MIGRATE 2009
Physiological Condition and Body Composition of Migratory Birds

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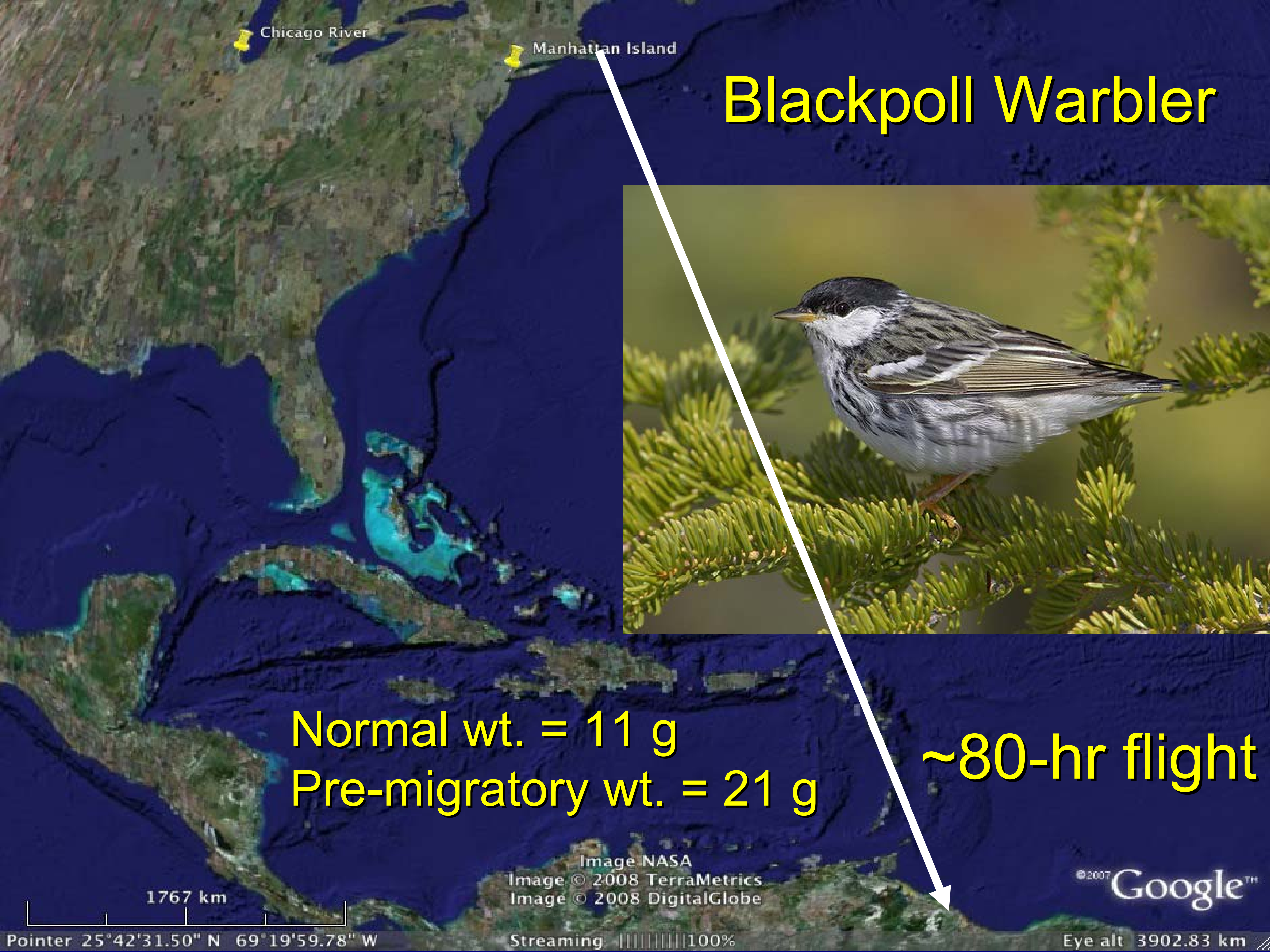
Survival during Migration requires Storage

- Requirements for certain nutrients are elevated during migration
  - migration incurs large costs in:

- protein
- water
- macro-minerals
- micro-nutrients
- ENERGY

Certain nutrients may not be readily available during migration

- Highly migratory species breeding in highly seasonal environments
  - e.g., arctic-nesting shorebirds and waterfowl
- Terrestrial species migrating overseas
  - e.g., Ruby-thr. Hummingbird crossing Gulf of Mexico
- Energy may be severely limited during migration
  - energy storage takes precedence over other nutrients
- Water may be limiting for overseas migrants


Blackpoll Warbler
Chicago River
Manhattan Island
Normal wt. = 11 g
Pre-migratory wt. = 21 g
~80-hr flight
Image NASA
Image © 2008 TerraMetrics
Image © 2008 DigitalGlobe
1767 km
©2007 Google™
Pointer 25°42'31.50" N 69°19'59.78" W
Streaming 100%
Eye alt 3902.83 km

How do migratory birds meet their water requirements during long distance trans-oceanic flights?

- Oxidative ("metabolic") water
  - produced as byproduct of oxidation of organic compounds containing hydrogen
- Grams of water formed per gram of food oxidized
  - glucose: 0.60
  - starch: 0.56
  - protein: 0.39
  - fat: 1.07 !

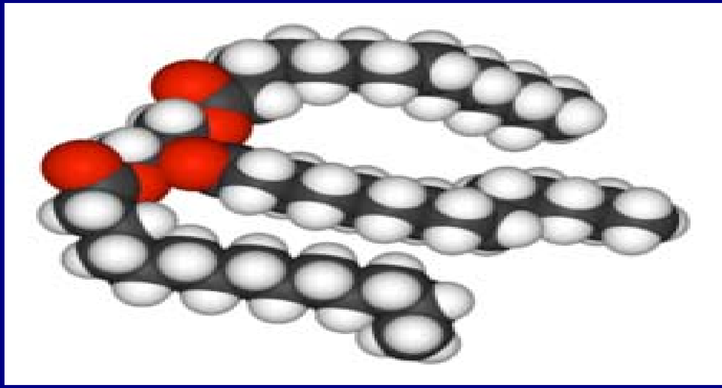
Bar-tailed Godwit

55% of live wt. in fat

New Zealand to Yellow Sea nonstop!

Energy Storage: Choice of energy storage molecule

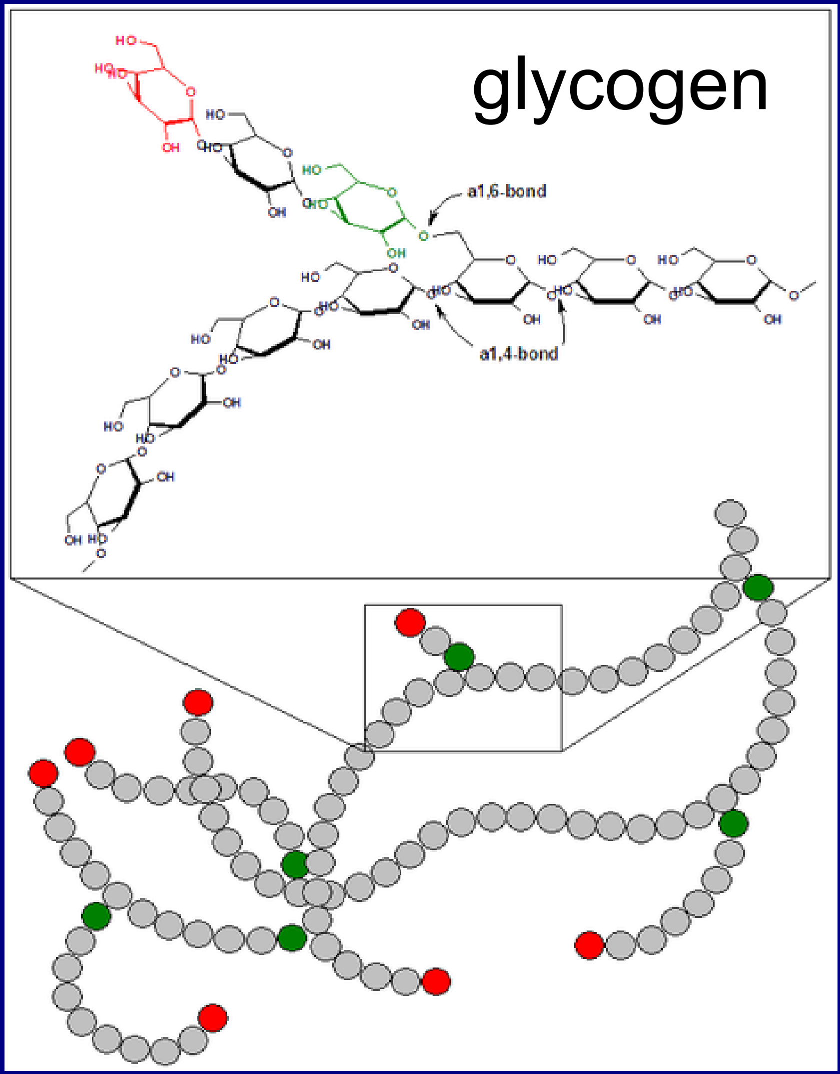
Triacylglycerol molecule



- **Lipids (fats)**
  - Higher energy density (calories/gram)
    - more than twice that of carbohydrates or protein
  - Fats can be stored without water
    - tissue density ~ 0.9
  - Fats can **not** be metabolized anaerobically
  - Fats not readily transported in body fluids
    - need lipoproteins and phospholipids

