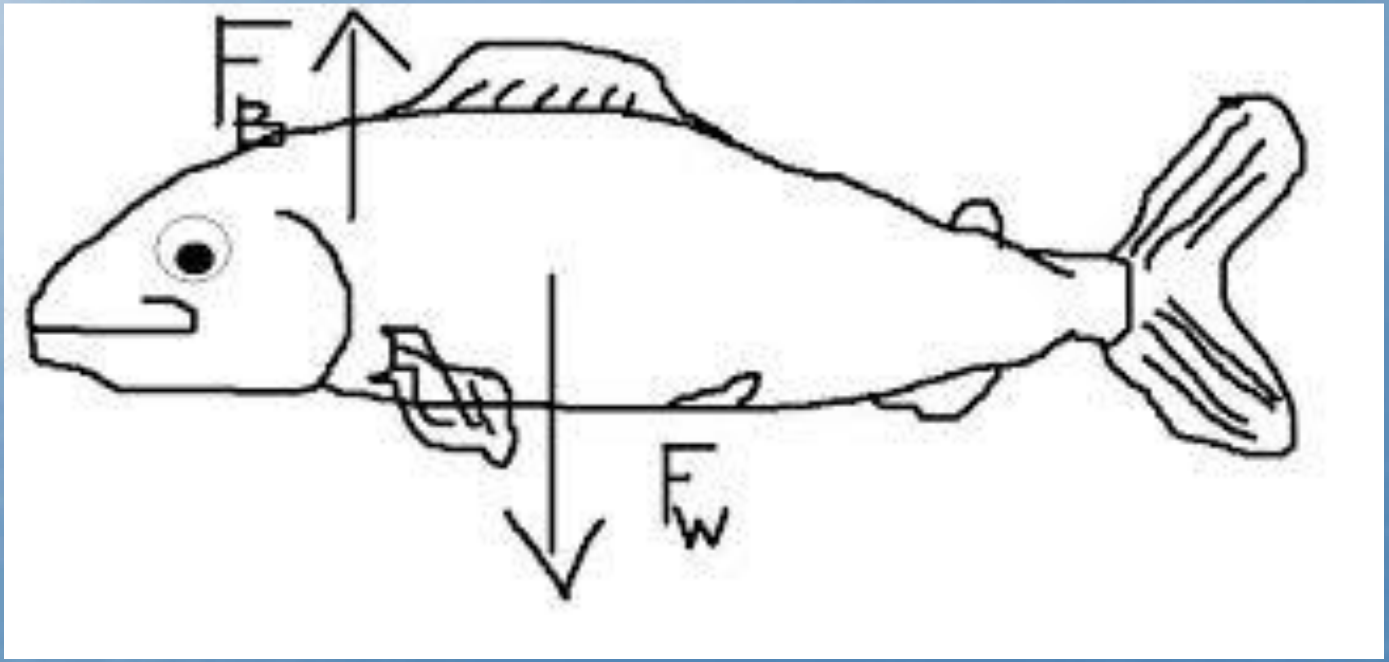
1. Describe the four ways that a fish can achieve neutral buoyancy
2. Differentiate physostomus and physoclistous gas exchange and describe how they work

3. Describe how fish use behavioral and physiological thermoregulation
4. Define euryhaline and stenohaline and describe the challenges associated with each

5. Describe the responses of fish to shock or stress
6. Explain how fish can change their freezing resistance in cold climates

NEUTRAL BUOYANCY

- Energetically costly using propulsion alone!



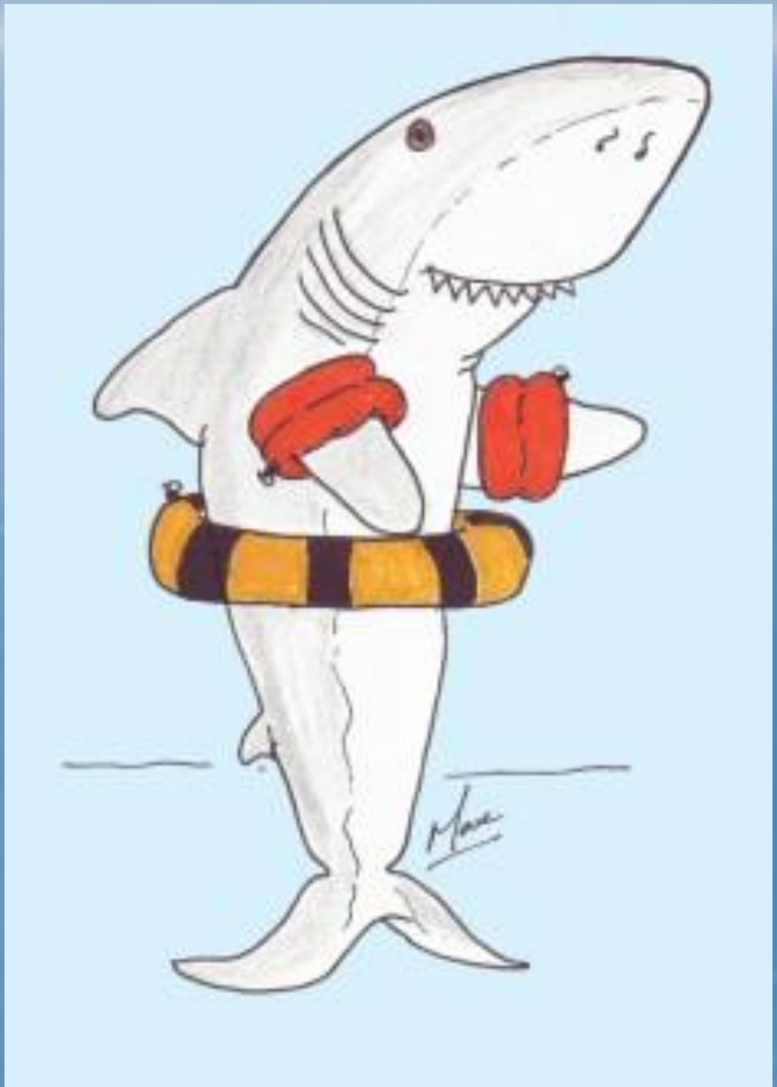
FOUR WAYS TO ACHIEVE NEUTRAL BUOYANCY

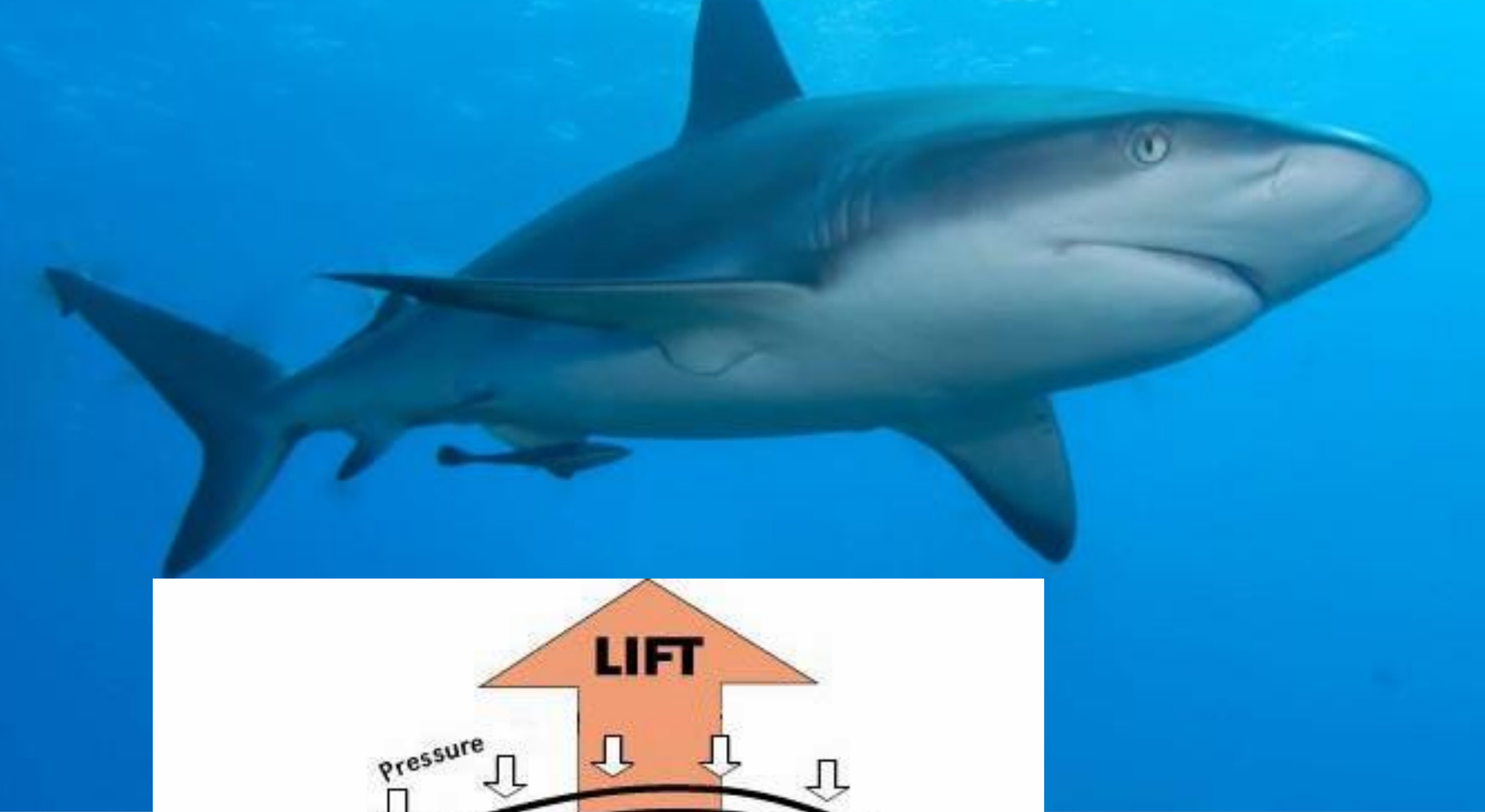
1. Incorporate low density compounds (lipids)
2. General movement patterns
3. Reduction of heavy tissues
4. Incorporate a swim-bladder

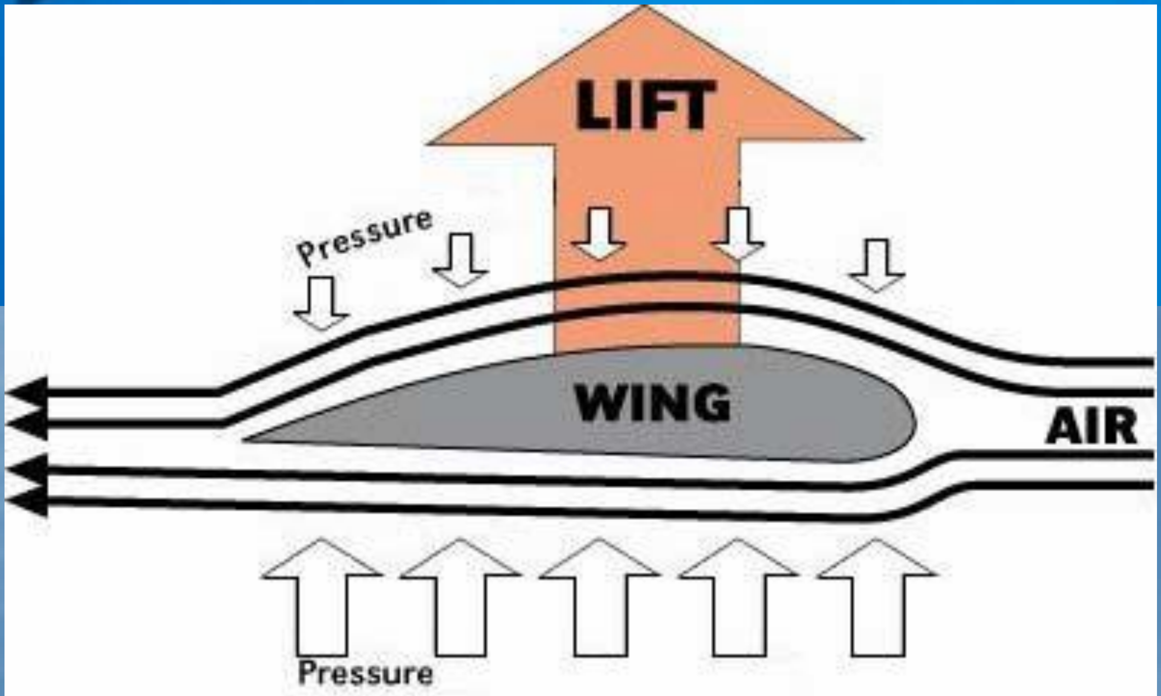
1. LOW DENSITY COMPOUNDS


Healthy Care
Australia
For General Wellbeing
SQUALENE
1000mg
Natural Food
Supplement
200 Capsules
AUST L 122596


