A preliminary study on the mechanisms of energy storage in tropical tunas from the Indian Ocean

N Bodin[1,3], P Dewals[3], M Adeline[2,3], G Berke[2], S Lawrence[2], V Lucas[2], M Grande[1,4], I Zudaire[1,4], E Chassot[1,3]

[1] IRD UMR 212 EME - France
[2] SFA - Seychelles
[3] IRD UMR 212 EME - Seychelles
[4] AZTI-Tecnalia - Spain

Context and challenges

A fundamental goal of conservation and fishery sciences:
Long-term survival of species at a population level
(Stevenson & Woods 2006)

Environmental pressures:
Climatic events
Population cycles
Interspecific interactions

Anthropogenic pressures:
Harvesting
Habitat alteration
Toxic substances

- Failure to reproduce
- Impact on survival
- Age truncation
- Population decline

To predict population changes depend on :

- understanding the mechanistic basis of growth, reproduction, migration, and survival (Lambert & Dutil 2000, Goldstein et al 2007, Willis & Hobday 2008)
- assessing variability in individual health, especially energetic condition through fish life history

Methods that are used to quantify or correlate with condition

Condition indices	Measurement methods	Examples of data obtained
Morphology	Individual lengths/weighs	Relative weight at length
		Relative fatness
		Growth rate
Anatomy (organ)	Weigh	Tissue mass
	Examination	Organ inflammation, parasitism
	Macroscopic analysis	Tissue histological alteration
Tissue and fluid composition	Energetic / chemical	Proximate composition (protein, lipids, carbohydrates, water)
	Hormonal	Testosterone, corticosterone
	Molecular	RNA, DNA

Lipids as the main energy source for fish

- Lipids = major storage material for fish (Urich, 1990) characterized by high energetic density coupled with relatively low volume
- Analyses of lipid composition highlight the role lipids take in the tissues:

Phospholipids	The most common membrane lipids Of biological importance for maintaining the structural integrity of cells	**Structure lipids**
Sterols (ex: Cholesterol)	Maintain membrane fluidity, and precursor of steroid hormones, bile salts and vitamin D	
Ketones	As fuel in fasting conditions	
Triacylglycerols	Primary mode of lipid transport and energy storage	**Reserve lipids**
Waxes	Important in energy storage and buoyancy	

- The Reserve/Structure ratio as an energetic condition index (Gallois et al, 1990)

Review on lipid studies in tunas

Ocean	Tuna species	Industry	Trophic ecology	Energetic	References
Atlantic	Bluefin			X	Mourente 2001
	Bluefin	X			Popovic et al 2011
	Albacore	X			Wheeler et al 2003
	Bluefin Bonito			X	Ortega & Mourente 2009
	Bonito			X	Zaboukas et al 2006
Pacific	Bluefin	X			Biswas 2009
	Bluefin	X		X	Nakamura et al 2007
	Skipjack	X			Hiratsuka 2004
	Skipjack	X			Hiratsuka 2008
	Tongol		X		Saito et al 2005
Indian	Skipjack	X			Intarasirisawat et al 2011
	Tongol	X			Intarasirisawat et al 2011
	Kawakawa	X			Intarasirisawat et al 2011

Objectives

1- To determine total fat content in somatic tissues of tropical tunas from the Indian Ocean

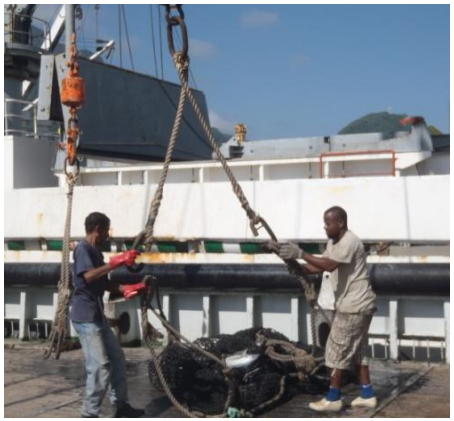
2- To compare their energy storage strategy by focusing on the “reserve/structure” condition index