• Carbohydrates (sugars and starches)

- Can be metabolized anaerobically
- Polysaccharides (starch) are carbohydrate energy storage compounds
- Glycogen is a polysaccharide stored in liver
  - 4-5 g water stored with each gram glycogen
- Glycogen is heavy way to store energy



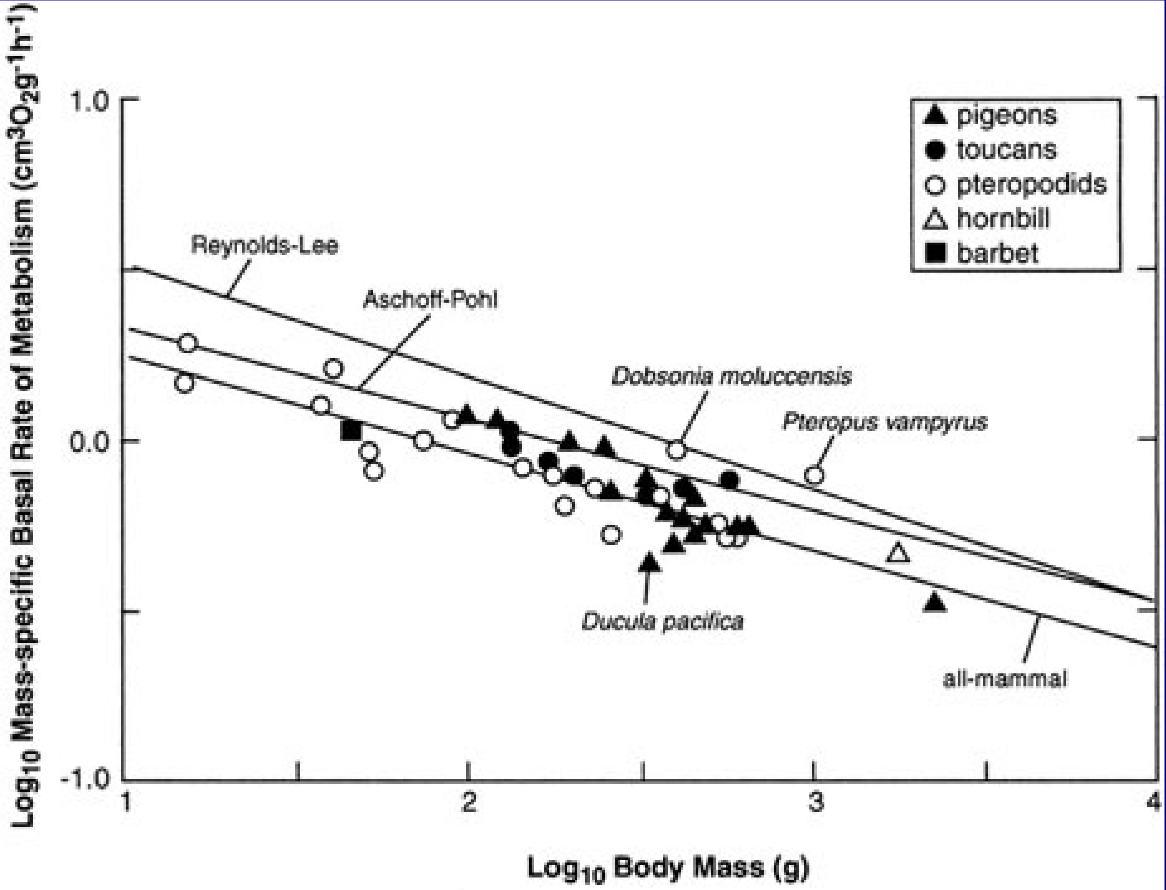
How much Fat should I store?

- Scaling of metabolic rates has a profound effect on energy expenditure rate

Body size determines:

- resistance to starvation

- flight range



- 10% of body mass in fat will last:

- 2 days for a 30-g mouse

- 20 days for a 100-kg human

- 80 days for a 1,000-kg elephant

- 160 days for a 10,000-kg (large) whale

Scaling of Migratory Range

- a goose with 20% of body mass as fat can migrate 6,000 km

- a hummingbird with 20% of body mass as fat can migrate only 800 km

Deficits in availability relative to requirement during migration produce strong selective pressures to store adequate nutrients

- But storage has **costs:**
  - procurement
  - synthesis
  - transport
  - mechanical
  - maintenance
  - remobilization

Adaptive strategy: leave fattening to the last minute to minimize fitness costs

- 10 days of pre-migratory fattening in white-throated sparrows produces 25% of body mass in fat
- Join feeding frenzy flocks just before migration
- Reduce costs of carrying extra load

How can you assess food availability and quality at a migration stopover?

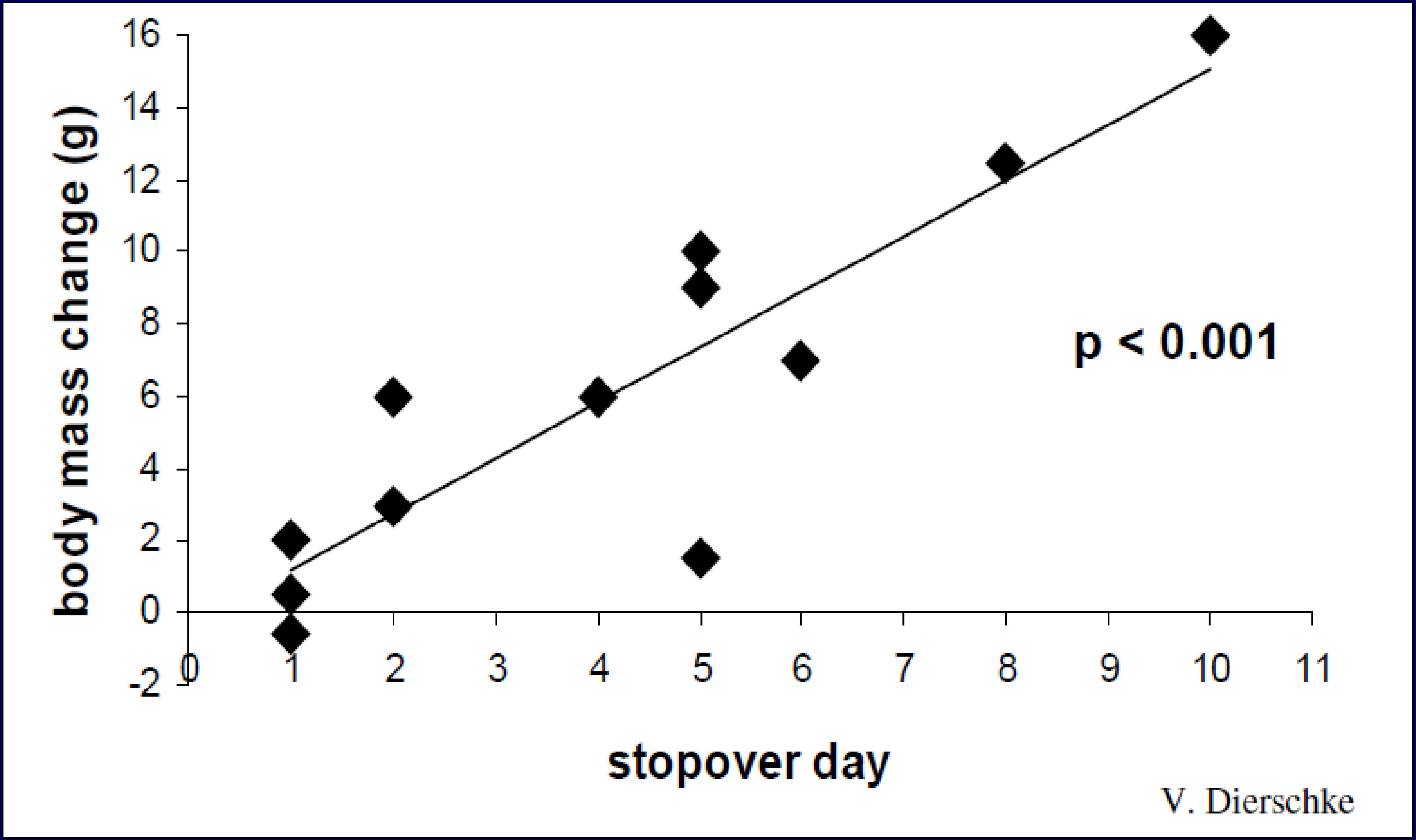
- Fat reserves change rapidly before migration
- Large fat reserves may not indicate plentiful food, but anticipated demand or shortage