2. GENERAL MOVEMENTS



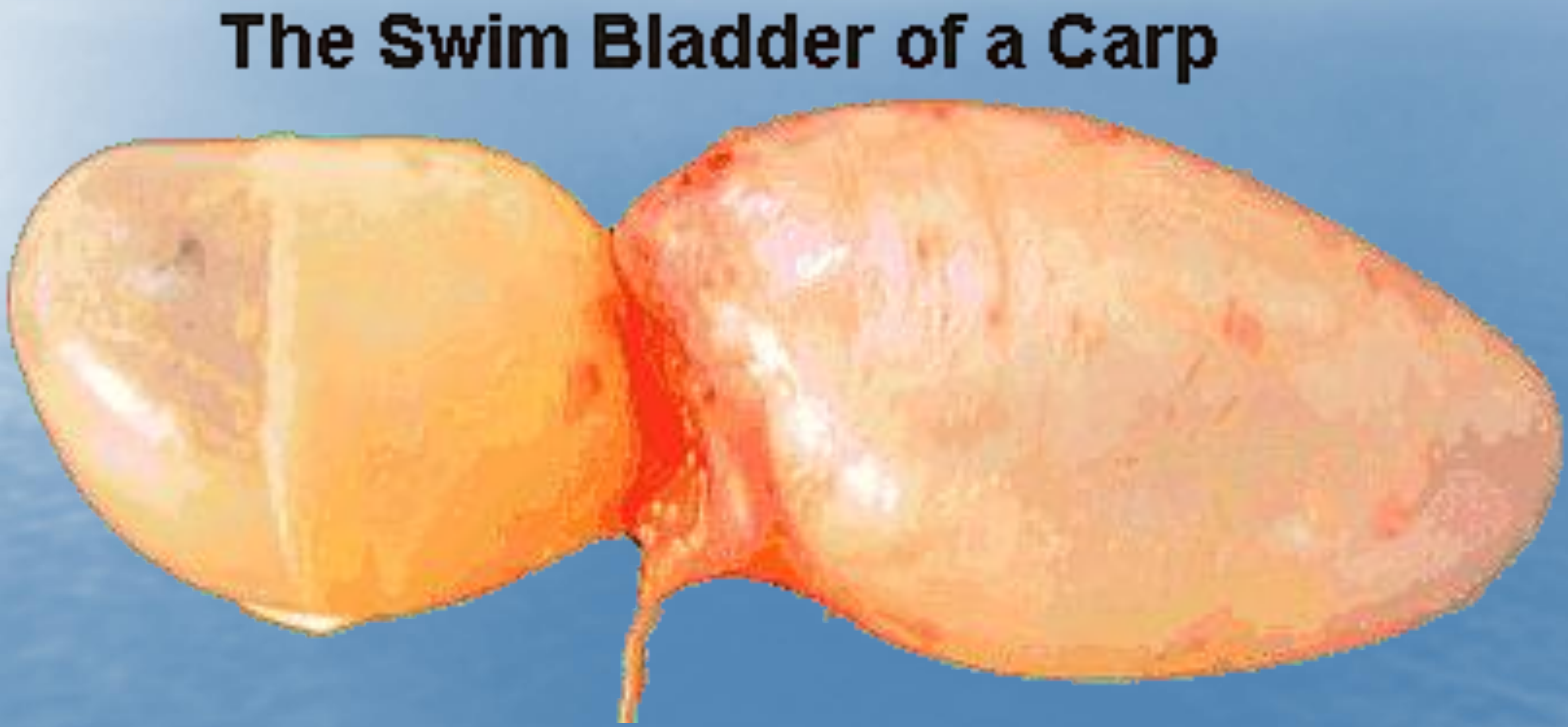



LIFT
Pressure
WING
AIR
Pressure


©Lill Haugen 2009

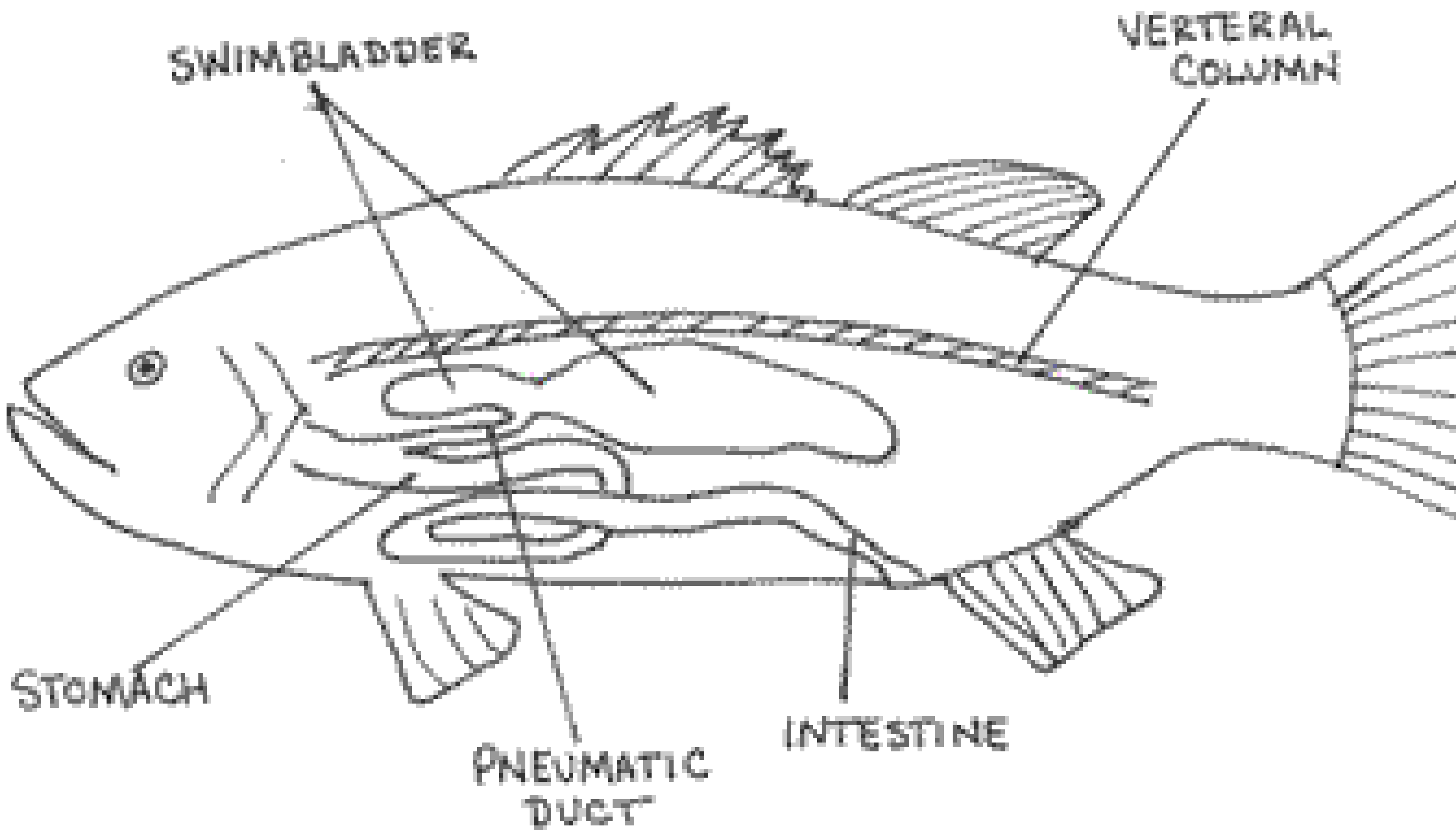
3. REDUCTION OF HEAVY TISSUES

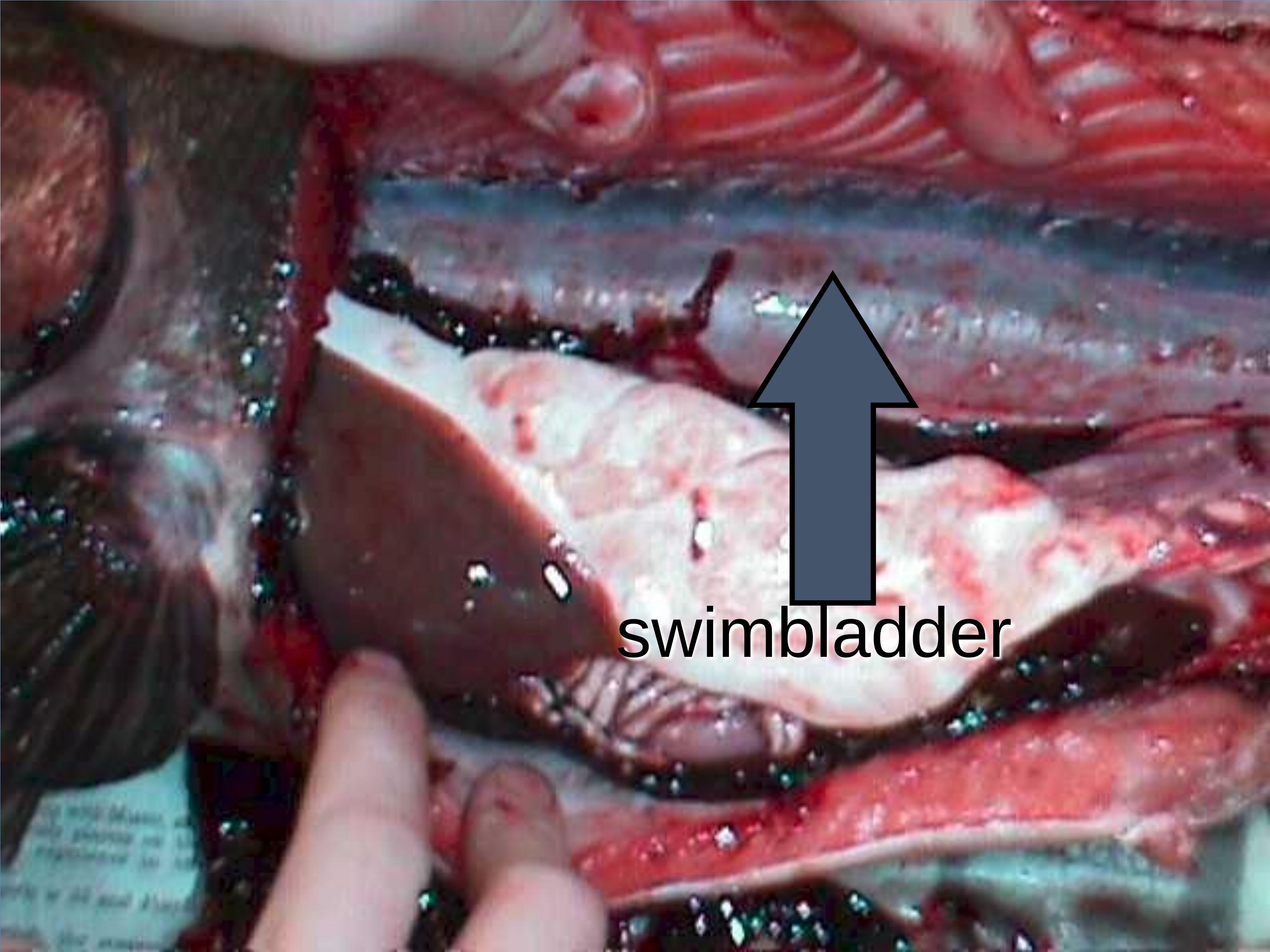
4. SWIMBLADDER



SWIMBLADDER

- adjust gas volume and pressure
  - mostly oxygen and nitrogen
- neutral buoyancy
  - saltwater - swimbladder 5%
  - freshwater - swimbladder 7%
- without swimbladder
  - 20% more energy spent to float
  - benthic (bottom dweller)