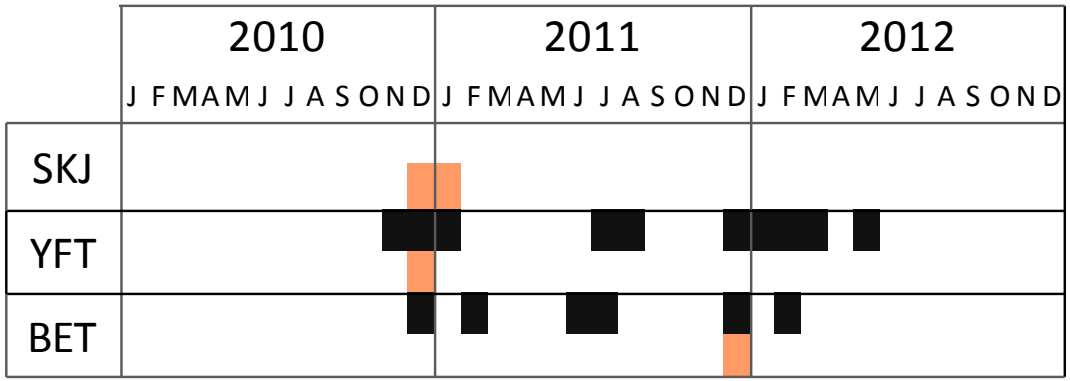
3- To investigate the differences of lipid class distribution in somatic and reproductive tissues between immature, male and female individuals

Sampling of tropical tunas (1)

➢**Tuna sampling done** in Seychelles at unloading of purse-seiners :

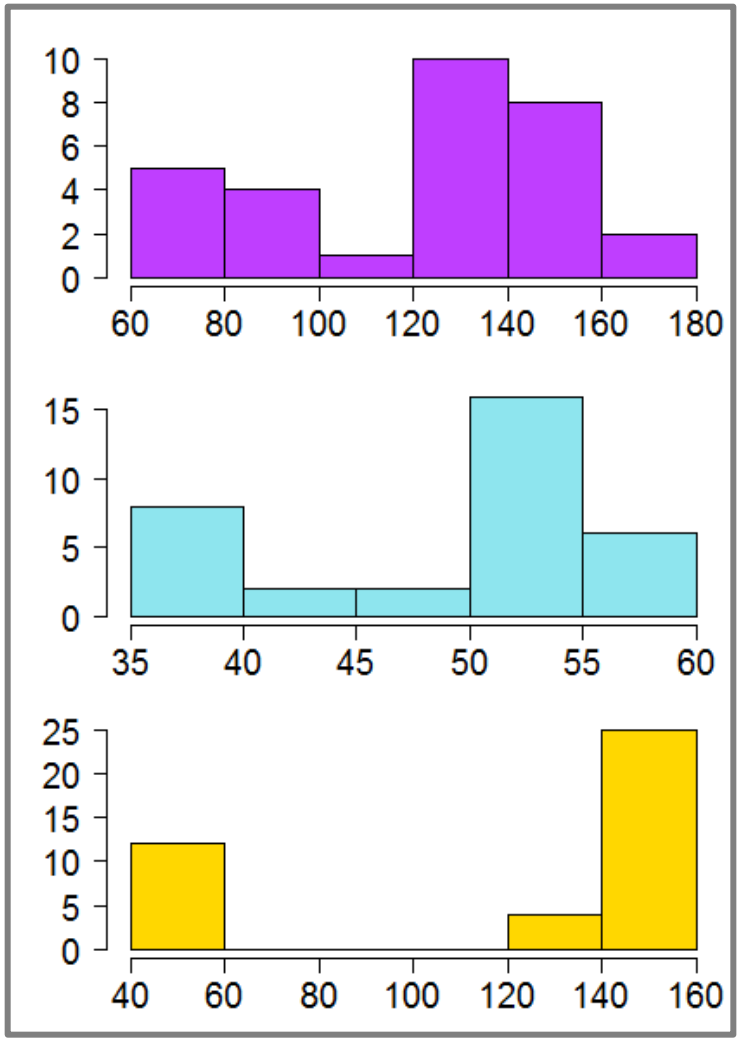
- RTTP-IO
- IRD project (EMOTION)



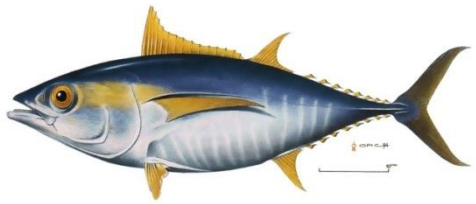


➢**Tissue collection done** at SFA (Seychelles)