- Rate of fat deposition (g/day) between captures used as index to food quantity and quality

Temporal changes in body composition used as an index to food availability at migratory stopovers

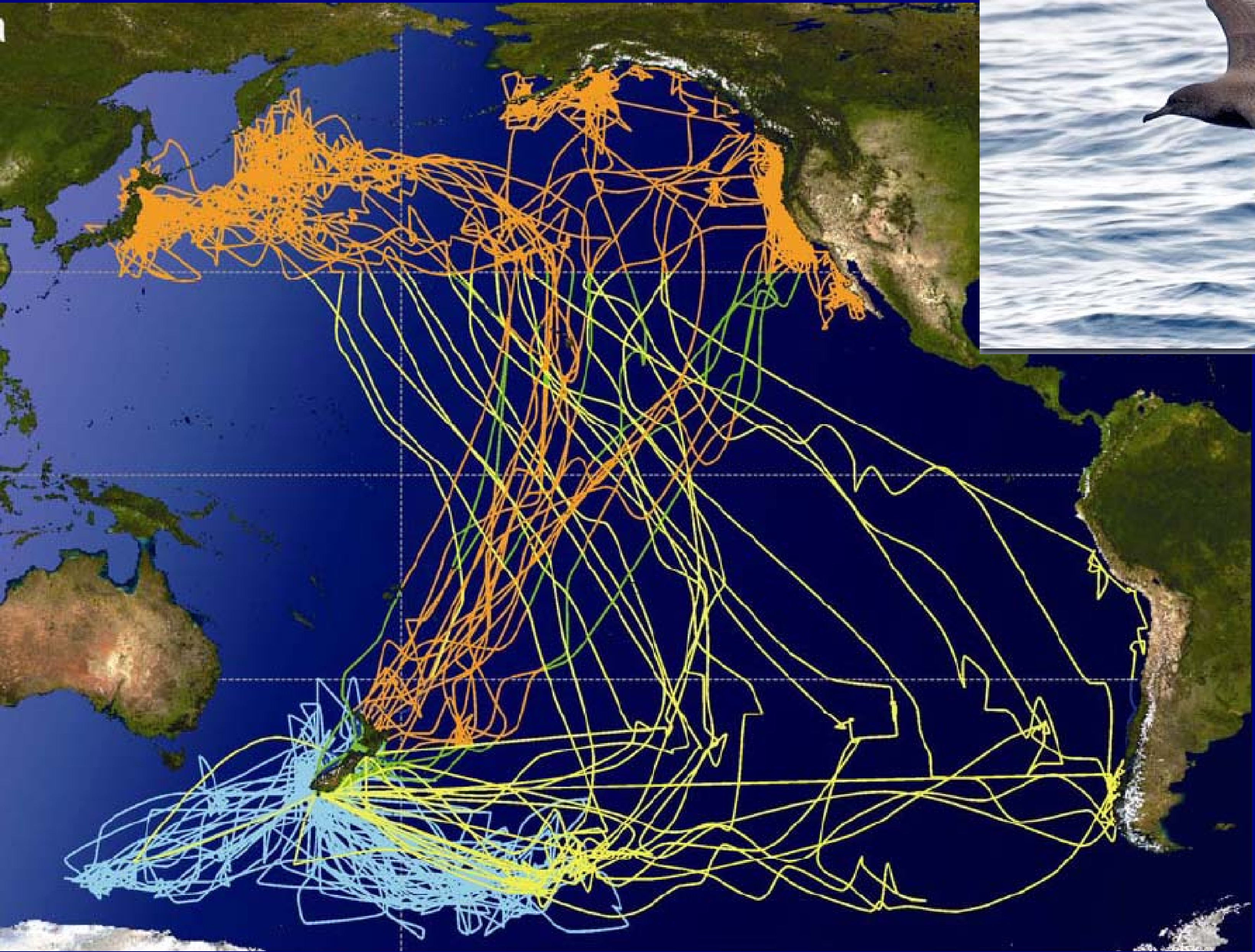
also an index to stress due to factors such as disturbance, environmental contaminants, or habitat degradation at stopovers

spring migration, Helgoland



Sooty Shearwater

Shaffer et al. 2006

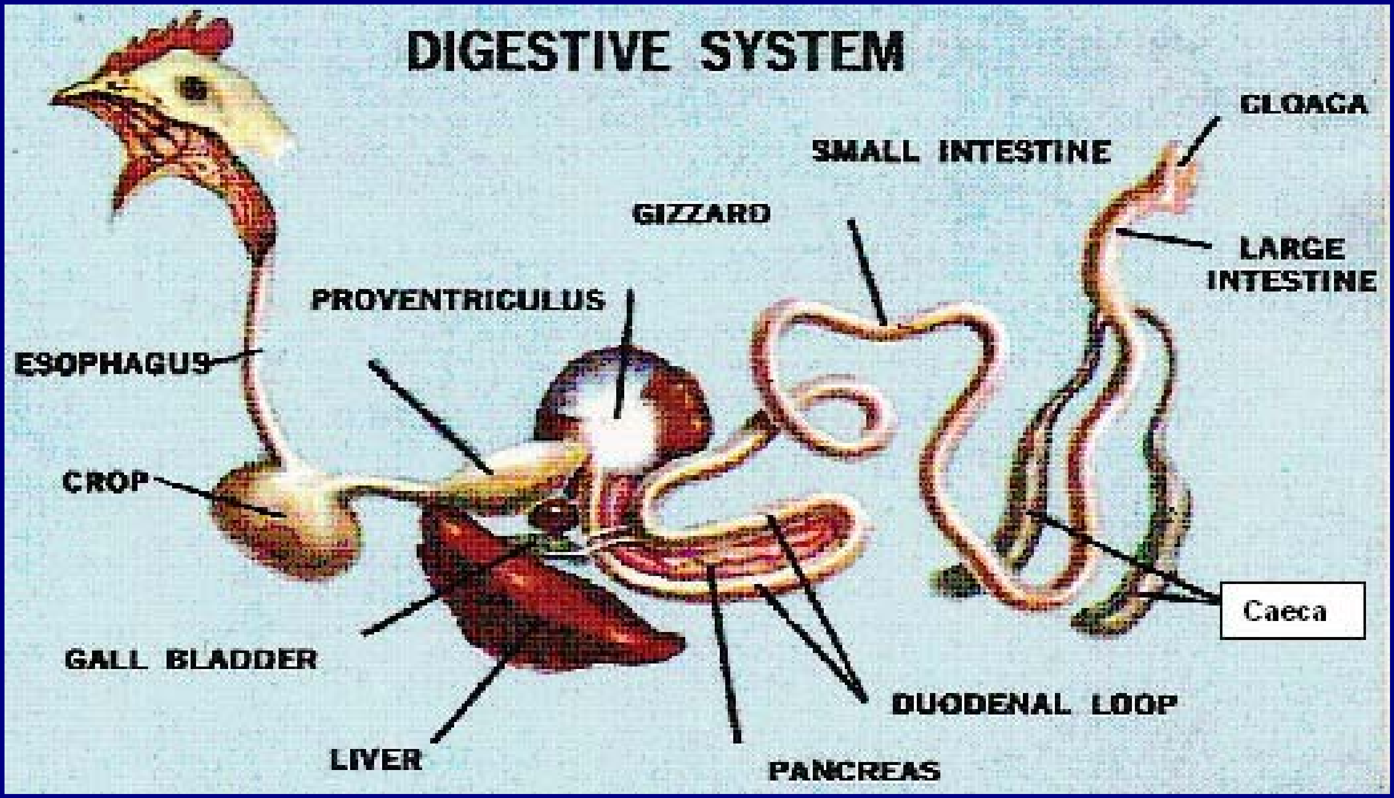


Production of stomach oil from dietary lipids gives procellariiform seabirds a bag lunch