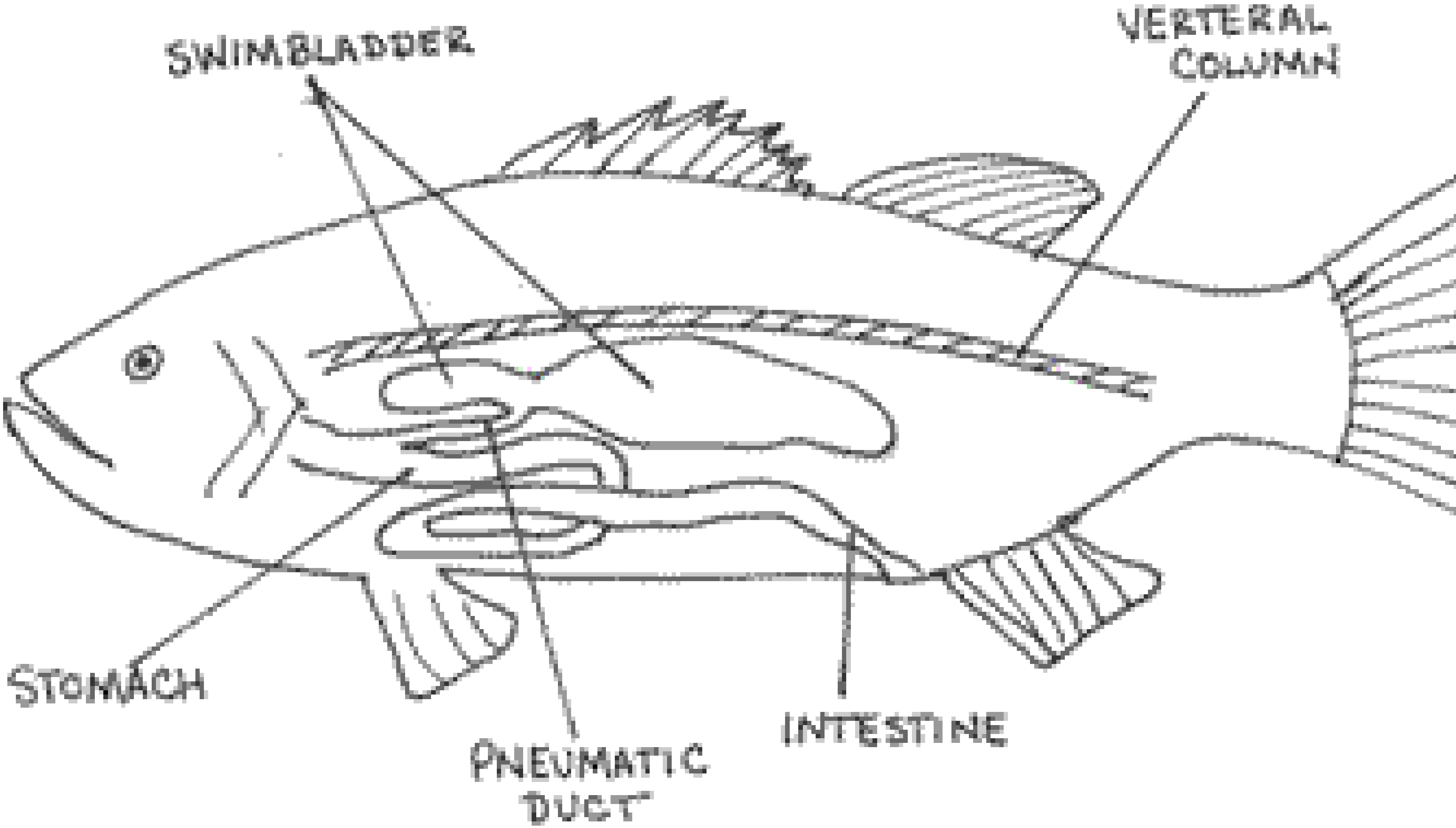

SWIMBLADDER
VERTERAL
COLUMN
STOMACH
PNEUMATIC
DUCT
INTESTINE

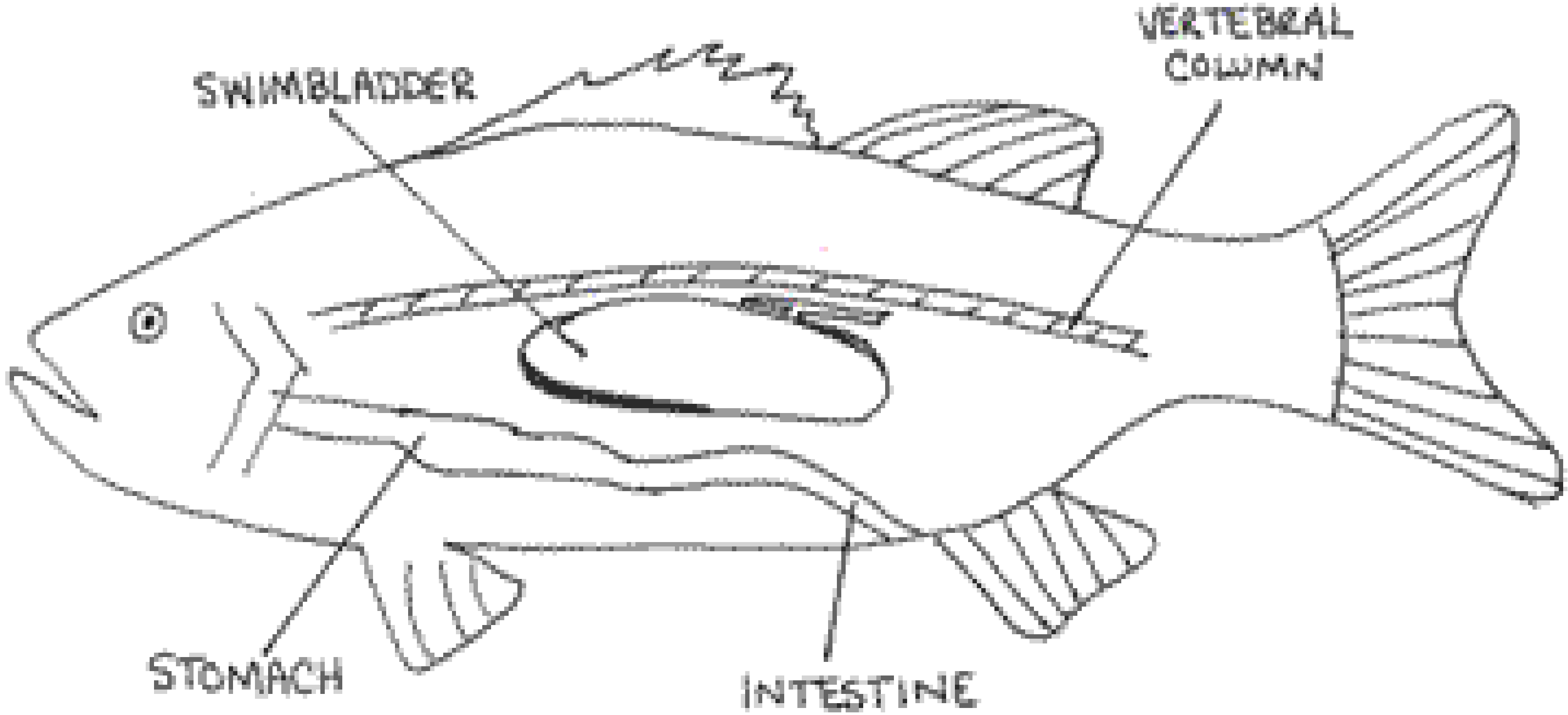

swimbladder

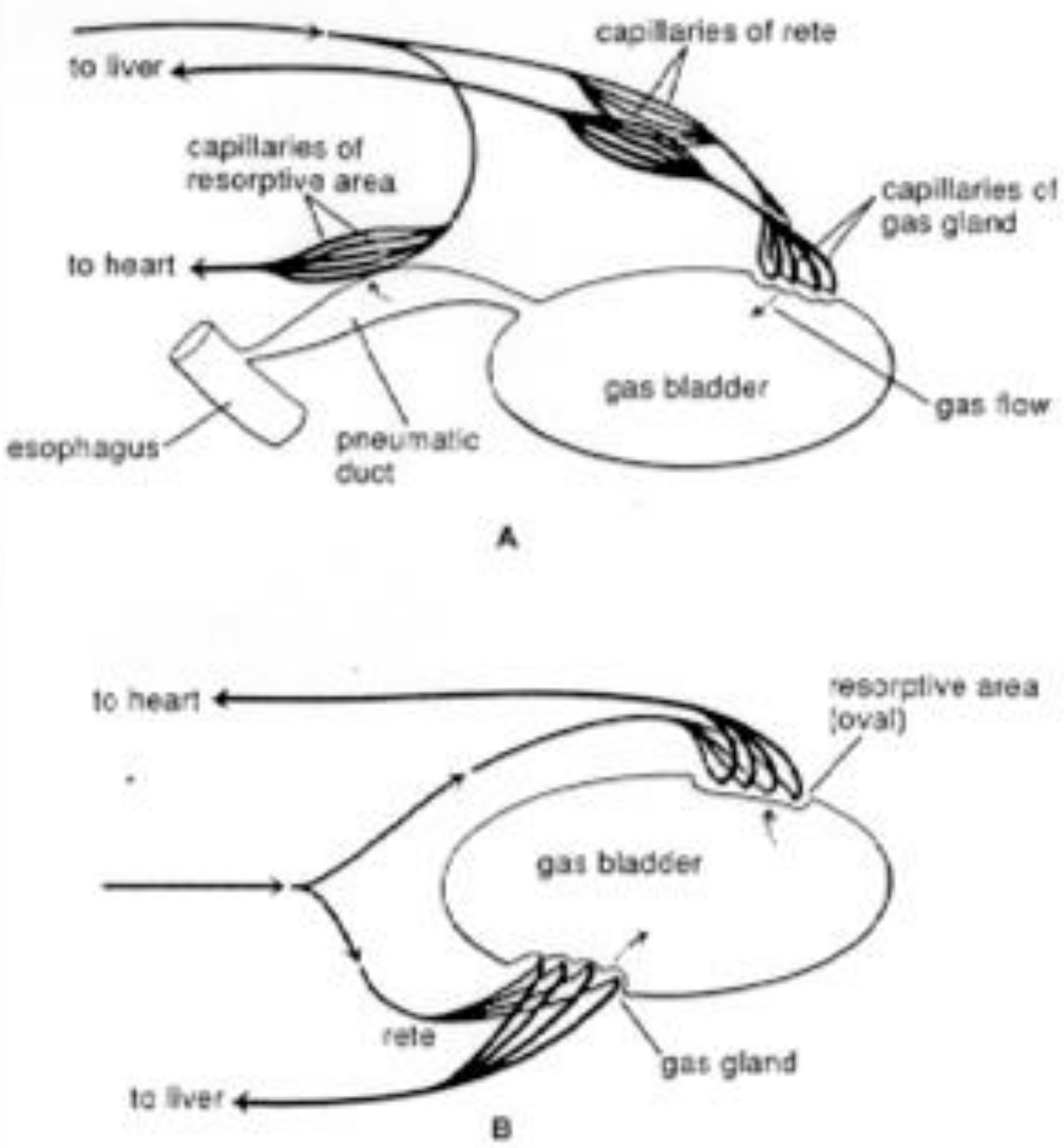
BREAK

2 BASIC TYPES OF SWIM BLADDERS:

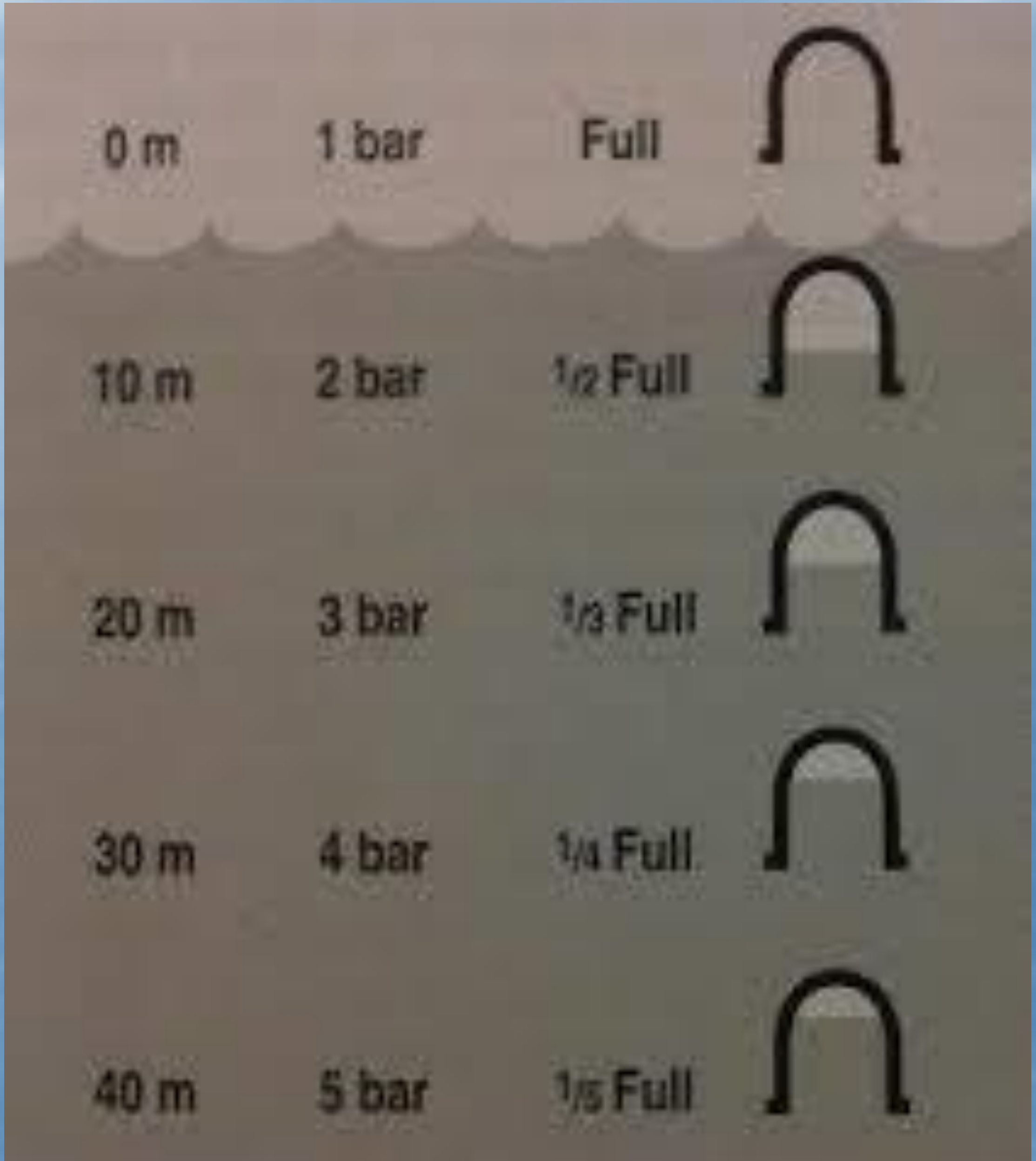
1. **physostomous** swimbladders are connected to the gut via the pneumatic duct
2. **physoclistous** swimbladders lack this connection


SWIMBLADDER
VERTERAL COLUMN
STOMACH
PNEUMATIC DUCT
INTESTINE


SWIMBLADDER
VERTEBRAL COLUMN
STOMACH
INTESTINE


capillaries of rete
to liver
capillaries of resorptive area
to heart
capillaries of gas gland
gas bladder
gas flow
esophagus
pneumatic duct
A
to heart
resorptive area (oval)
gas bladder
rete
gas gland
to liver
B

DEPTH AND PRESSURE (BOYLES LAW)



(Neutral) Buoyancy

- deeper water has more pressure
  - fixed amount of gas provides less buoyancy at great depths (Boyle's law)
    - must increase gas in swimbladder
      - prevent pressure compression
  - fish moves to surface (pressure ⇓)
    - must release gas (less dense)
    - gas expansion makes fish lighter
      - without compensation, fish rises at increasing speed

CHALLENGES A FISH MUST FACE

1. If the air that a fish has in its swim bladder decreases due to increased pressure with depth, they must add air

2. If a fish surfaces with air in its bladder, the decrease in pressure will cause that air to increase so they must get rid of air.

IF A FISH WAS TRYING TO DESCEND . . .

- **Physoclistou**s?
- **Physostomous** ?

IF A FISH WAS TRYING TO ASCEND . . .

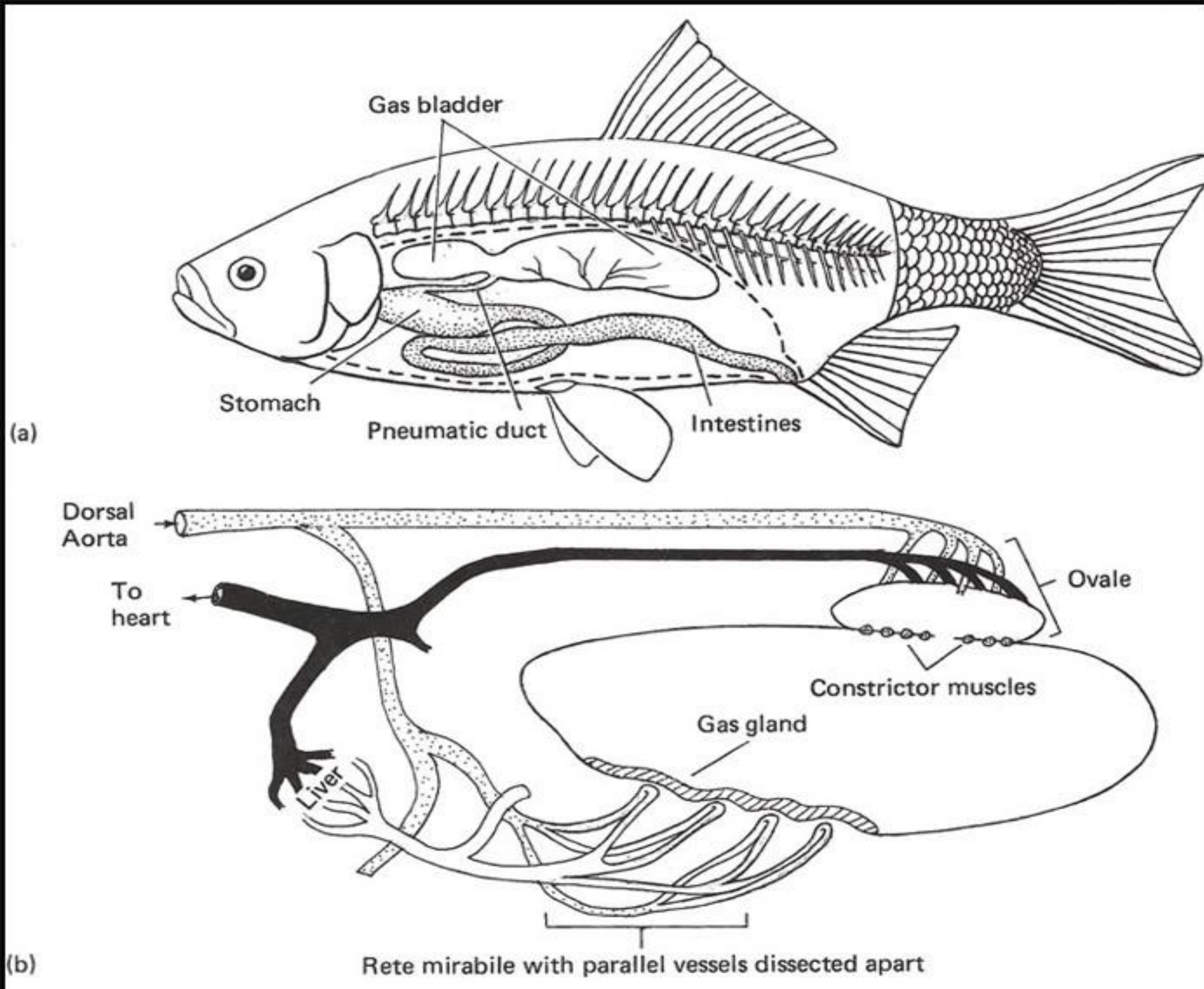
- **Physoclistou**s?
- **Physostomous** ?

PHYSOSTOMOUS SWIMBLADDERS

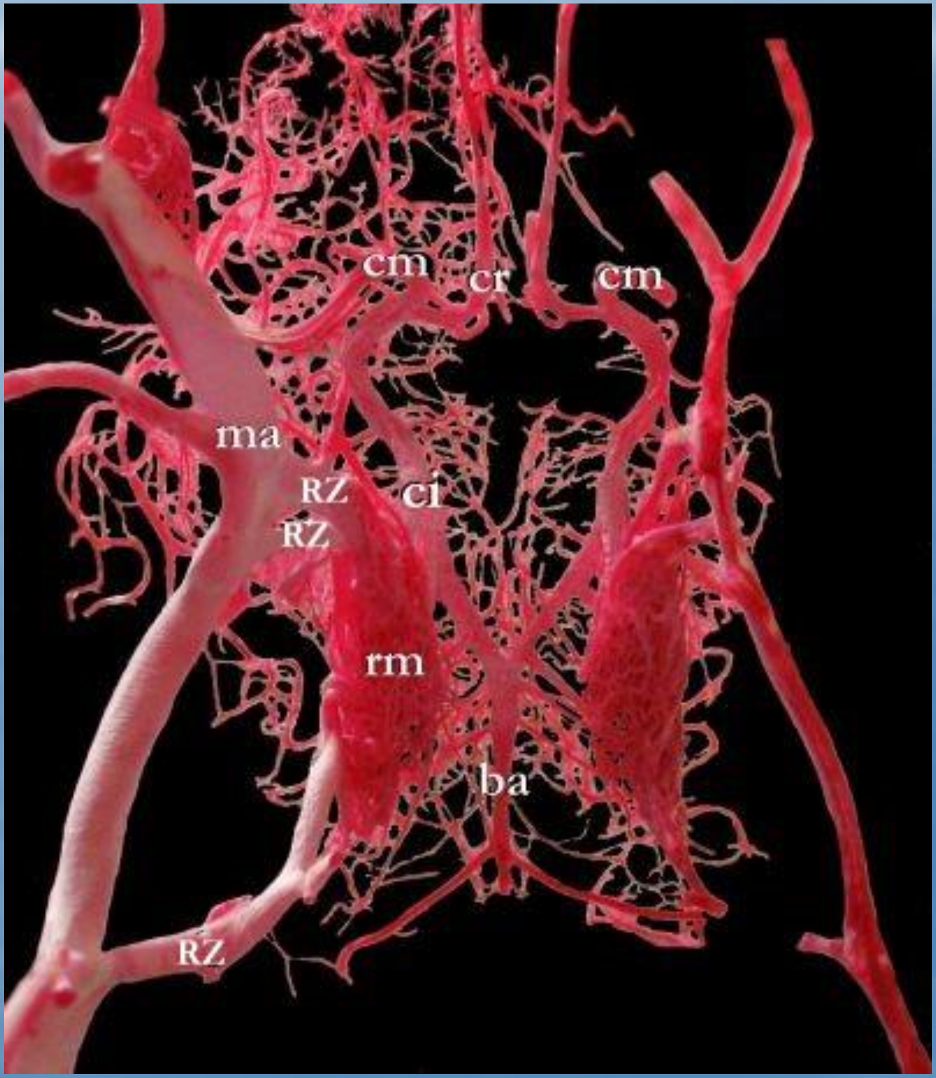
- Inflation by gulping air at the surface
- additional swimbladder inflation is needed at greater depths than the surface gulping
- deflation by a reflexive gas spitting (gass-puckreflex)
- gas exchange probably plays minimal role in inflation and deflation– muscle control and expulsion used more

PHYSOCLISTOUS SWIMBLADDERS

- have special structures associated with circulatory system for inflating and deflating the swimbladder
- 2/3 of all teleosts are physoclistous – including all the most derived spiny rayed teleosts
- rete mirabile (wonderful net)
- Deflation of physoclistous swim bladder is accompanied by diffusion of gas back into the blood stream via richly vascularized area adjacent to enclosed gasses.