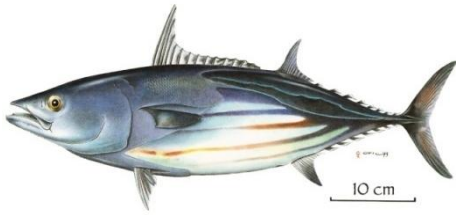
Sampling of tropical tunas (2)



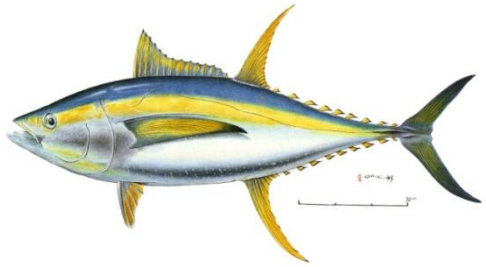
n(BET) = 30
Male=19
Female=11



n(SKJ) = 34
Male=12
Female=12
Immature=10



n(YFT) = 42
Male=22
Female=10
Immature=10



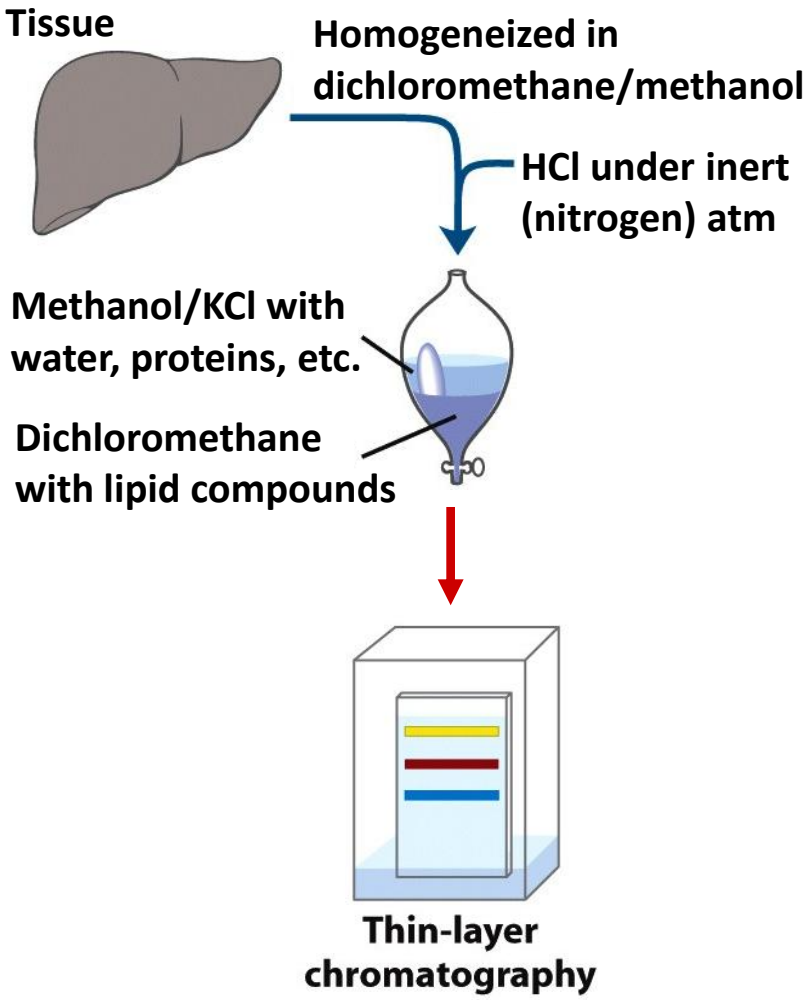
Method for lipid class analysis

(a) Tissue collection : white and red muscles, liver and gonads

(b) Tissue grinding under inert gas

(c) Organic solvent extraction to separate lipid compounds from everything else (*Folch, 1957)*