Photo courtesy John Croxall

Lipid digestion/assimilation in birds is more efficient than in mammals

- avian lipase is bile dependent
- no co-lipase required, as in mammals
- completely hydrolyzes fats and wax esters



Avian Body Composition

- Major components: water, protein, fat, ash (minerals)
  - carbohydrates always a minor (< 1%) constituent

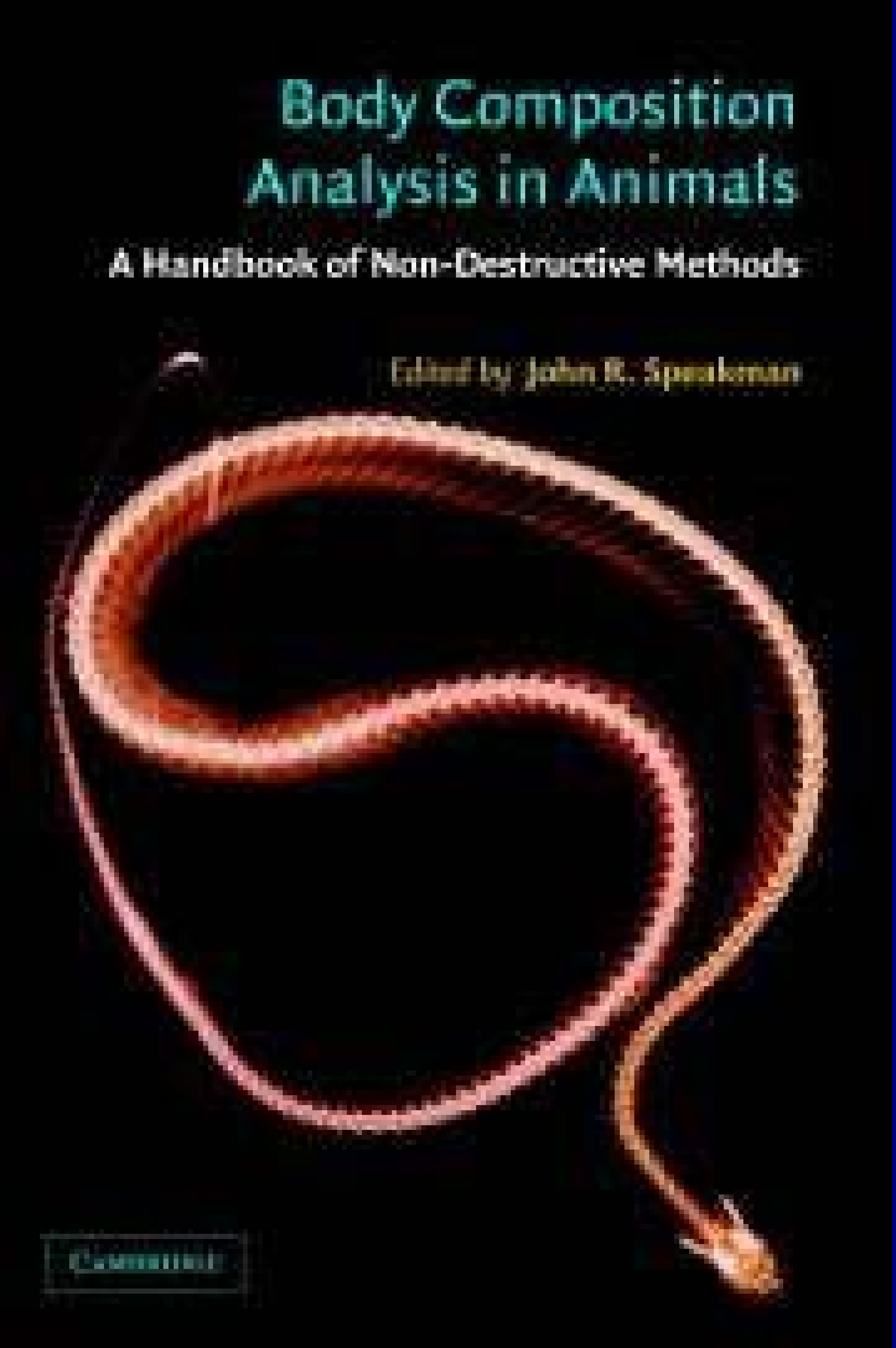
- Percent fat and percent water inversely related
  - as body fat is metabolized, body water increases

- Why is body composition of interest?
  - fat as a % of total body mass is a widely used condition index

Measuring Body Composition in Migratory Birds

- **Carcass Analysis - destructive**
  - **Bomb Calorimetry (adiabatic)**
    - bomb submerged in water to absorb heat of combustion when tissue sample reduced to ash
  - **Proximate Composition Analysis**
    - determine water, lipid, protein, carbohydrate, and ash fractions of homogenized carcass
    - use appropriate caloric conversion terms to estimate total caloric value

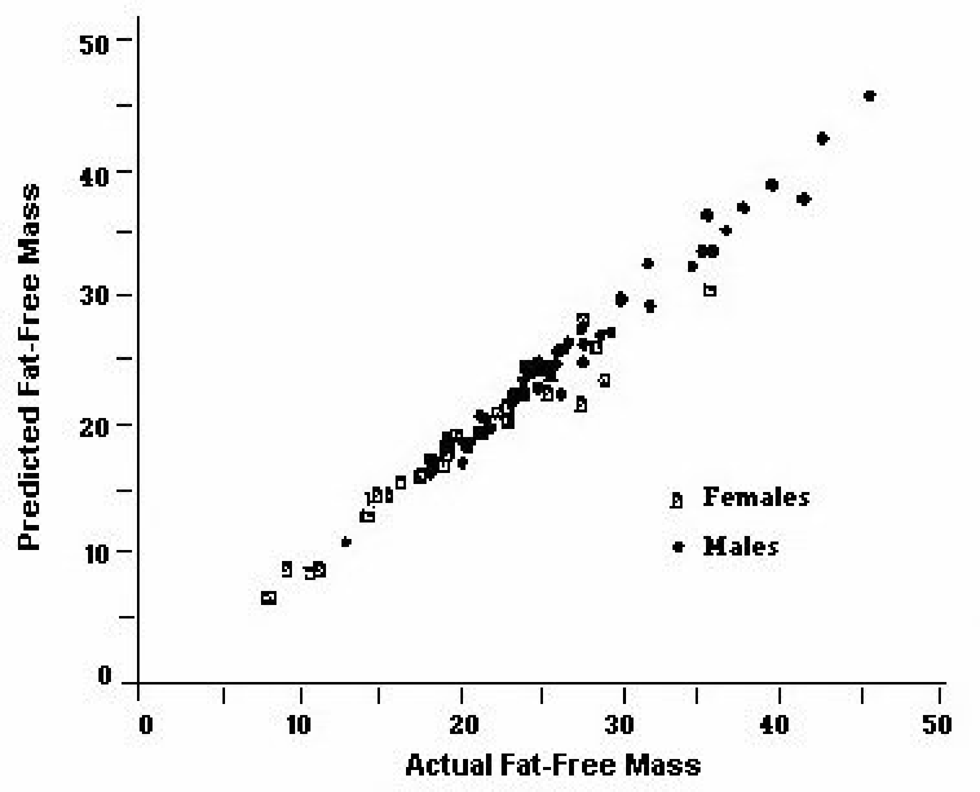
(fat - 39.3 kJ/g; protein - 17.8 kJ/g; carbohydrates - 17.6 kJ/g)



- Morphological indicators
- Isotope dilution method
- Gas dilution methods
- Total body electrical conductivity (TOBEC)
- Bioelectrical impedance analysis (BIA)
- Ultrasound scanning
- Dual-energy X-ray absorptiometry

Total Body Electrical Conductivity (TOBEC)