Gas bladder
Stomach
Pneumatic duct
Intestines
(a)
Dorsal
Aorta
To
heart
Liver
Ovale
Constrictor muscles
Gas gland
Rete mirabile with parallel vessels dissected apart
(b)

RETE MIRABILE




GRIP

OH DEAR GOD!

http://www.youtube.com/watch?v=b7y3Af0NEkM

http://www.dfw.state.or.us/MRP/research/

Yellow eye release

BREAK

THERMAL REGULATION

Most fish are ectothermic

Most fish have a range of temperatures they can tolerate

Fish have behavioral and physiological temperature regulating mechanisms

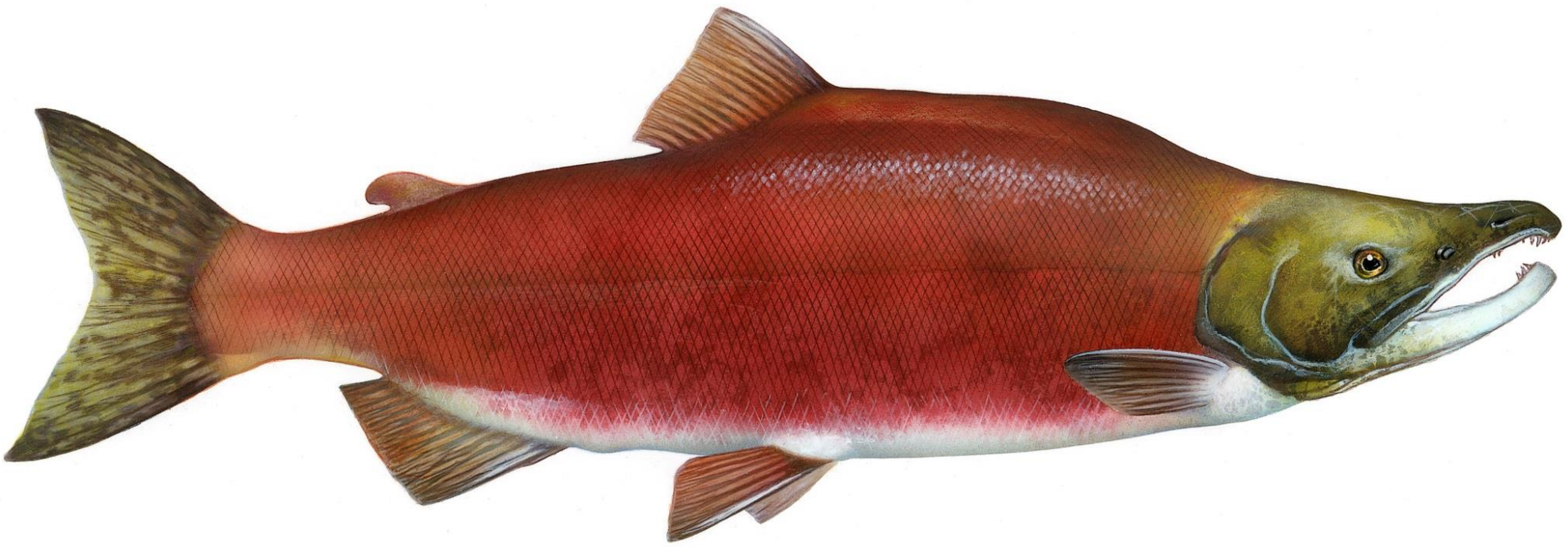
BEHAVIORAL MECHANISMS

Move to find cooler/ warmer waters

Change activity level

BEAR LAKE SCULPIN

SOCKEYE SALMON



PHYSIOLOGICAL THERMOREGULATION

Only exhibited by several continuously swimming fish

Warm muscles confer swimming performance advantages to these species

Red muscle metabolism greatly enhanced by warmer temps

Warm muscles contract faster than cooler ones

DISADVANTAGES OF HEAT PRODUCTION???

OTHER MEANS OF HEAT REGULATION

Regional Endothermy

or

Brain heater

HYDROMINERAL BALANCE

Need to maintain critical levels of salts, alkalinity (buffering capacity) and dissolved organic compounds

Fish use different methods of osmoregulation – but all are costly energetically and affect growth and swimming performance

CHALLENGES

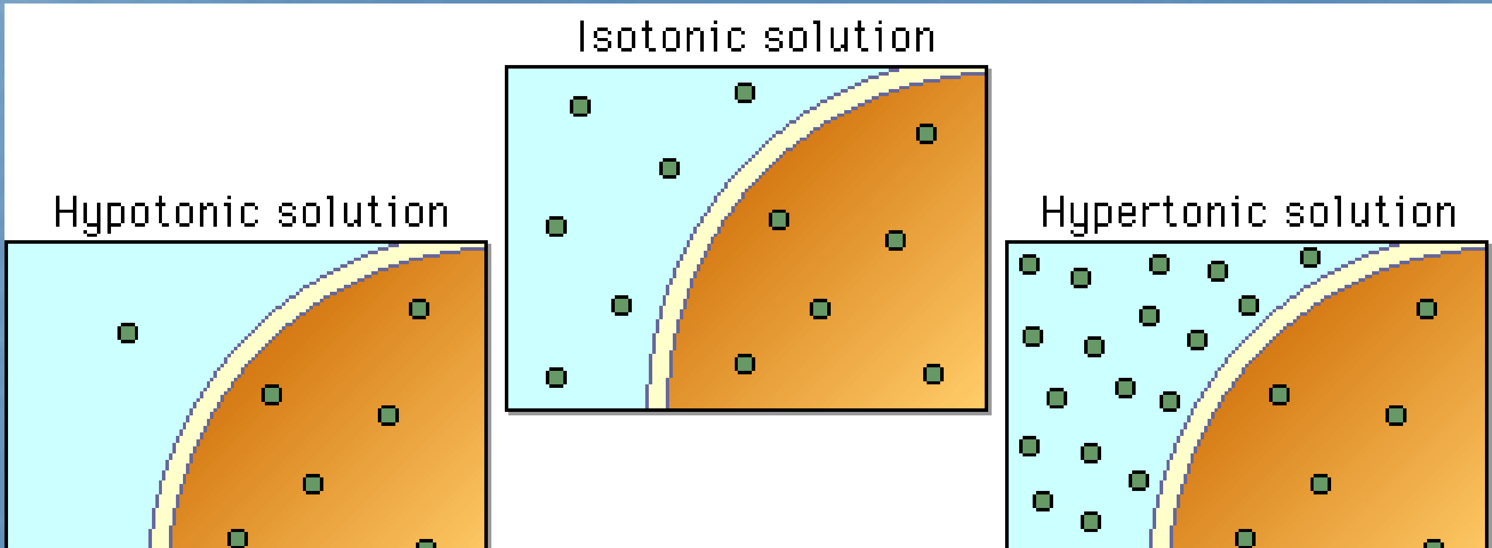
Osmotic regulation - Water balance

Ionic regulation - Composition of solutes in body fluids

Nitrogen excretion - Pathways to remove wastes

OSMOREGULATION

Adaptations to control water balance in organisms living in hypotonic, hypertonic and isotonic environments



FISH CAN BE . . .

Osmoconformers – internal conditions similar to external

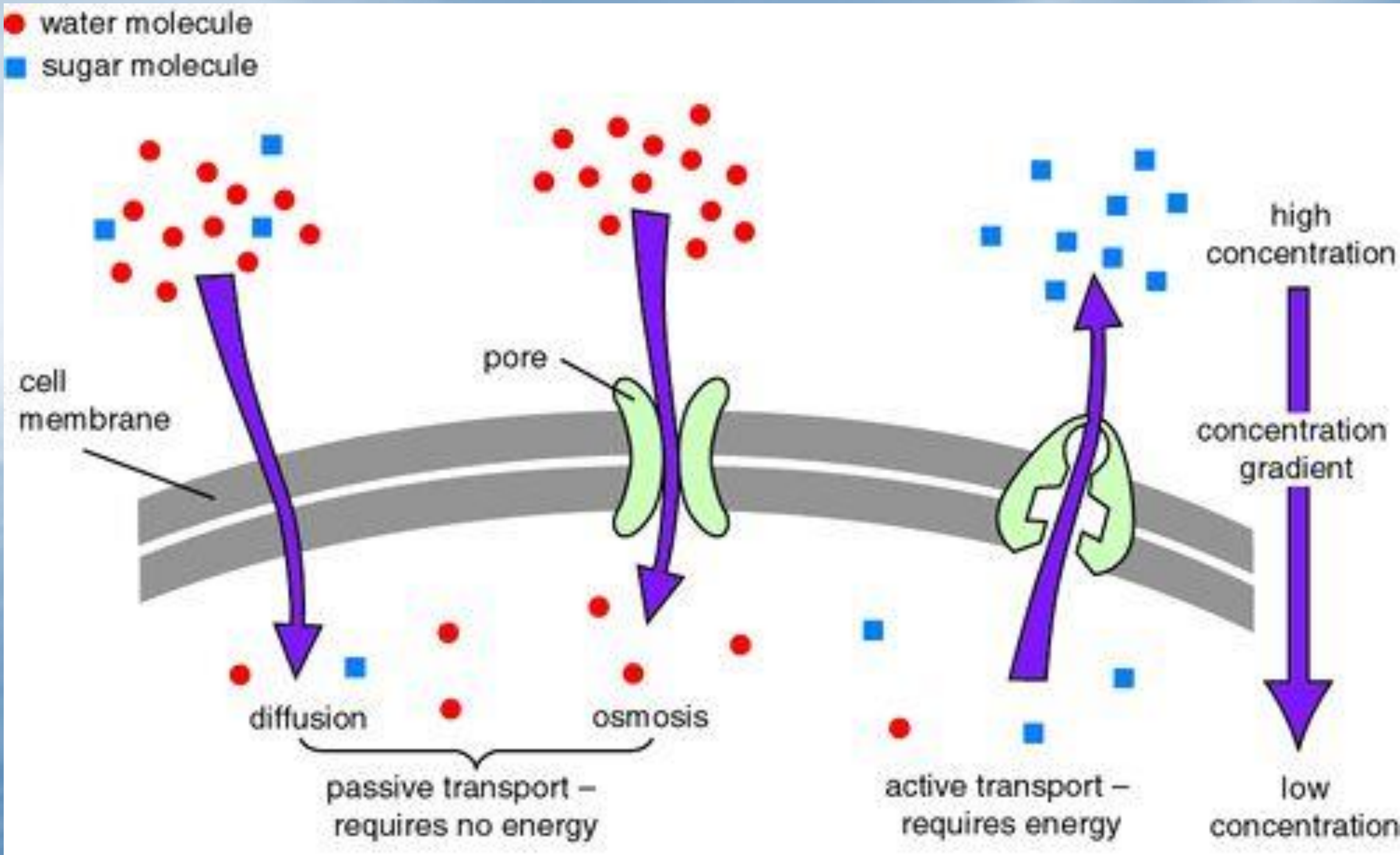
Osmoregulators – defent a nearly constant internal state that is distinct from external conditions

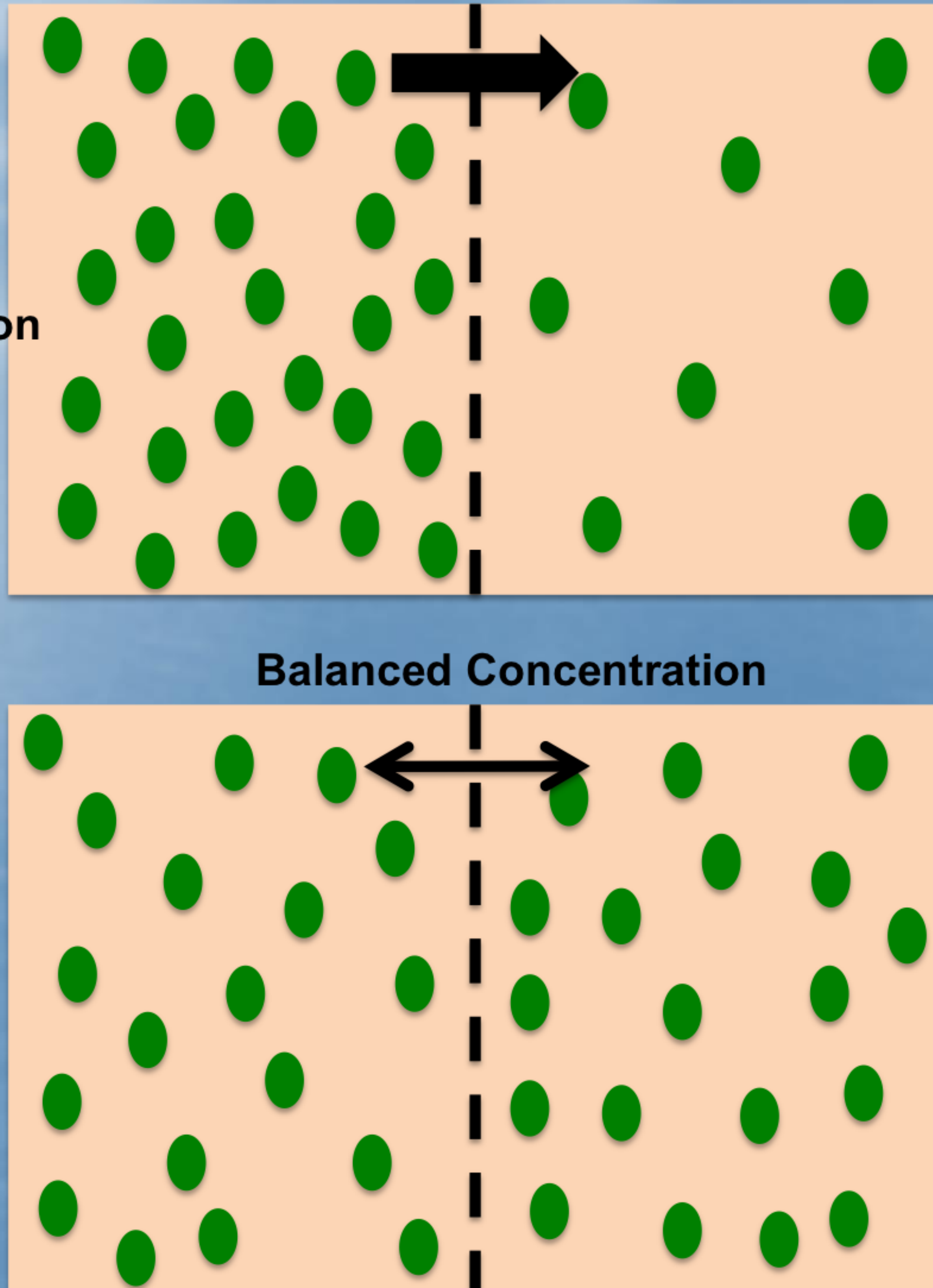
OSMO-TERMS

Stenohaline – animals that can only tolerate a narrow range of salt concentrations

Euryhaline – animals that can tolerate a wide range of salinities

DIFFUSION


water molecule
sugar molecule
cell
membrane
pore
high
concentration
concentration
gradient
low
concentration
diffusion
osmosis
passive transport –
requires no energy
active transport –
requires energy