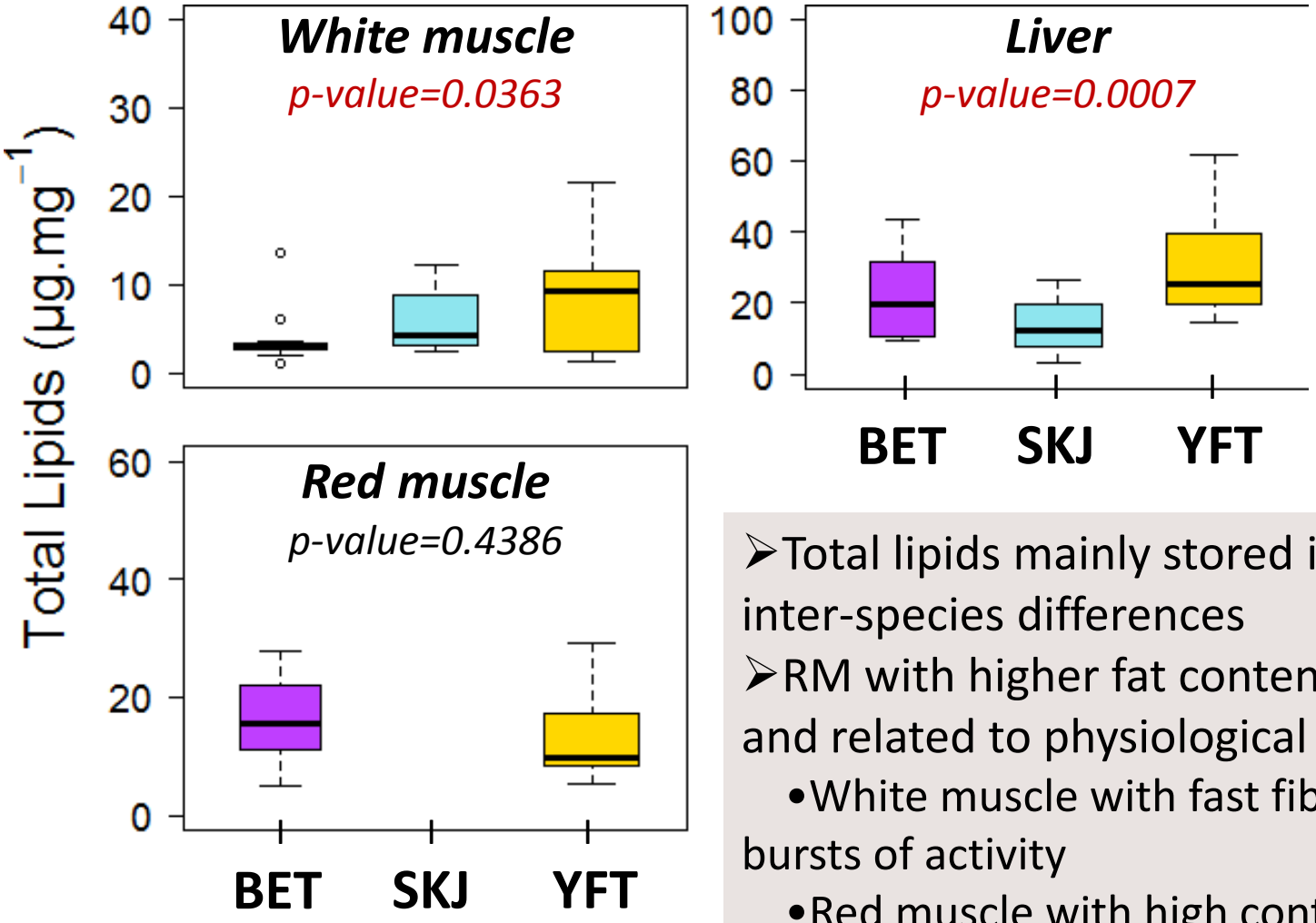
(d) Lipid class determination with tin-layer chromatography *(Parrish, 1987)*



Objective 1

Total fat content in somatic tissues of tropical tunas from the Indian Ocean

Fat content in somatic tissues of tropical tunas



- Total lipids mainly stored in liver with high inter-species differences
- RM with higher fat content compared to WM, and related to physiological functions:
  - White muscle with fast fibres used for quick bursts of activity
  - Red muscle with high content of myoglobin proteins used to carry oxygen, and provide continuous energy

Comparison with worldwide tunas

		White muscle *(min-max; µg.mg^{-1})*	Red muscle *(min-max; µg.mg^{-1})*	**RM/WM ratio**	Liver *(min-max; µg.mg^{-1})*	**L/WM ratio**
Indian Ocean (This study)	SKJ	2-12			3-27	**×2**
	YFT	1-27	5-29	**×2**	15-61	**×4**
	BET	1-14	9-28	**×5**	9-44	**×6**
Atlantic Ocean (Mourente et al 2001; Zboukas et al 2006)	BON	4-10	6-20	**×2**	5-25	**×2**
	BFT	1-3	4-5	**×2**	5-10	**×4**
Pacific Ocean (Saito et al 1997; Roy et al 2009)	SKJ	1-2	3-5	**×2**	5-10	**×2**
	PBT	1-4	4-5	**×2**		