- body alters electromagnetic field within a coil, changing coil's impedance



- accuracy depends on consistent body posture

- precision depends on size & variability of fat reserves

Isotope Dilution Method

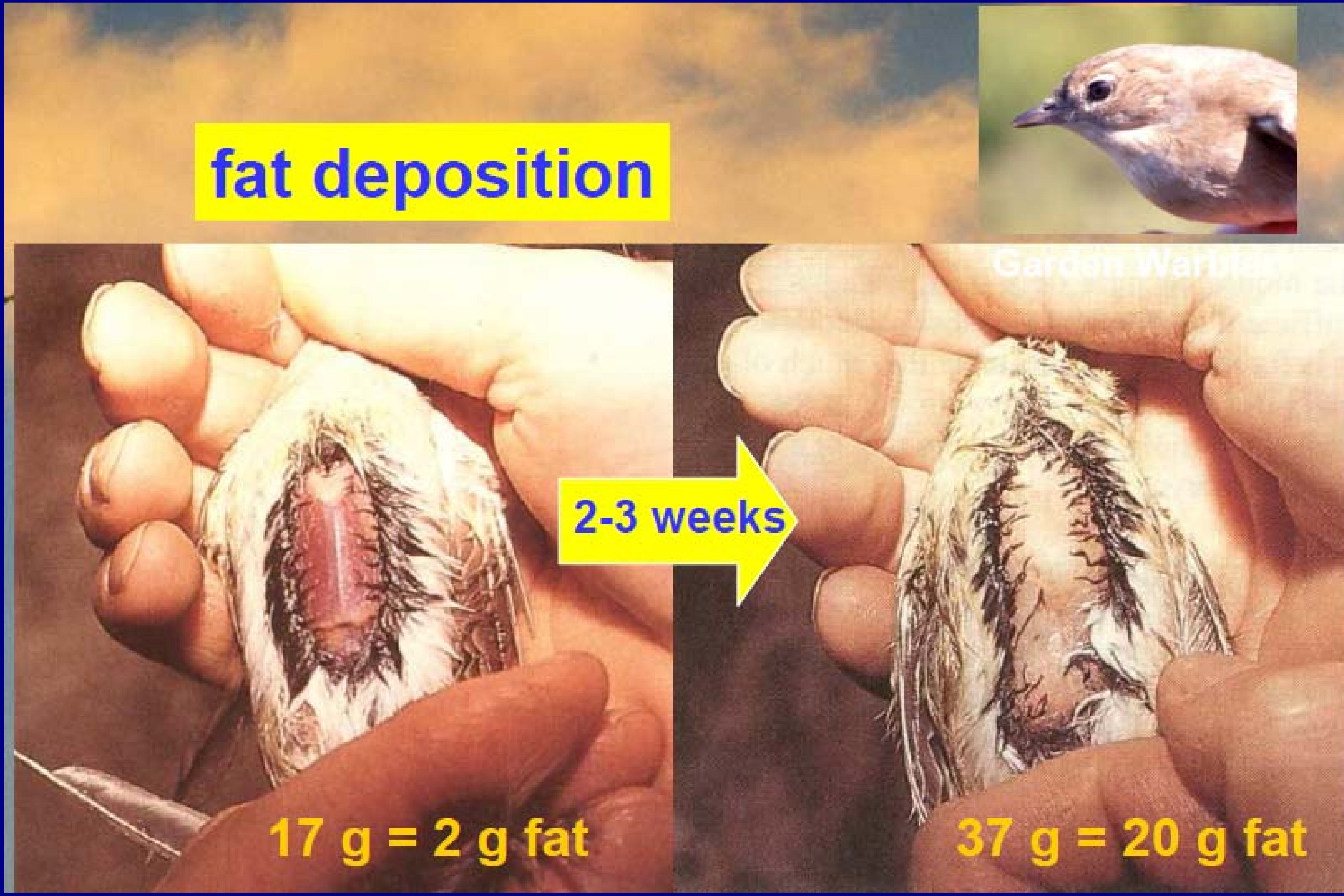
- Deuterium dilution space
  - fat content based on water estimate
  - water content varies inversely with fat content
  - inject precise amount of deuterated H_2O
  - take blood sample after equilibration (half-hr)
  - requires mass spectrometer for measuring D_2O

Other Non-destructive Methods

- Bioelectrical impedance analysis (BIA)
  - passing a weak current through body
  - varies with posture
  - problematic with unrestrained wild birds
- Gas dilution method (cyclopropane technique)
  - absorption and elimination of lipid-soluble gases
  - not appropriate for endothermic vertebrates
- Ultrasonic scanning of fat depots
  - measures fat pad thickness
- Dual-energy X-ray absorptiometry
  - requires trained lab tech, expensive

Other Indices to Body Condition

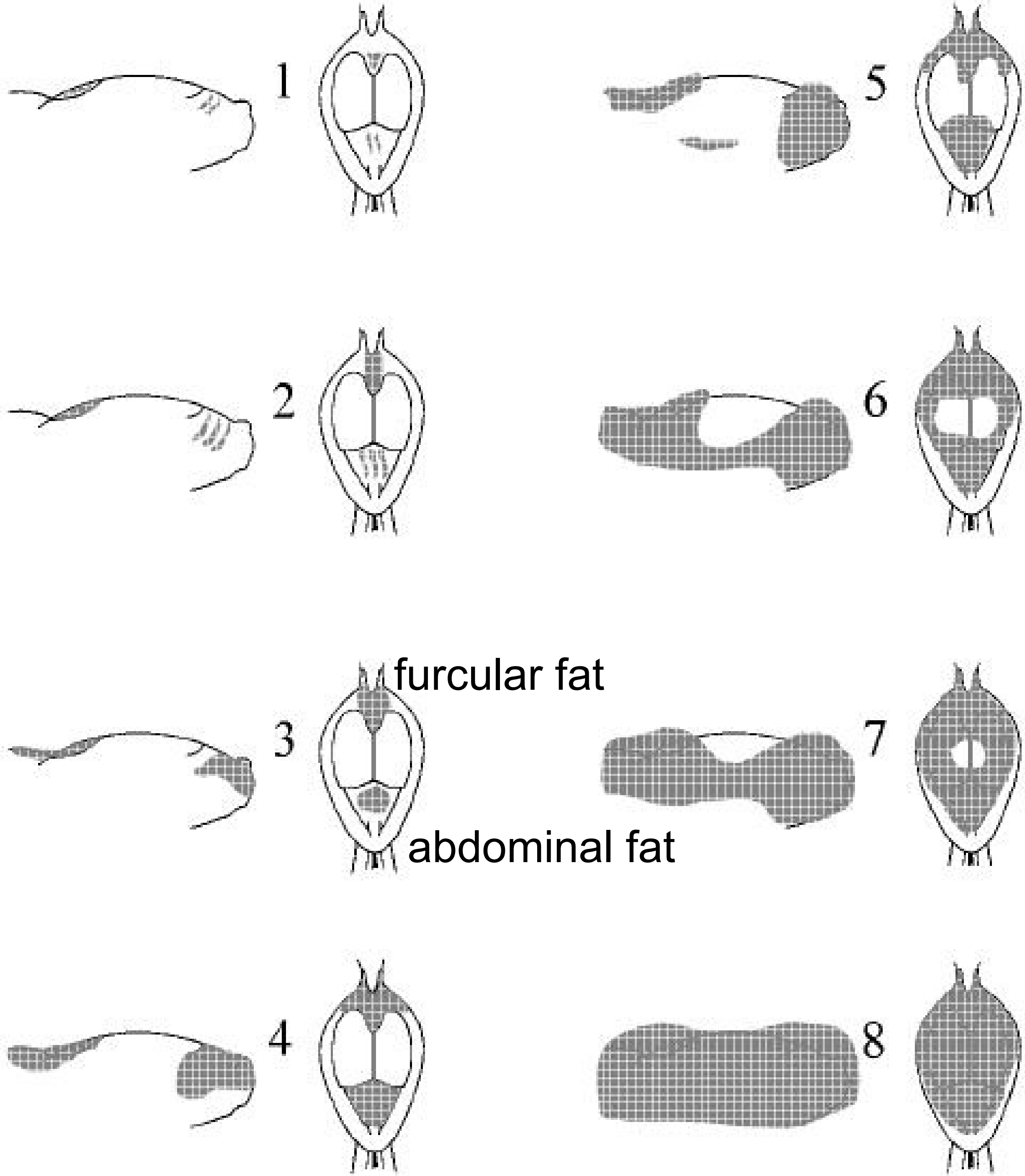
- Body Weights and Linear Measurements
  - use measurements to adjust body weight for variation in body size
  - size adjusted body weight usually correlated with condition
  - problem: don't know composition of weight
  - problem: don't know weight of gut contents
  - problem: don't know which measurements to use
    - wing chord; culmen length; tarsus length; head plus bill length
- Should validate method using carcass analysis