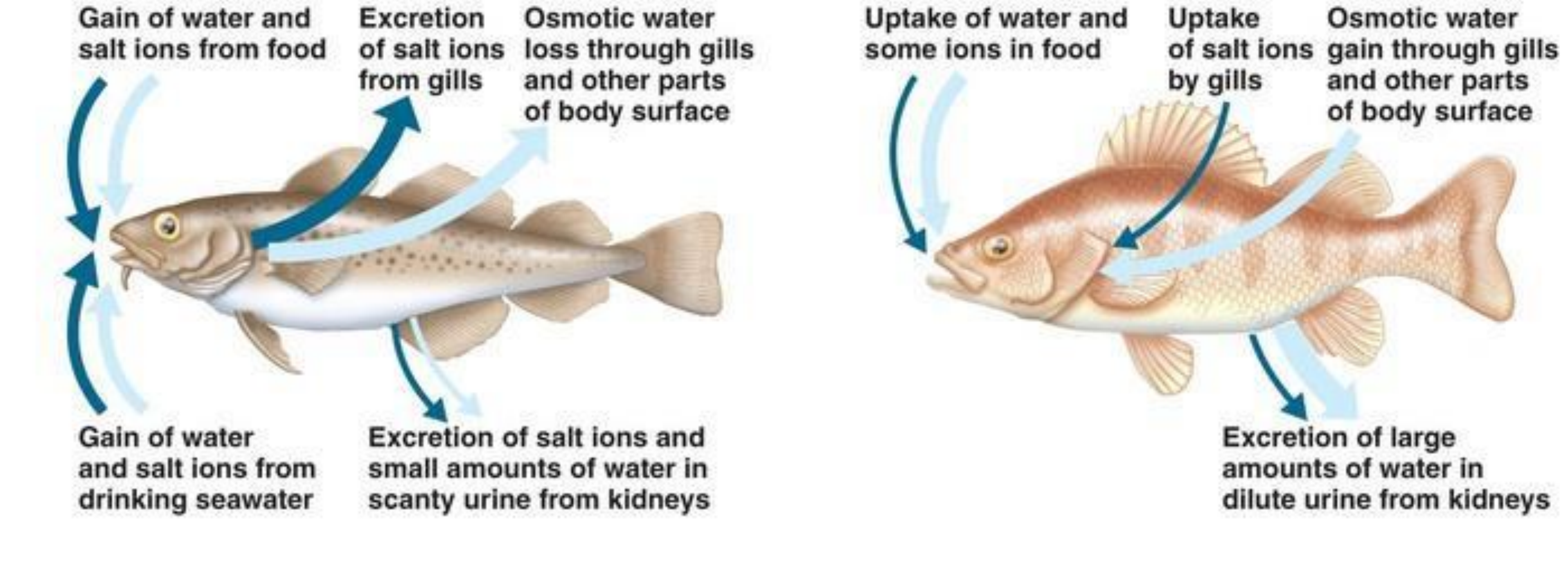

High Concentration
Low Concentratio
Balanced Concentration

ALL FISH NEED WATER

Fish ingest some liquid water while eating

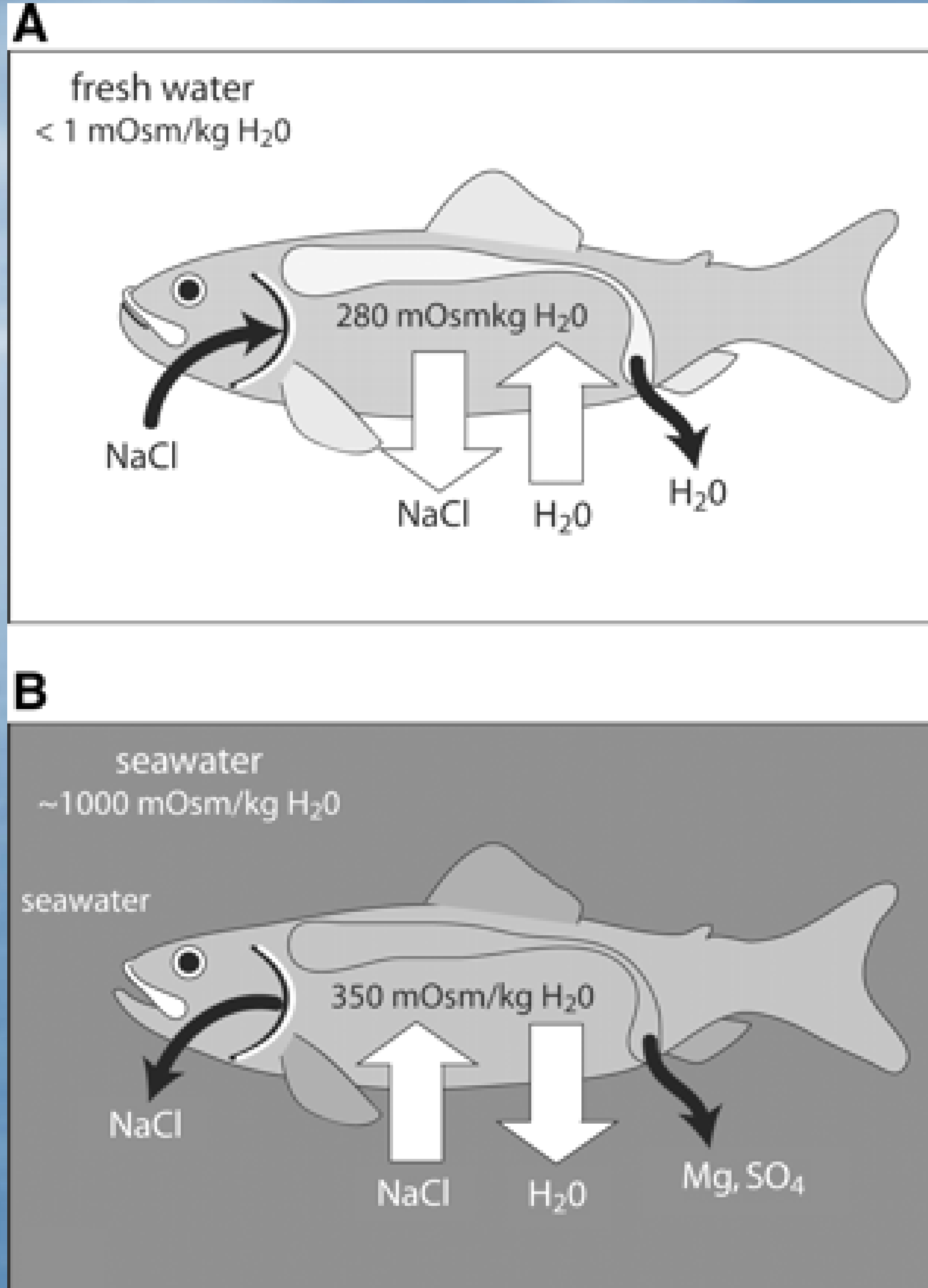
Fish that drink seawater have the challenge that water must be absorbed into the system and salt must be expelled

Fish that drink freshwater have the challenge of diluting the important solutes that they need

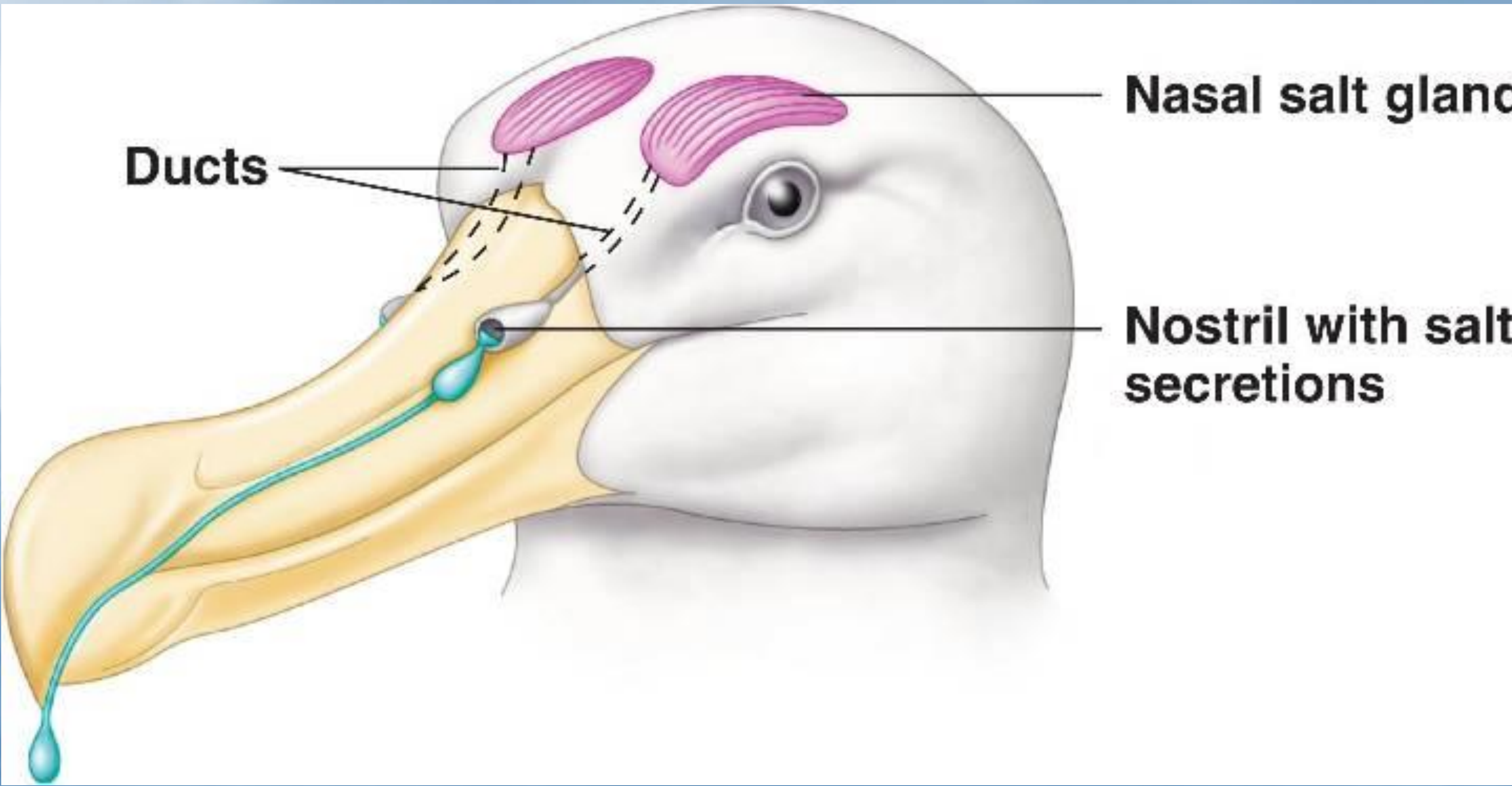


(a) Osmoregulation in a saltwater fish

(b) Osmoregulation in a freshwater fish


A
fresh water
< 1 mOsm/kg H_20
280 mOsmkg H_20
NaCl
NaCl
H_20
H_20
B
seawater
~1000 mOsm/kg H_20
seawater
350 mOsm/kg H_20
NaCl
NaCl
H_20
Mg, SO_4

SALT GLANDS IN BIRDS



OSMOREGULATION IN HAGFISH

Osmoconforming – maintain internal salinity identical to water in which they live

Stenohaline

OSMOREGULATION STRATEGIES

Elasmobranchs

- **maintain internal salt concentration ~ 1/3 seawater, remaining 2/3 is urea and trimethylamine oxide (TMAO). So total internal osmotic concentration equal to seawater.**

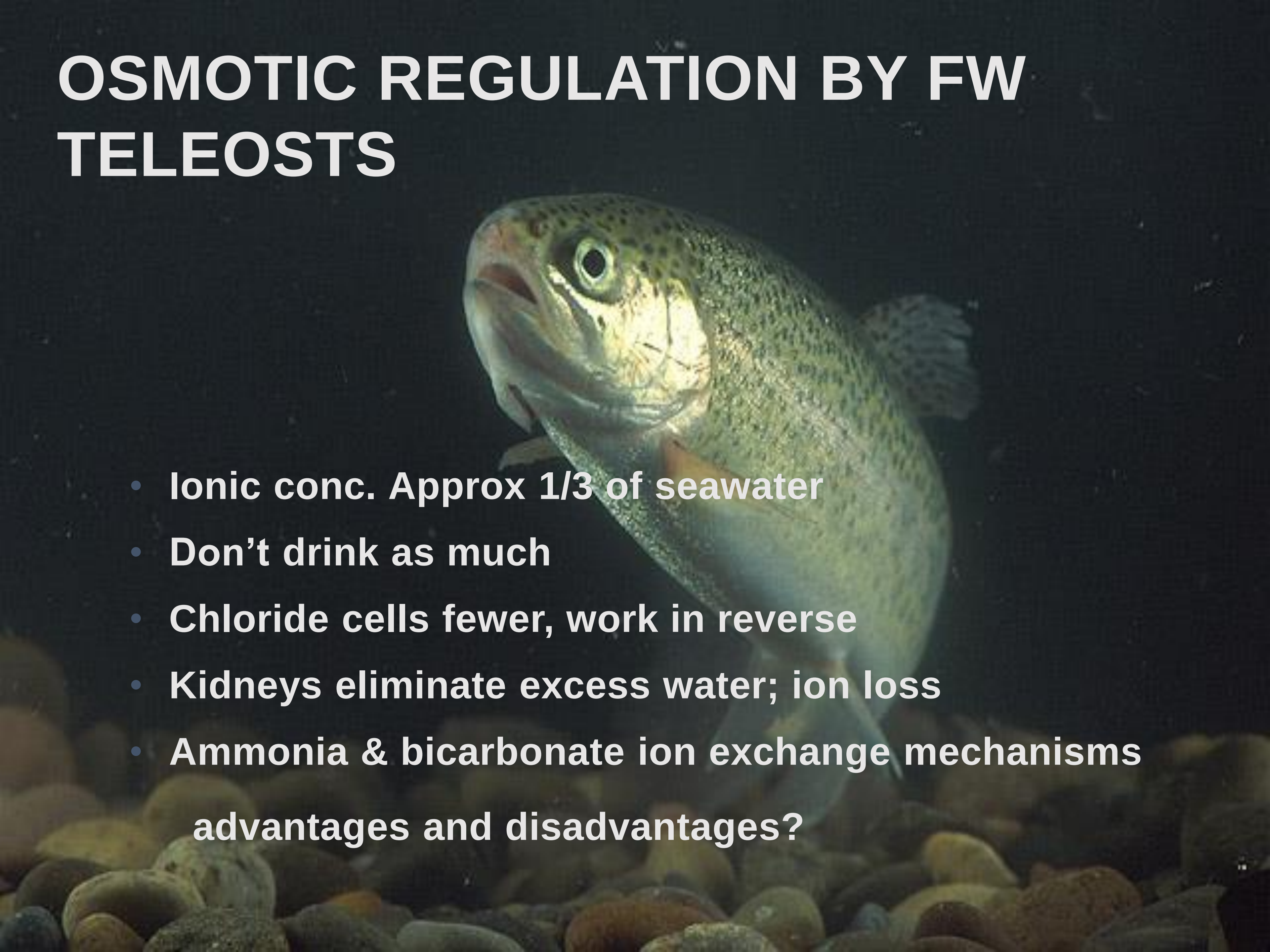
- **Gill membrane has low permeability to urea so it is retained within the fish. Because internal inorganic and organic salt concentrations mimic that of their environment, passive water influx or efflux is minimized.**

Osmotic regulation by marine teleosts...

- ionic conc. approx 1/3 of seawater
- drink copiously to gain water
- Chloride cells eliminate Na^{+} and Cl^{-}
- kidneys eliminate Mg^{++} and $SO_4^{=}$

advantages and disadvantages?