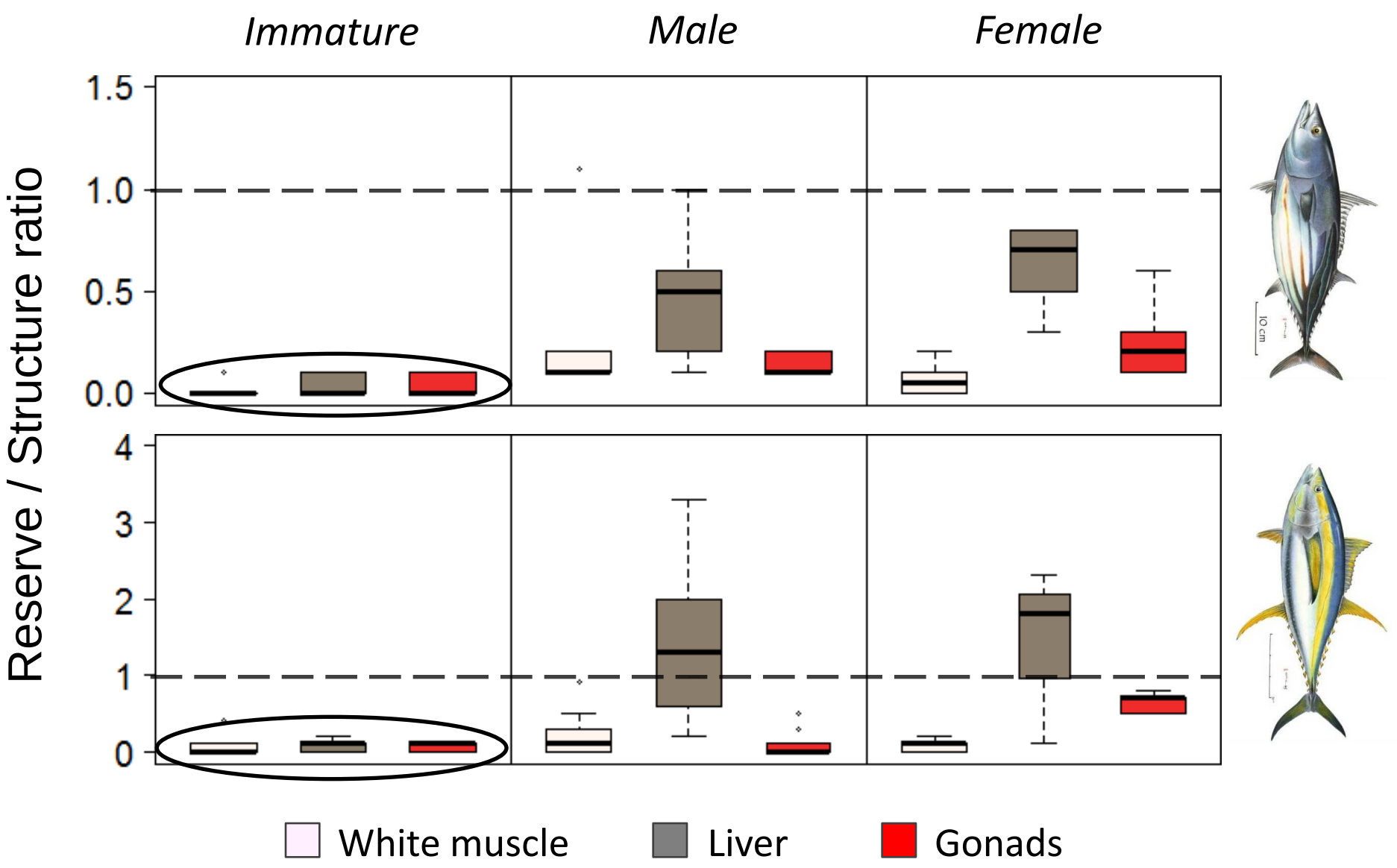
- Red muscle fatter than white muscle by a factor 2, excepted in BET
- Lower fat contents in liver for small tunas (SKJ, BON) compared to larger ones (YFT, BFT, BET) → due to different strategy of energy storage and/or allocation