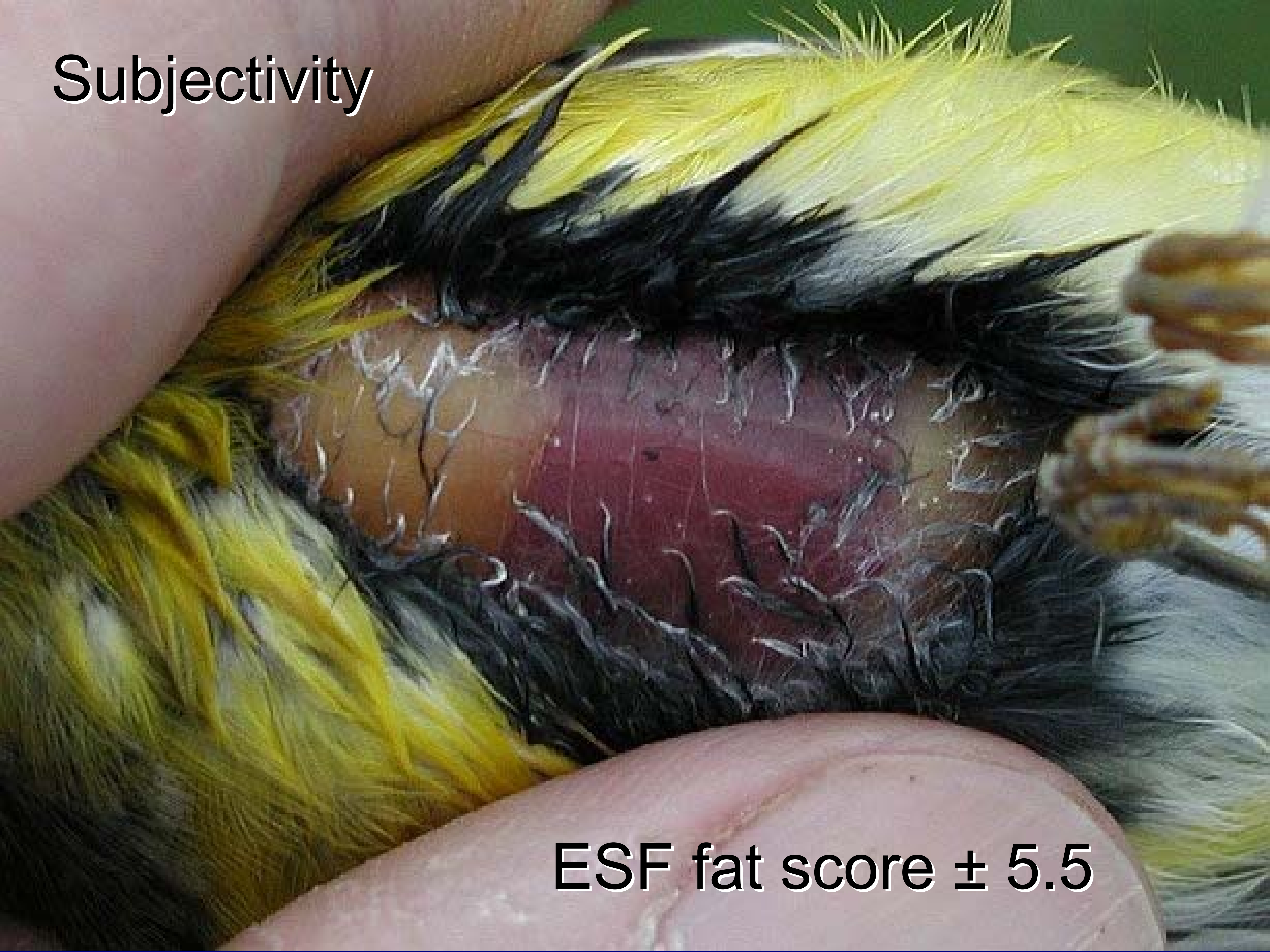

fat deposition
2-3 weeks
17 g = 2 g fat
37 g = 20 g fat

Fat Scoring

ESF protocol classes 0-8

- Semi-transparent skin required
- Mostly limited to passerines
- Experience required
- Subjective
- Should be validated with carcass analysis




Subjectivity
ESF fat score ± 5.5

Muscle Scoring

ESF protocol - classes 0-3

- size of breast muscles
- subjective
- should be validated using carcass analysis

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

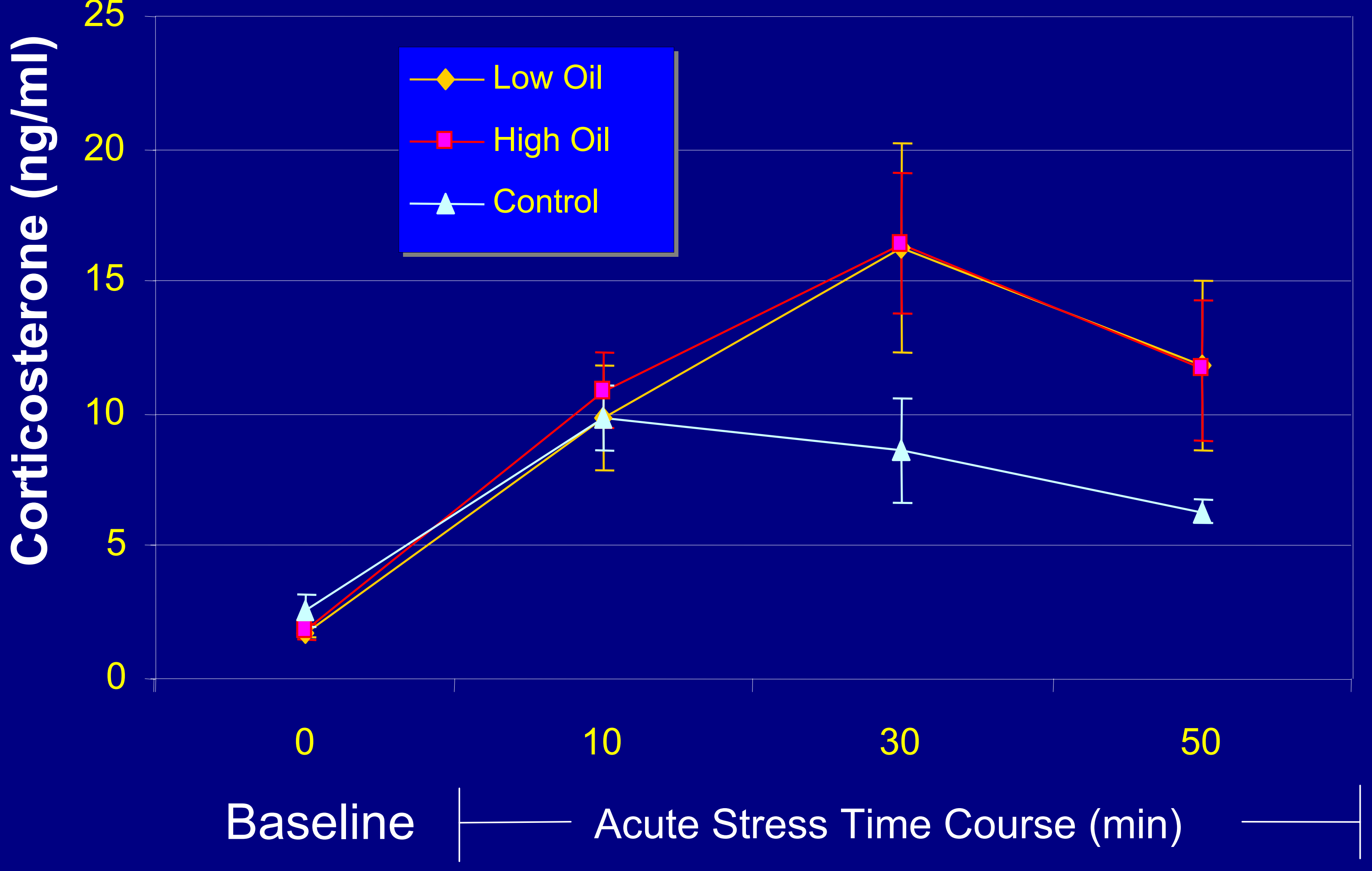
Other Indices of Physiological Condition