OSMOTIC REGULATION BY FW TELEOSTS

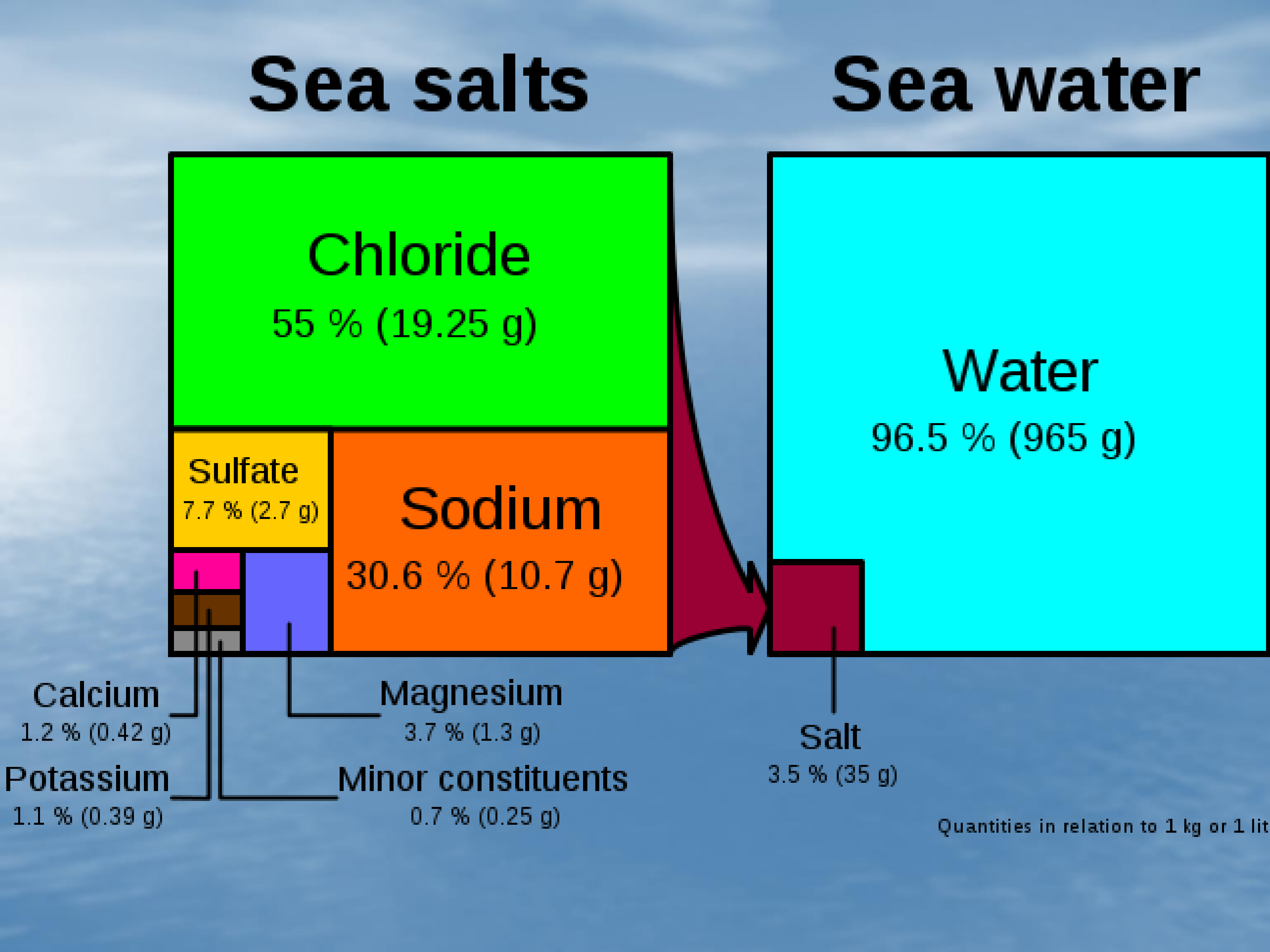


- Ionic conc. Approx 1/3 of seawater
- Don’t drink as much
- Chloride cells fewer, work in reverse
- Kidneys eliminate excess water; ion loss
- Ammonia & bicarbonate ion exchange mechanisms

advantages and disadvantages?

OH DEAR GOD PART II

http://www.youtube.com/watch?v=OiwWm8imc2w


Sea salts
Sea water
Chloride
55 % (19.25 g)
Water
96.5 % (965 g)
Sulfate
7.7 % (2.7 g)
Sodium
30.6 % (10.7 g)
Calcium
1.2 % (0.42 g)
Magnesium
3.7 % (1.3 g)
Salt
3.5 % (35 g)
Potassium
1.1 % (0.39 g)
Minor constituents
0.7 % (0.25 g)
Quantities in relation to 1 kg or 1 lit

IONIC REGULATION IN HAGFISH

Nearly Isotonic with seawater

With exception of higher [ ] sodium and lower [ ] of divalent ions magnesium, calcium and sulfate.

Hagfish kidneys secrete divalent ions and slime excretion seems to play a role in retarding sodium loss

IONIC REGULATION IN ELASMOBRANCHS

Must still manage [ ] of sodium and chloride ions

- This is accomplished by excreting sodium and chloride via rectal gland (which is found ONLY in elasmobranchs)

IONIC REGULATION IN MARINE TELEOSTS AND LAMPREYS

Selective excretion of excess ions is main method of maintaining ionic balance

Gills primary site of monovalent ion excretion while the kidneys are primary site of divalent ion excretion

IONIC REGULATION IN FRESHWATER TELEOSTS

Most ion exchange is across the gills

Ion exchange mechanisms

Gills aid in maintaining acid-base balance

EURYHALINE AND DIADROMOUS TELEOSTS

- These fish live in dramatically different external environments
- Euryhaline fishes tolerate wide range of salinities
- Diadromous fishes are euryhaline fishes that move between fresh and salt water at a particular phase of their life
- Ability of these fishes to adapt to changes in salinity, which in estuarine fishes is both random and constant, is mediated by hormones

RESPONSES TO STRESS

- physiological changes
- Adaptive
- Detrimental, sometimes fatal

WHAT ABOUT STRESS??

- Stressors (handling, sustained exercise such as escape from predator pursuit) cause release of adrenaline (epinephrine) - for mediating escape, etc.
- Adrenaline causes diffusivity of gill epithelium to increase (become “leaky” of water & ions)
- This accentuates the normal osmoregulatory challenge for FW or marine fishes

HOW TO REDUCE STRESS IN STRESSED FISHES?

- Minimize the osmotic challenge by placing fish in conditions that are *isosmotic*
  - add salt to freshwater, e.g. in transporting fish or when exposing them to some other short-term challenge
  - dilute saltwater for same situation with marine species

CARBON DIOXIDE STRESS

- Hypercapnia stress occasionally occurs in natural systems and is common in fish culture facilities. Although oxygen is aerated through the enclosures, a high density of fishes leads to elevated CO_2 levels which in water, becomes carbonic acid (H_2CO_3).
- This lowers the pH of the water and therefore the fish. Fish respond to this by using their metabolically produced bicarbonate ion (HCO_3^-) to buffer their pH and also excrete H^+.

FREEZING RESISTANCE

- Hagfish, marine elasmobranchs, and freshwater fishes usually are not subject to freezing as long as the water they reside in does not freeze (why?)
- However, marine teleosts may be subject to freezing even though the water around them is still liquid.
- To avoid freezing, many marine teleosts increase their osmolality of their blood and tissues by increasing glycerol, urea, and TMAO concentrations.
- Some fishes also produce special molecular antifreeze compounds (antifreeze glycopeptides (AFGP) and peptides (AFP). These bond to forming ice crystals and lower the bloods freezing point.

FREEZING RESISTANCE:

- What fishes might face freezing?

  hagfishes?

    isotonic

  marine elasmobranchs?

    isotonic

  freshwater teleosts?

    hypertonic

  marine teleosts?

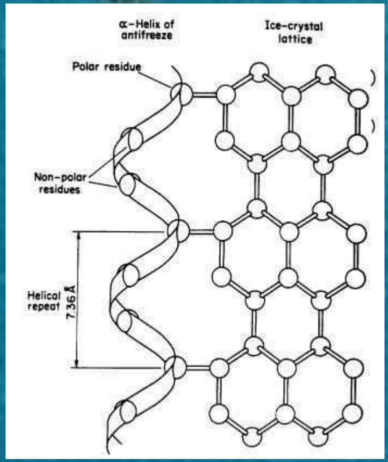
    hypotonic

SOLUTION FOR ANTARCTIC FISH

- Macromolecular antifreeze compounds

peptides (protein)
glycopeptides
(carbohydrate/protein)

→ rich in alanine



- molecules adsorb (attach) to ice crystal surface
- interfere with ice crystal growth (disrupt matrix)
- Why is this important???
- ice ruptures cells; hinders osmoregulation

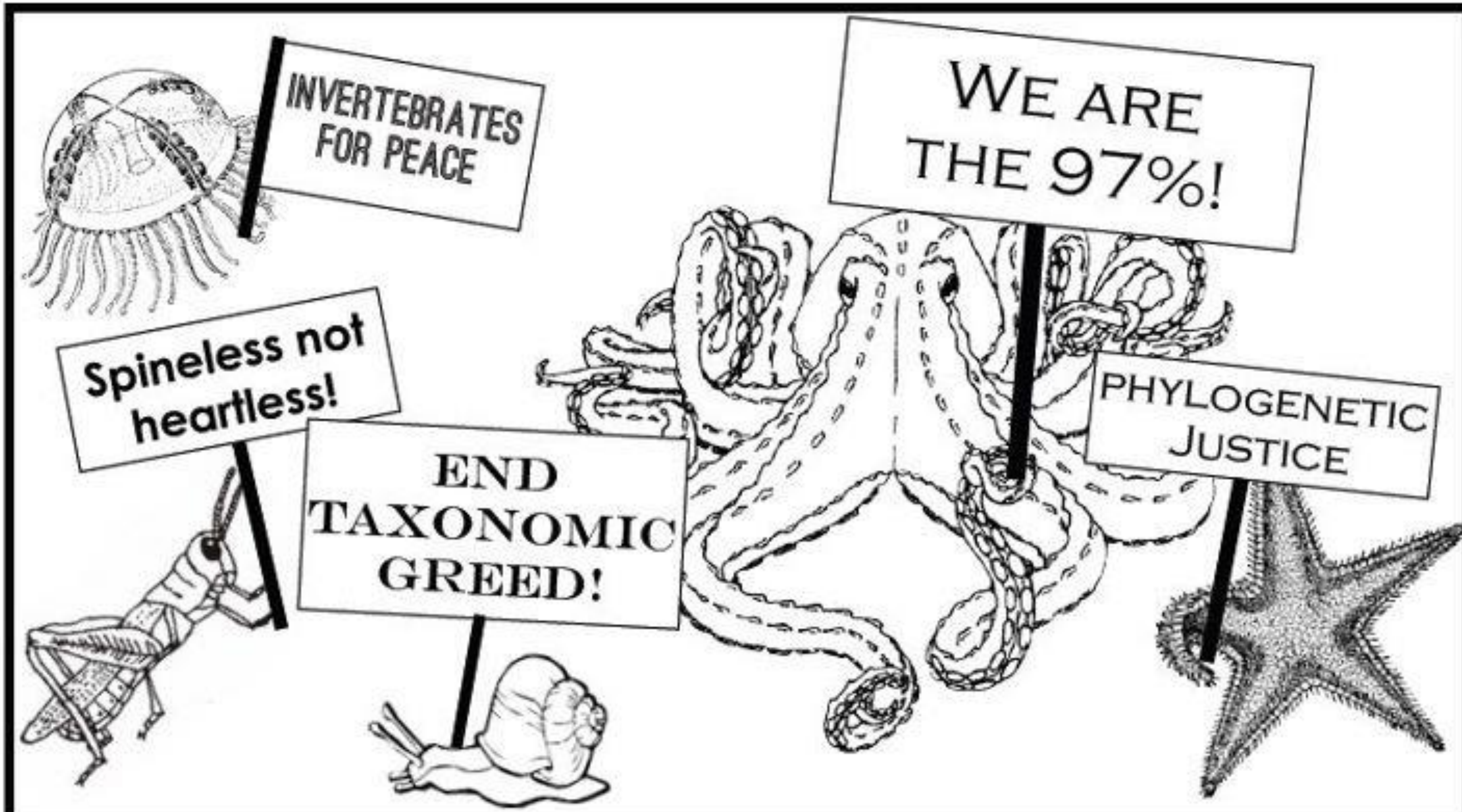
BREAK

NOVEL TECHNOLOGIES AND CHARISMATIC MEGAFAUNA: HOW WE ARE LEARNING ABOUT THE ECOLOGY OF THE ELUSIVE NORTH PACIFIC GIANT OCTOPUS

Reid Brewer
(SFOS, UAF)

Brenda Norcross
(SFOS, UAF)

OCTOPI WALL STREET

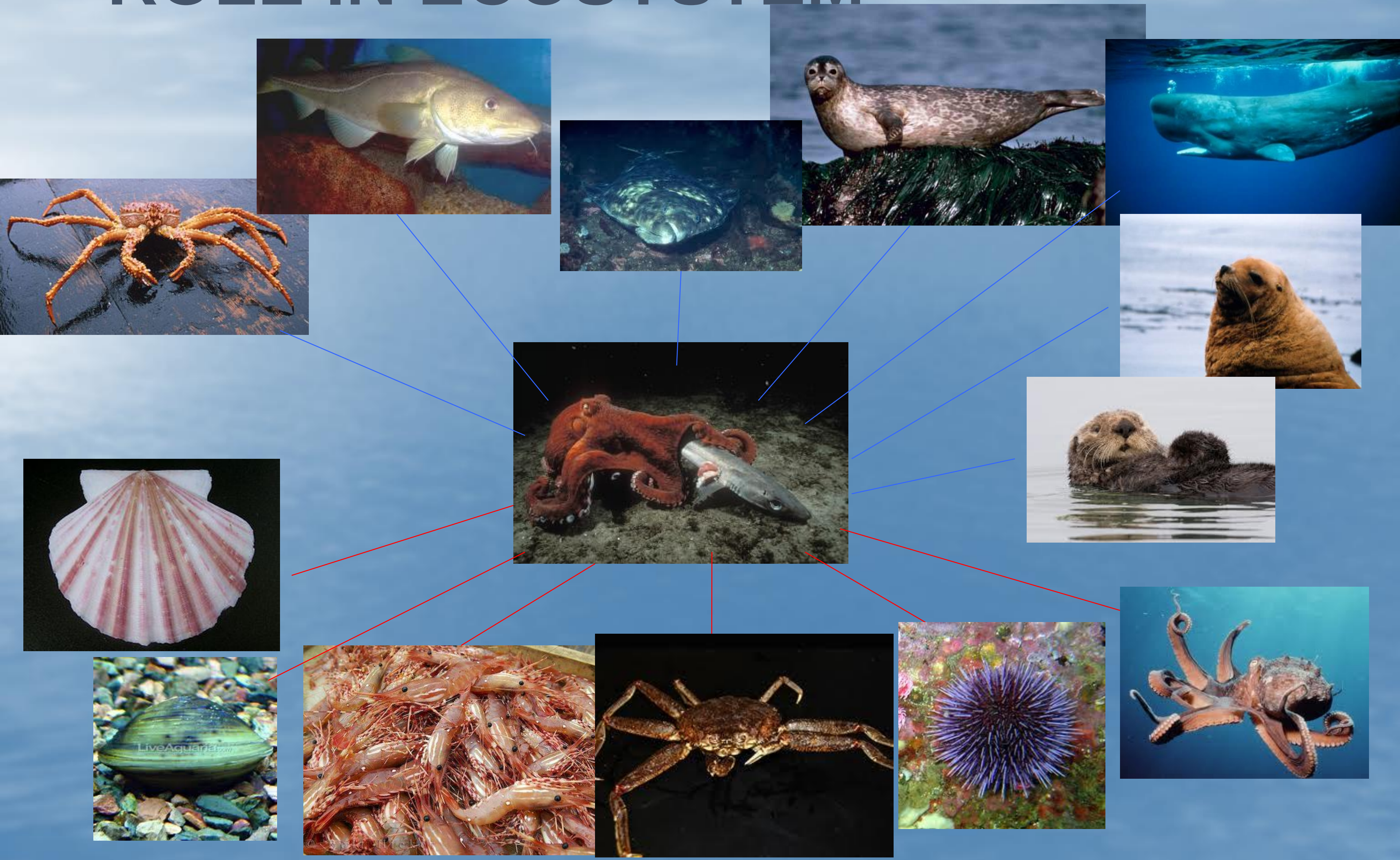


Invertebrates are 97% of animal diversity!

OUTLINE

- Importance of octopus
- Methods
- Results
- Conclusions

ROLE IN ECOSYSTEM



WHAT WE DON’T KNOW

- Ecology
  - Growth rate
  - Movement patterns
  - Reproduction

- Fisheries
  - Biomass estimate
  - Size at maturity
  - Early Life history
  - Discard mortality

FEDERAL FISHERIES MANAGEMENT

- Through 2010 – “other species” complex
  - Based upon average incidental catch from 1997-2007

- *2011 – “max historical catch from 1997-2007”   ABC = 396 MT, OFL = 528 MT

- 2012 – “consumption estimate”

  ABC = 2,589 MT, OFL = 3,452 MT

DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

50 CFR Part 679

[Docket No. 101126521-0640-02]
RIN 0648-XA794

Fisheries of the Exclusive Economic Zone Off Alaska; Pacific Cod and Octopus in the Bering Sea and Aleutian Islands Management Area

AGENCY: National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), Commerce.

ACTION: Temporary rule; closure.