Objective 2

Energy storage strategies in tropical tunas through the “reserve/structure” condition index

Reserve *vs* structure lipids in YFT & BET

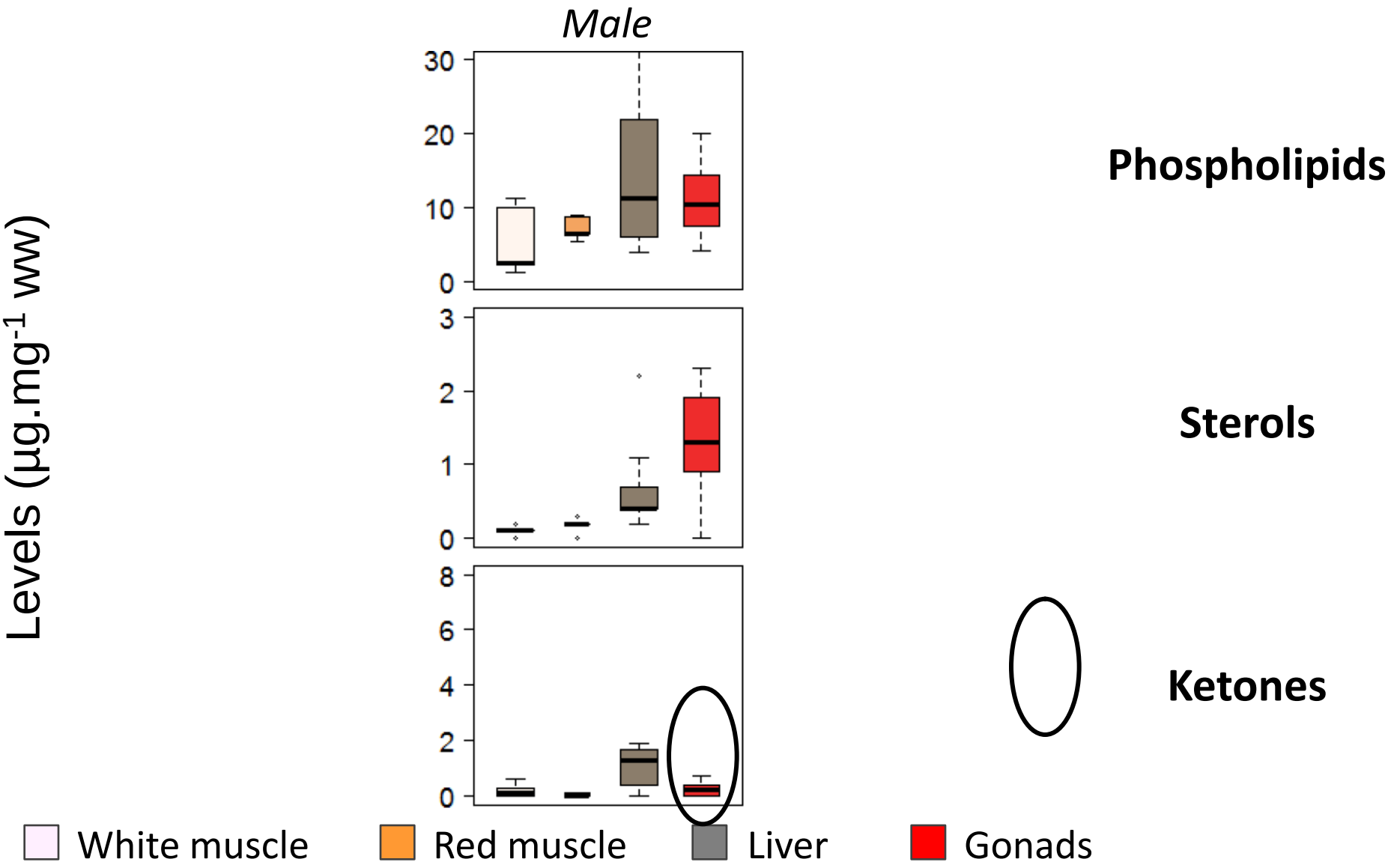
Reserve *vs* structure lipids in SKJ & YFT