- Corticosterone (stress hormone levels in blood)
    - Baseline cort levels
        - blood must be collected within 3 min
    - Cort levels during stress response
        - sample blood periodically during stress

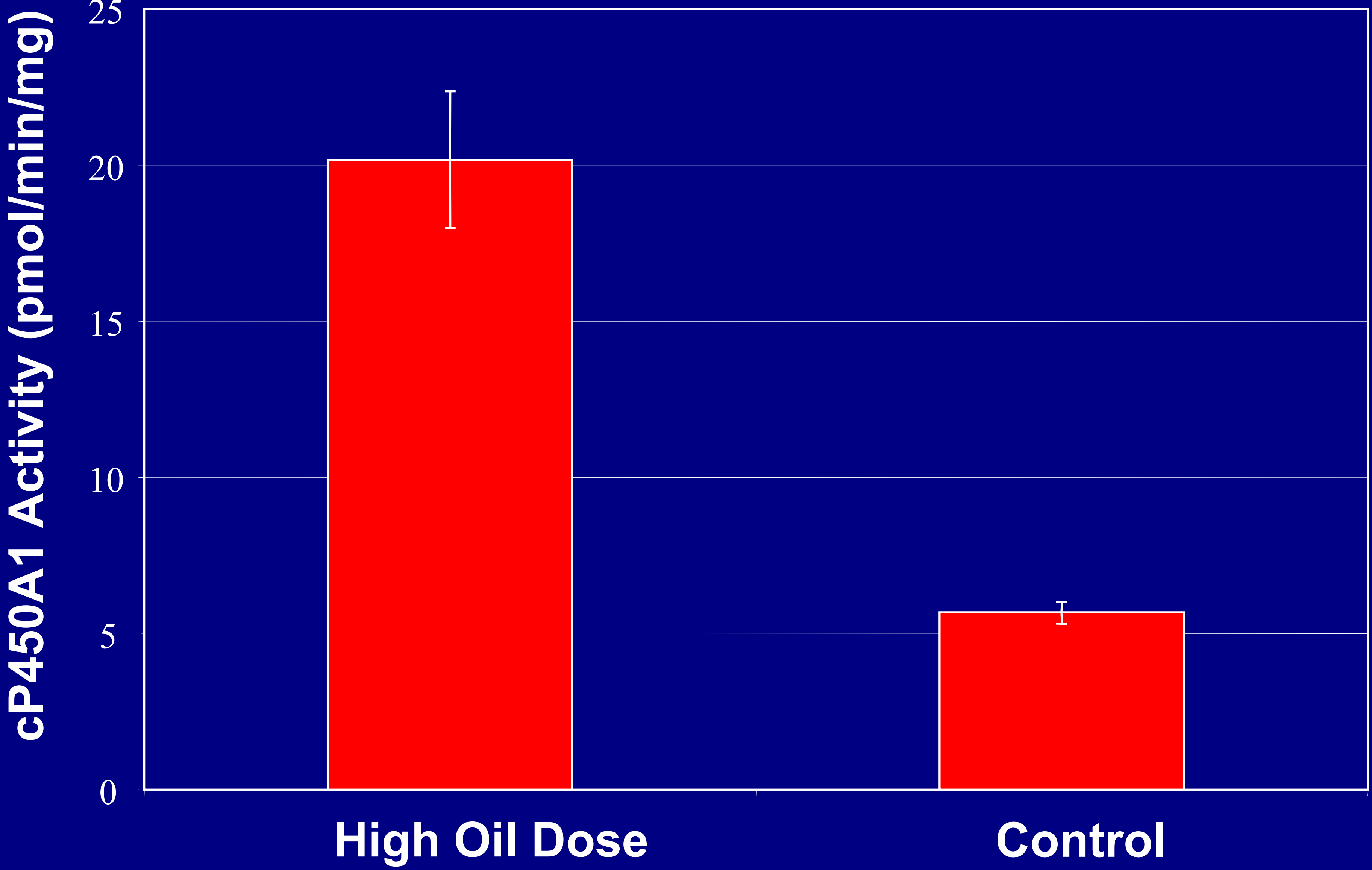
- cP450 (cytochrome P-450)
    - mixed function oxidase induced during stress
    - frequently used to detect exposure to contaminants (e.g., crude oil)
    - requires liver biopsy