SUMMARY: NMFS is prohibiting directed fishing for Pacific cod by vessels using pot gear in the Bering Sea and Aleutian Islands management area (BSAI). This action is necessary to limit incidental catch of octopus by vessels using pot gear to fish for Pacific cod the BSAI.

DATES: Effective 1200 hrs, Alaska local time (A.l.t.), October 24, 2011, through 2400 hrs, A.l.t., December 31, 2011.

FOR FURTHER INFORMATION CONTACT: Josh Keaton, 907-586-7228.

SUPPLEMENTARY INFORMATION: NMFS manages the groundfish fishery in the BSAI exclusive economic zone according to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area (FMP) prepared by the North Pacific Fishery Management Council under authority of the Magnuson-Stevens Fishery Conservation and Management Act. Regulations governing fishing by U.S. vessels in accordance with the FMP appear at subpart H of 50 CFR part 600 and 50 CFR part 679.

The Magnuson-Stevens Fishery Conservation and Management Act requires that conservation and management measures prevent overfishing. The 2011 octopus overfishing level in the BSAI is 528 metric tons (mt) and the acceptable biological catch (ABC) is 396 mt as established by the final 2011 and 2012 harvest specifications for groundfish in the BSAI (76 FR 11139, March 1, 2011). NMFS closed directed fishing for octopus on January 13, 2011 (76 FR 3044, January 19, 2011) and prohibited retention of octopus on September 1, 2011 (76 FR 55276, September 7, 2011).

As of October 15, 2011, approximately 530 mt of octopus has been harvested in the BSAI. Vessels using pot gear have significant incidental catch of octopus and have taken the vast majority of octopus in the BSAI. Substantial fishing effort by vessels using pot gear is being directed at remaining amounts of Pacific cod in the BSAI. If vessels using pot gear were allowed to continue fishing for Pacific cod in the BSAI then further incidental catch of octopus would occur.

The Regional Administrator has determined, in accordance with Sec. 679.20(d)(3), that prohibiting directed fishing for Pacific cod by vessels using pot gear in BSAI is necessary to prevent further incidental catch of octopus by the Pacific cod sector.

- October 24, 2011
- The OFL for octopus (~530MT) was reached
- Vessels using pot gear have a significant incidental catch of octopus
- Prohibited directed fishing for Pacific cod by vessels using pot gear

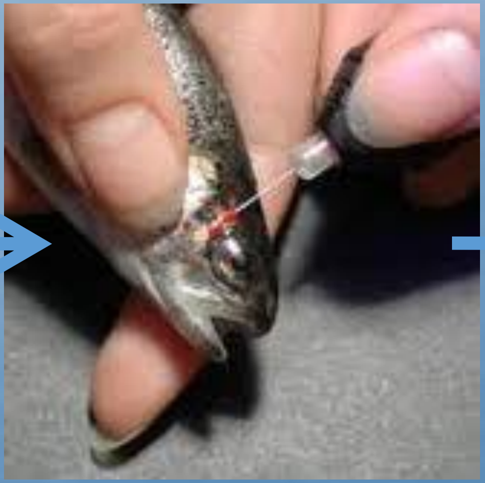
CASE OF NEED

- Estimates of octopus biomass using trawls
  - No species id
  - Trawl gear may not be appropriate
  - Lack of overlap between trawl areas and fisheries data
- Fisheries managers have suggested a tag and recapture survey using groundfish pots

PROBLEMS

- Octopus are difficult to age
- Octopus are difficult to tag
- Octopus have relatively short life spans
- Octopus are highly mobile
- Octopus have relatively few hard parts

VISIBLE IMPLANT ELASTOMERS



STUDY DESIGN

- Tag and recapture study

ELSEVIER

Fisheries Research

Volume 84, Issue 3, May 2007, Pages 308–313

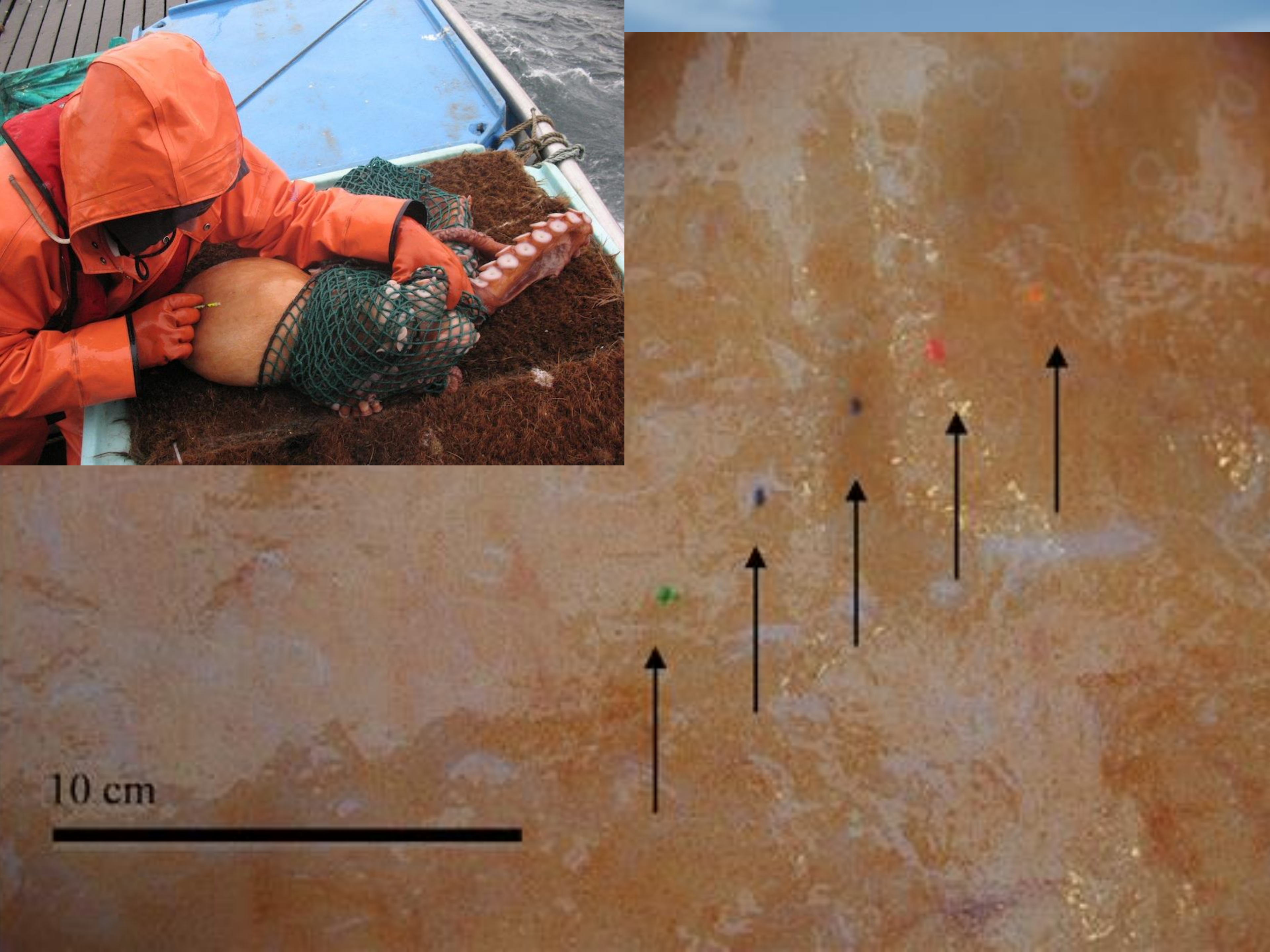
A preliminary investigation of the use of subcutaneous tagging in Caribbean reef squid *Sepioteuthis sepioidea* (Cephalopoda: Loliginidae)

S.E. Replinger, J.B. Wood

Bermuda Institute of Ocean Sciences, St. George's GE 01, Bermuda

http://dx.doi.org/10.1016/j.fishres.2006.11.028, How to Cite or Link Using DOI

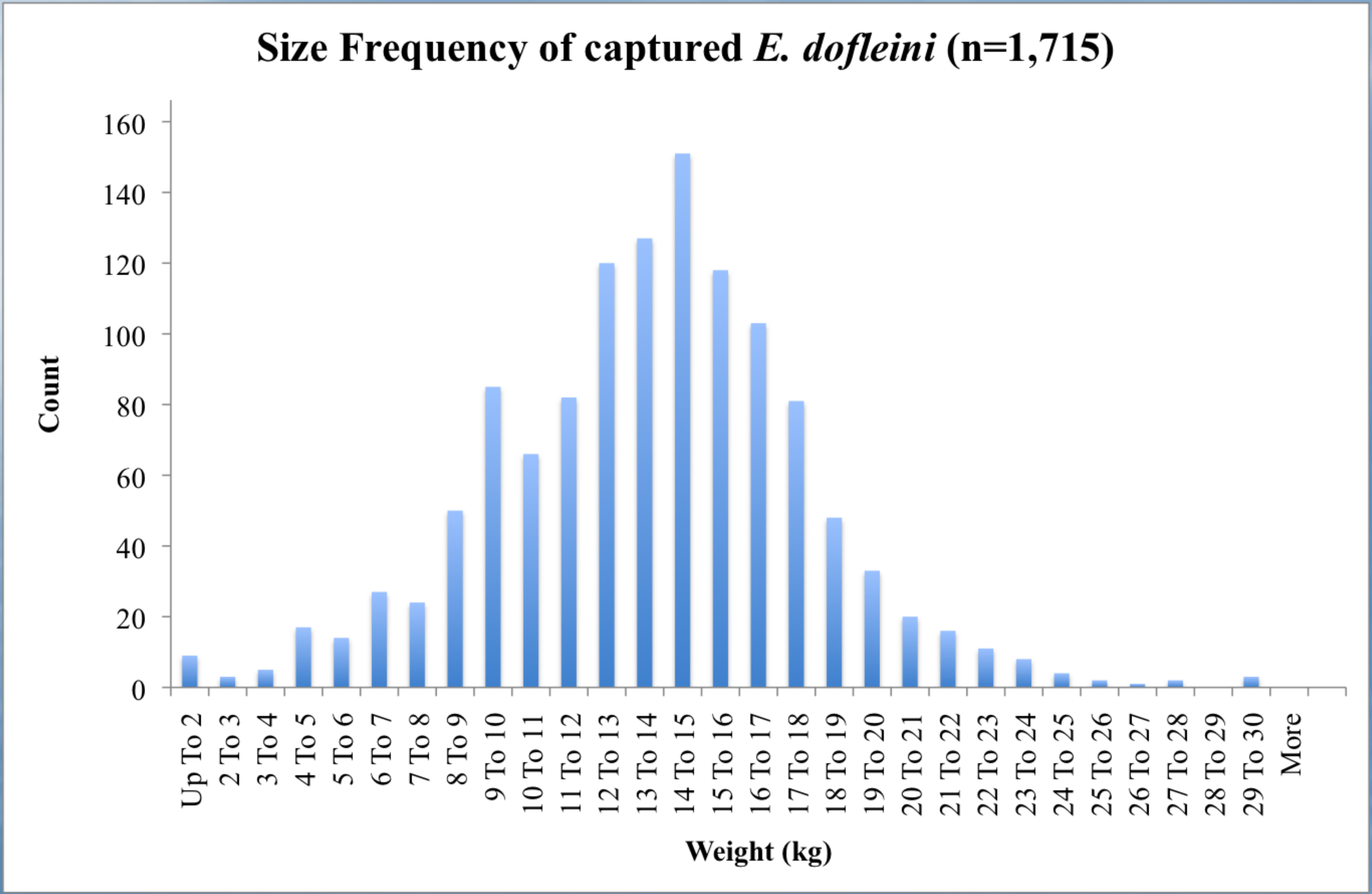

Asia
Ala
80km
Unalaska
Island
Bering
Sea
Aleutian archipelago
North
Pacific
Ocean
53°0'0"N
176°0'0"E
174°0'0"W
164°0'0"W
154°0'0"W


10 cm

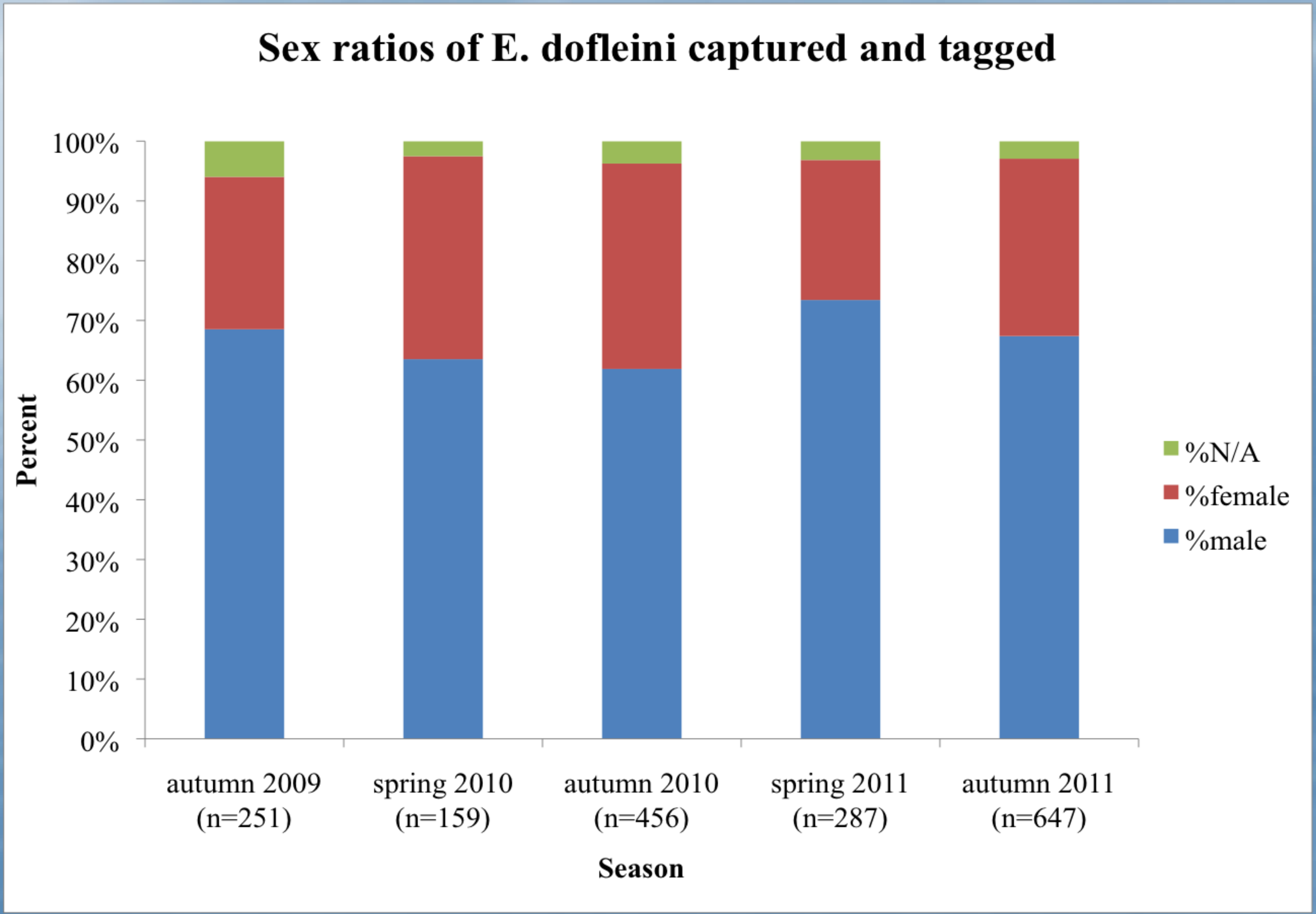
RESULTS

- 2009 to 2011
  - 5 tagging seasons, 5 recapture efforts
  - 1,714 *Enteroctopus dofleini* were tagged
  - 246 were recaptured (14 %)
  - Longest time b/t tag and recapture 374 days
  - 31 were at liberty for more than 60 days

GENERAL RESULTS

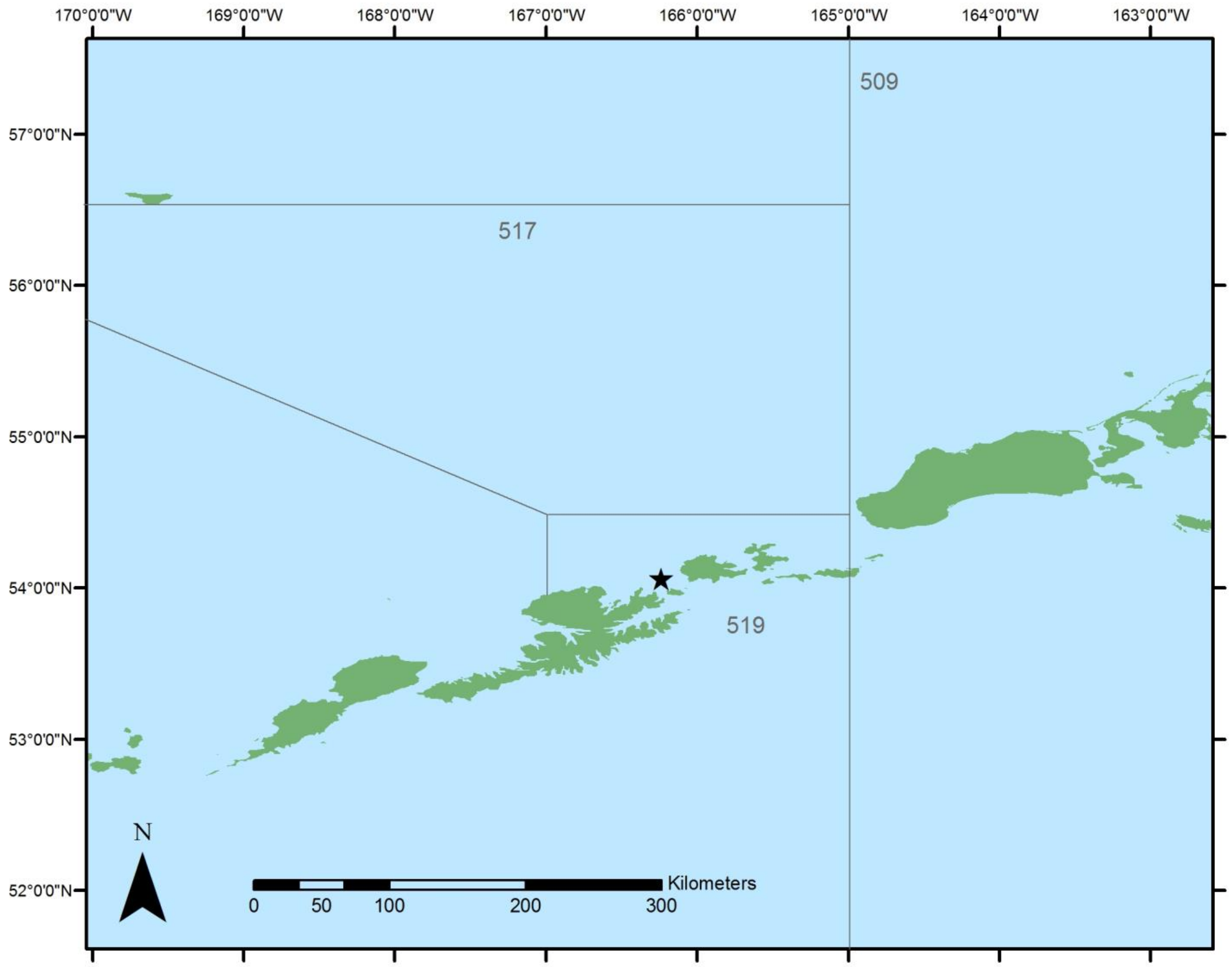


GENERAL RESULTS

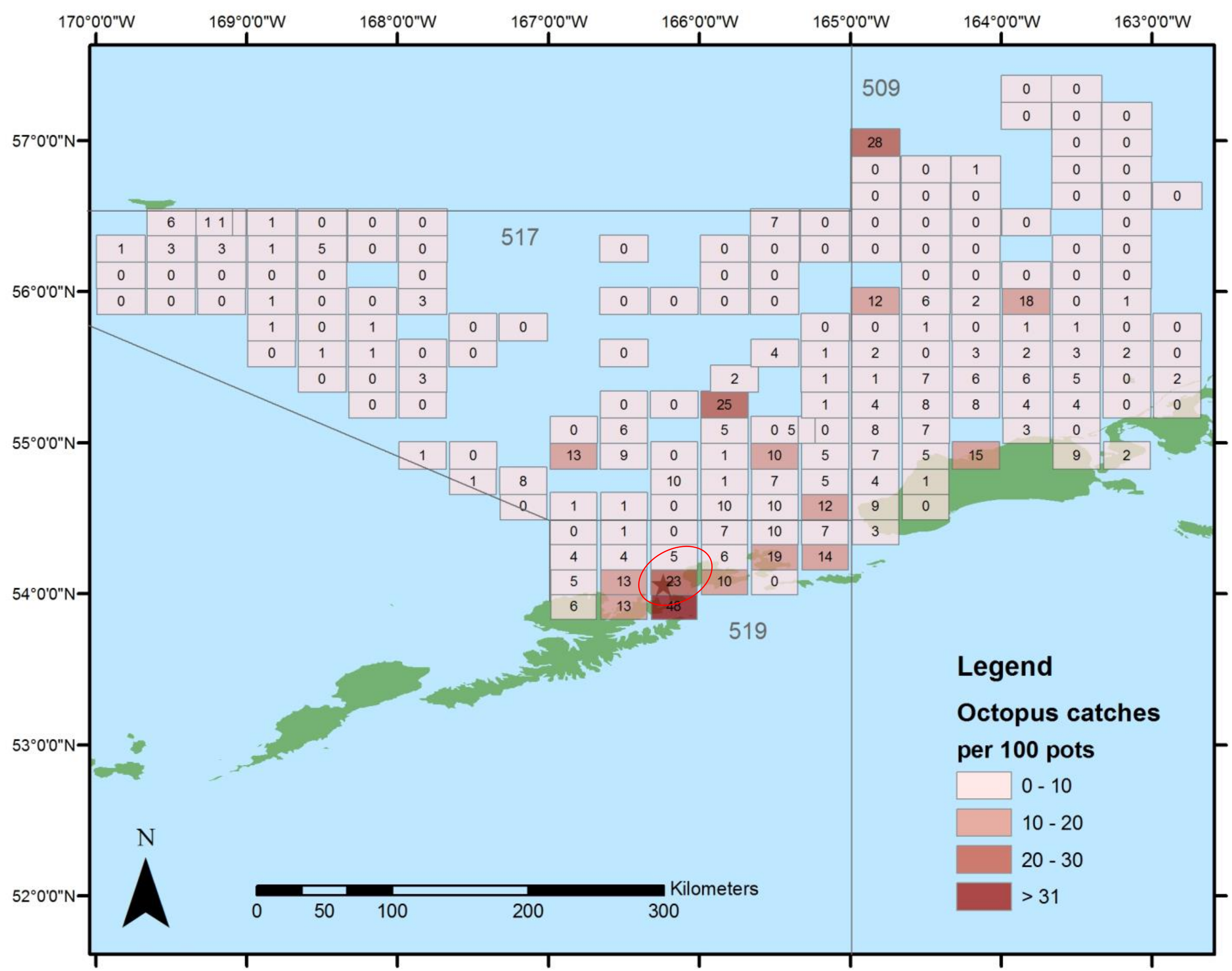


BIOMASS ESTIMATE

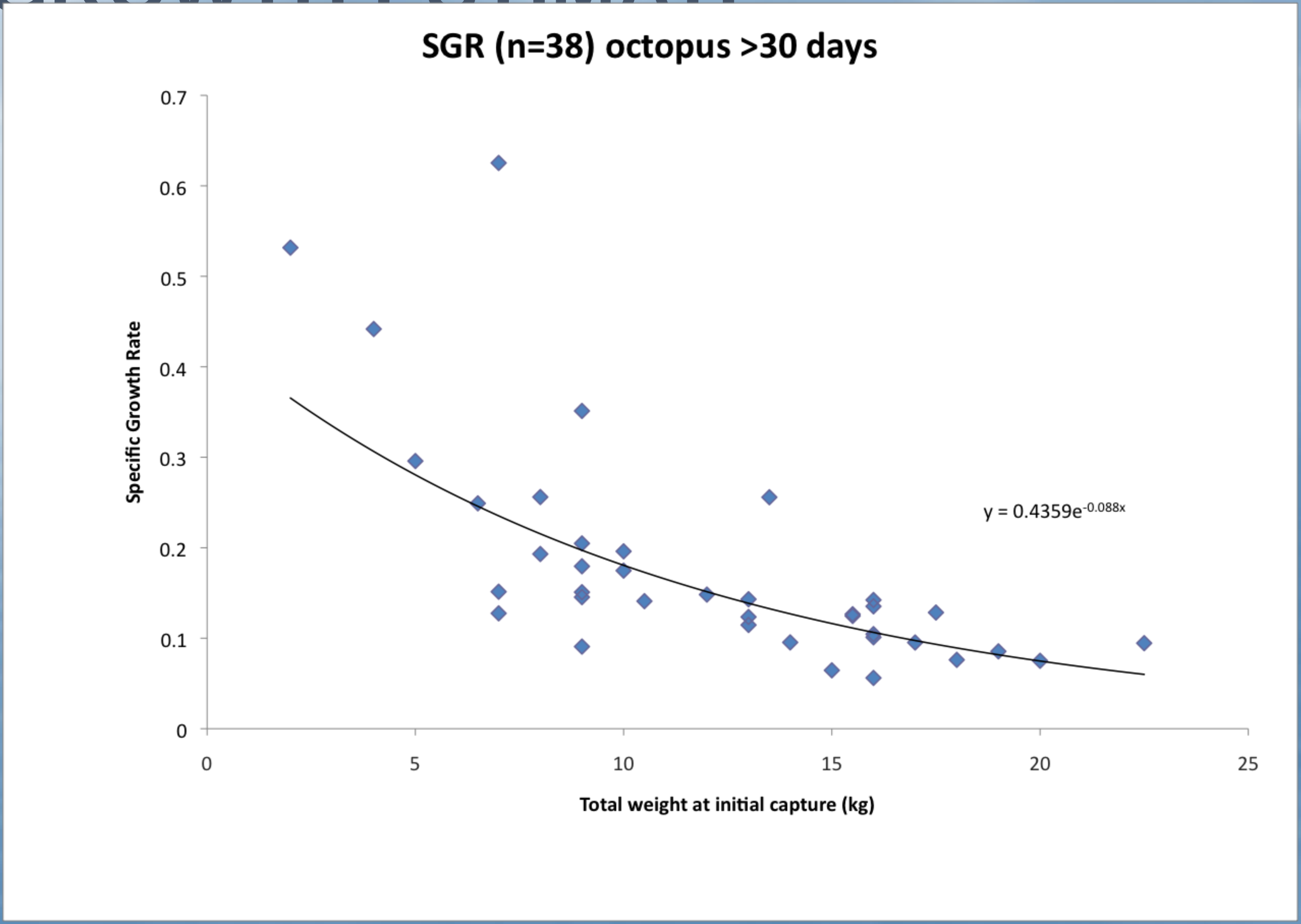
- Rough estimate of 300 octopus per km^2
- In my 25 km^2 area = 7,500 octopus
- Assuming 14.1 kg per octopus = 75 tons



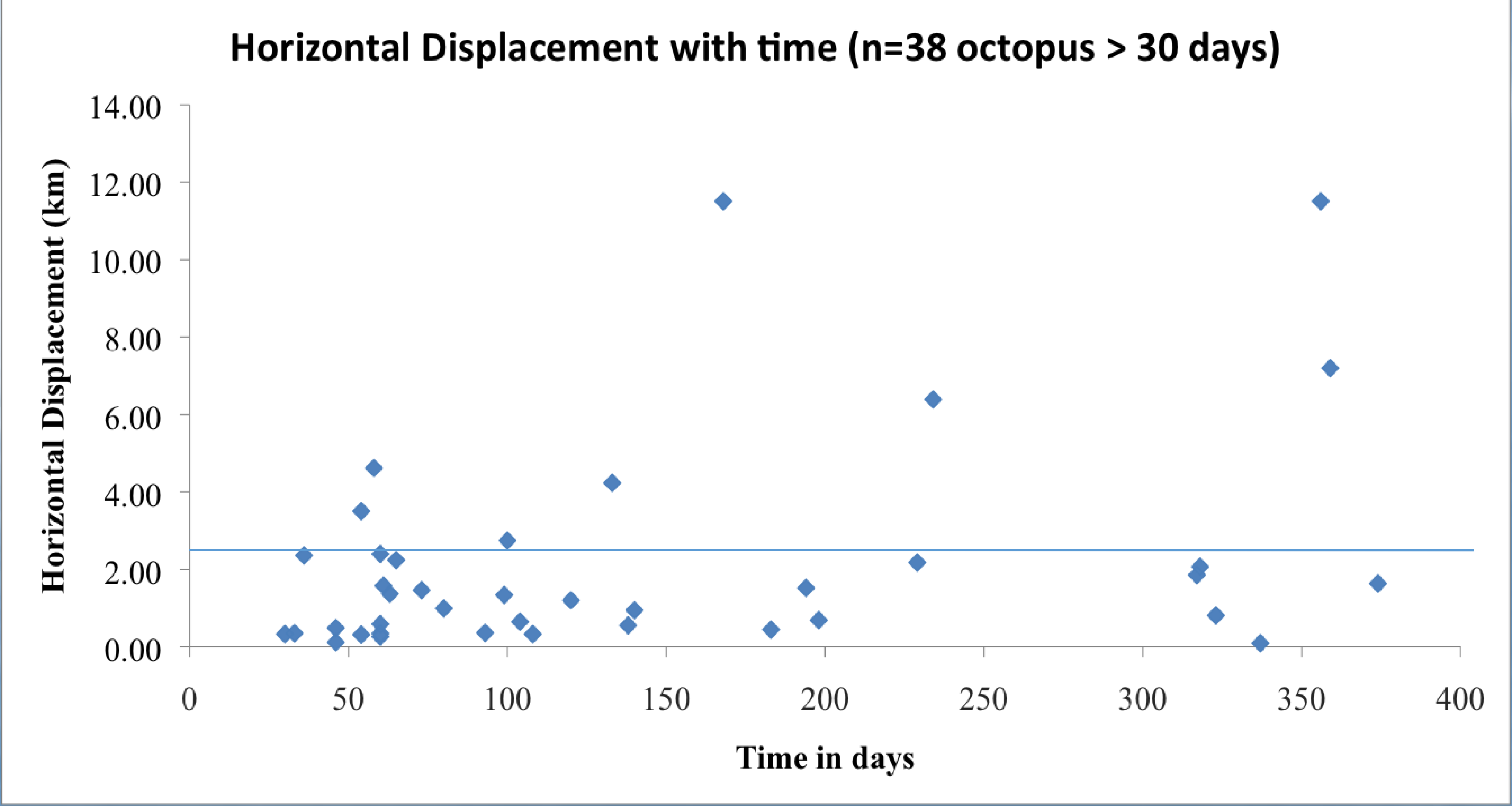
- Assuming a 400 km2 area = 1,200 tons
- 2011 OFL = 528 tons
- 2012 OFL = 3,452 tons



GROWTH ESTIMATE



MOVEMENT



Horizontal Displacement with time (n=38 octopus > 30 days)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Horizontal Displacement (km)
0
50
100
150
200
250
300
350
400
Time in days

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Short communication

Long-term retention of internal elastomer tags in a wild population of North Pacific giant octopus (*Enteroctopus dofleini*)

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ABSTRACT

Visible Implant Elastomer (VIE) tags represent a viable approach for long-term tracking of North Pacific giant octopus (*Enteroctopus dofleini*) in Alaska. Over a two year period, 1730 *E. dofleini* were tagged with individually identifiable VIE tags and 238 *E. dofleini* were recaptured in a 25 km^2 area. Of the 238 *E. dofleini* recaptured, 31 were at liberty for 60 days or more with a maximum time at liberty of 374 days. This study shows that long-term retention of VIE tags may prove to be a vital tool in determining important life-history information for octopus species.

TO CONCLUDE…

- Octopus are important in food webs, as bycatch and other countries as directed fisheries

- VIEs are a proven means to work with difficult to tag animals

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