Pigeon Guillemots
and *Exxon Valdez* oil spill

Corticosterone

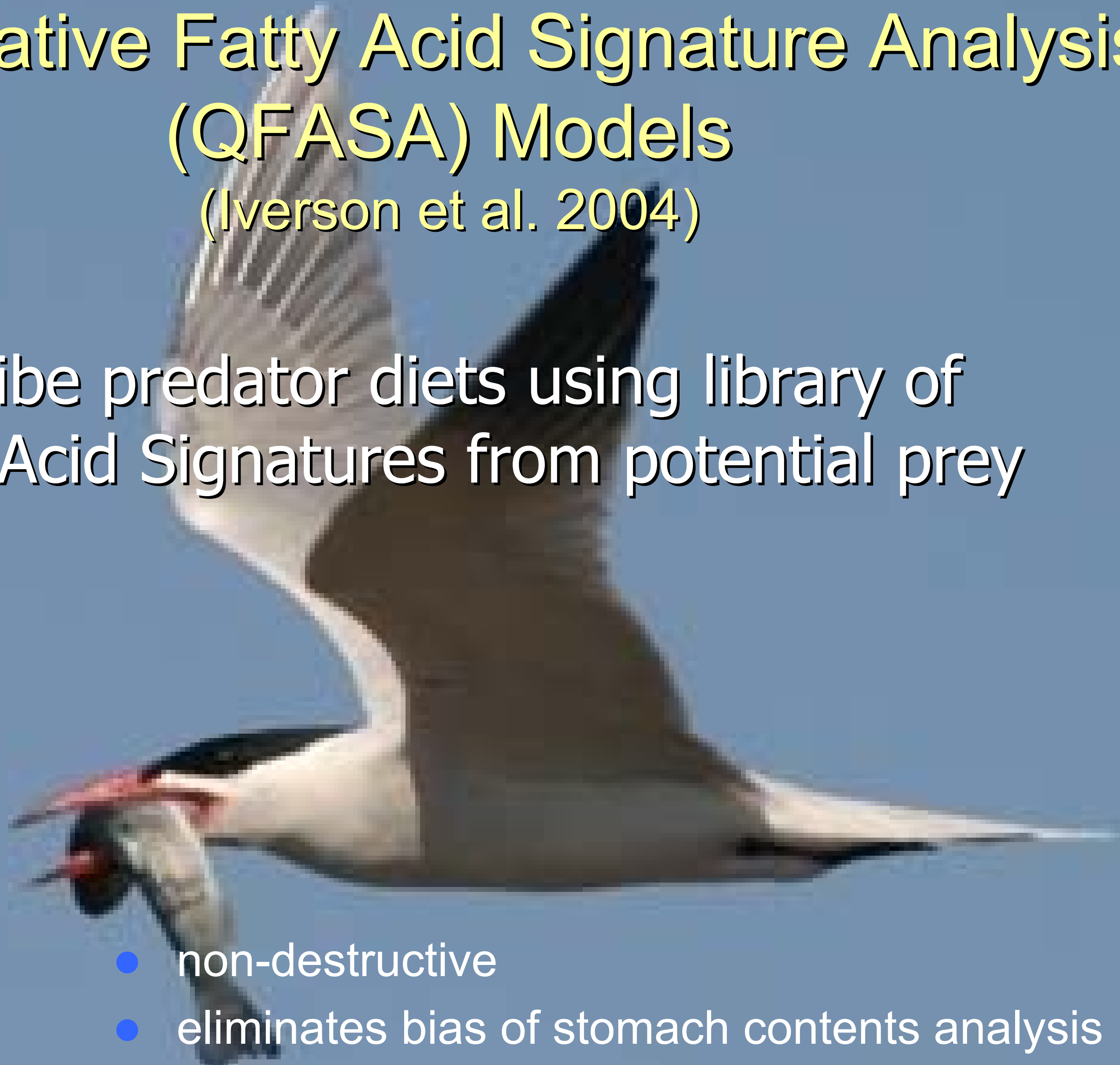


Activity of hepatic cP450



Quantitative Fatty Acid Signature Analysis (QFASA) Models

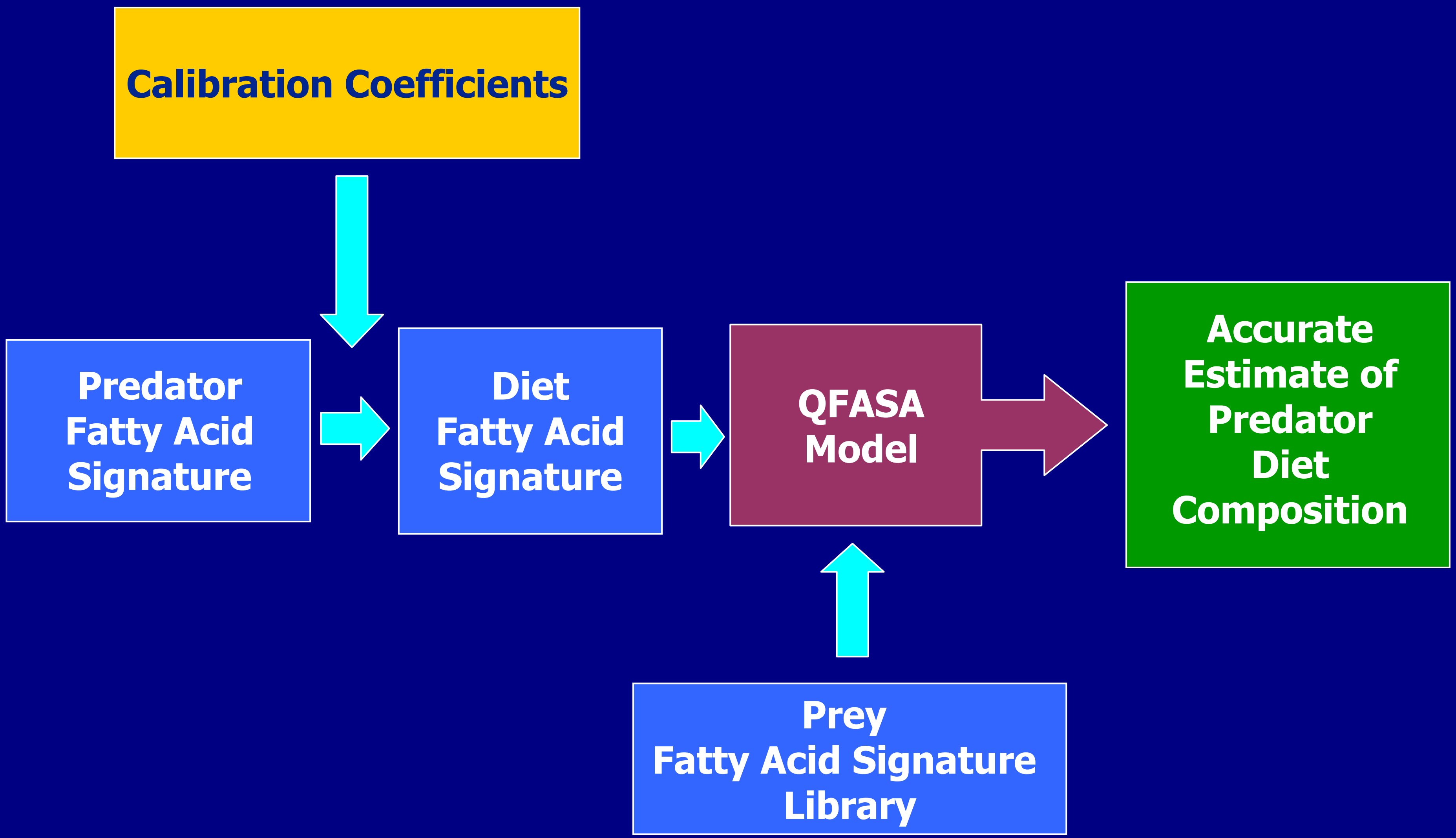
(Iverson et al. 2004)



Describe predator diets using library of Fatty Acid Signatures from potential prey

- non-destructive
- eliminates bias of stomach contents analysis
- integrates diet composition over time
- superior to traditional diet analysis methods

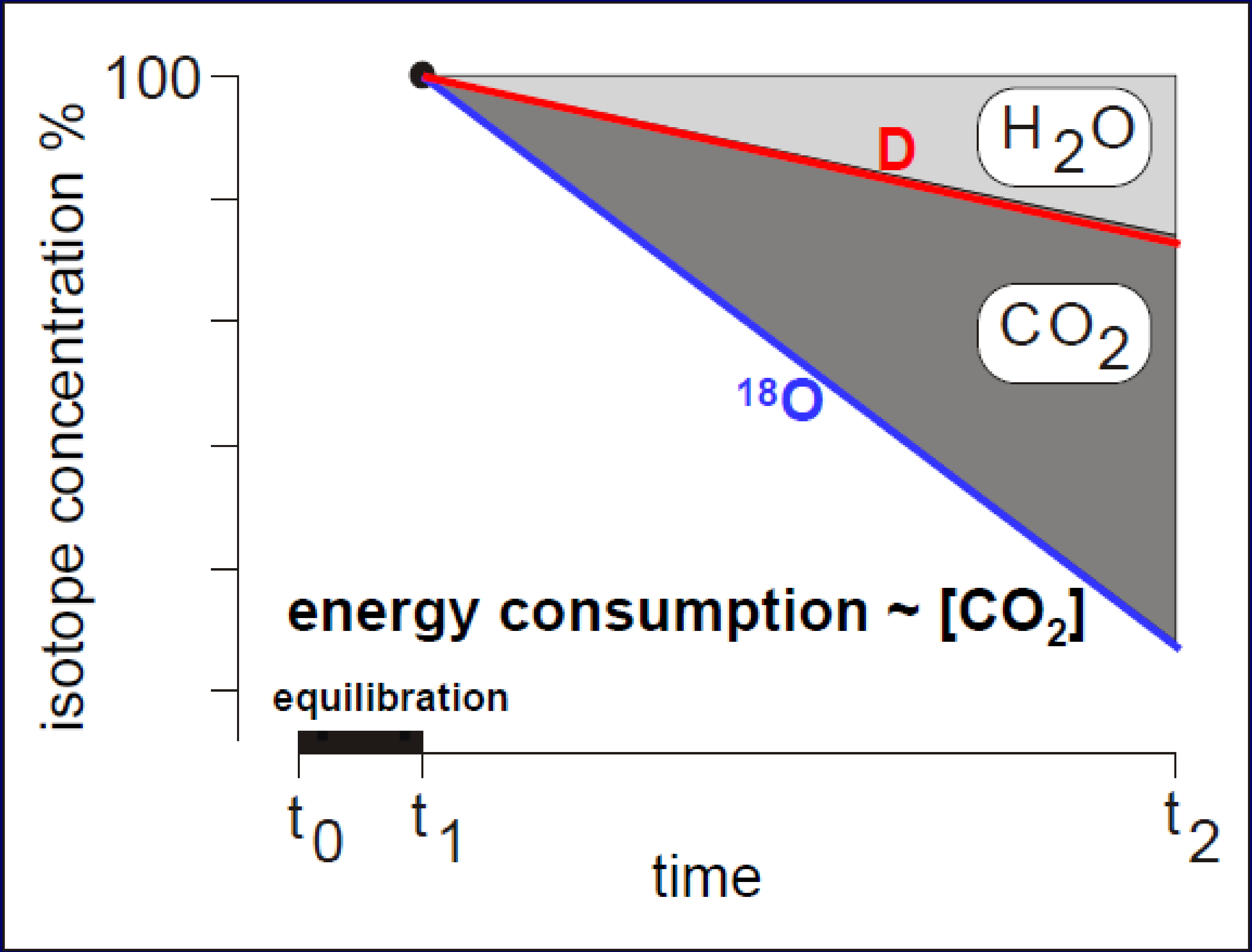
Calibration Coefficients
for Fatty Acid Signatures



Fatty Acid Signature Analysis Caveats:

- 11 of 12 fatty acid calibration coefficients varied with diet, age, or species of seabird
- variable fatty acid calibration coefficients may preclude accurate determination of seabird diet composition from fatty acid signatures
- QFASA models need to incorporate uncertainty in calibration coefficients

$D_2{}^{18}O$ (DLW)-method




Questions?

Caspian Tern Chick Condition
East Sand Island colony