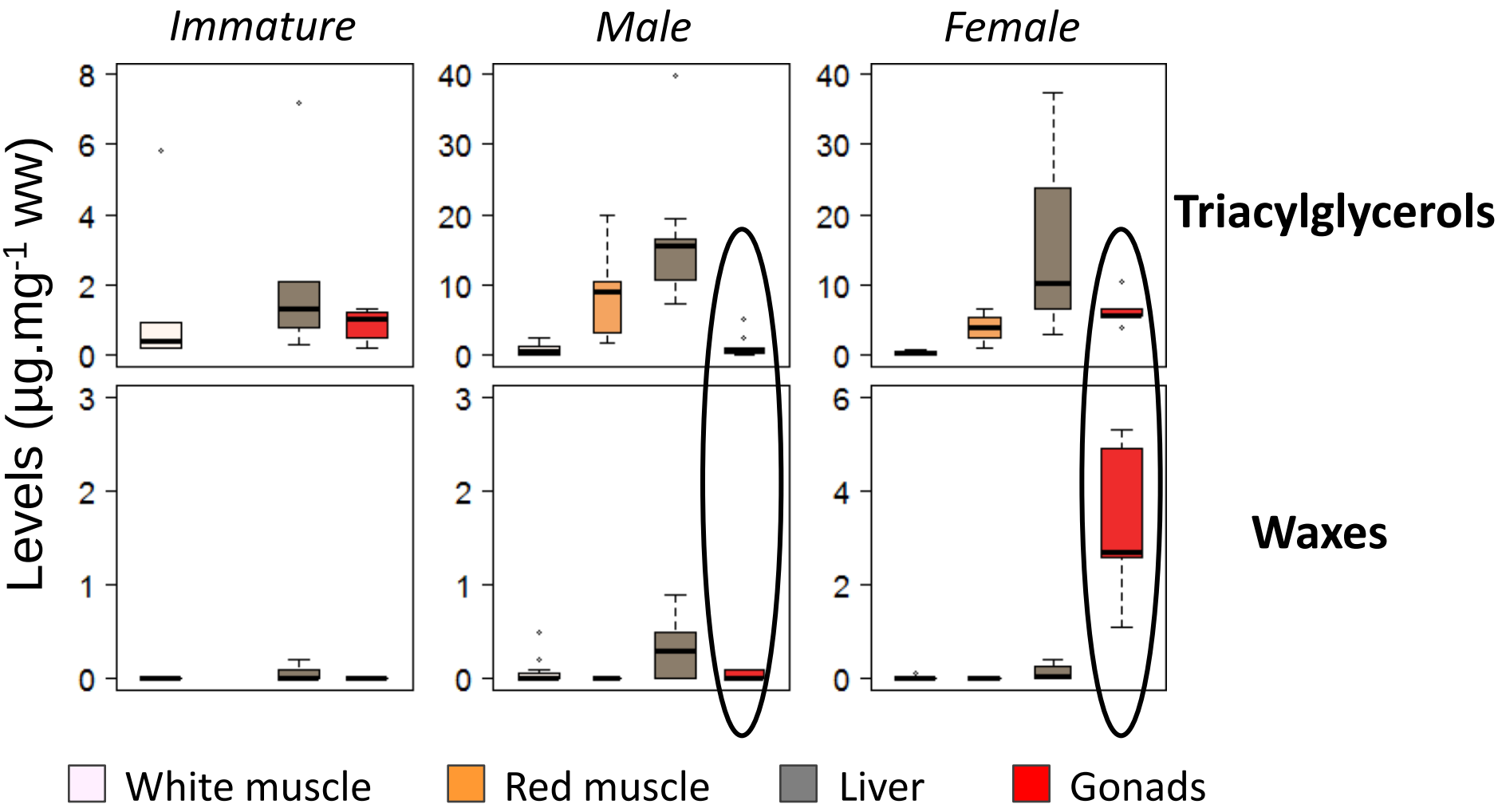
Objective 3

Effect of age and sex on the lipid class distribution in somatic and reproductive tissues: the case of YFT

Structure lipids in YFT population



Reserve lipids in YFT population



Conclusions

1- Inter-species differences of fat content in liver and white muscle

2- Sex effect for adult large tunas:

- Higher accumulation of reserve lipids (triacylglycerols and waxes) and ketones in female gonads compared to males ⇨ linked to gonad maturation

Note: More significant effect in YFT compared to BET due to a sampling biais: YFT females in spawning capable phase ≠ BET females in active spawning phase

- BET males with higher concentrations of reserve lipids in red muscle...?

3- Age effect for tropical tunas:

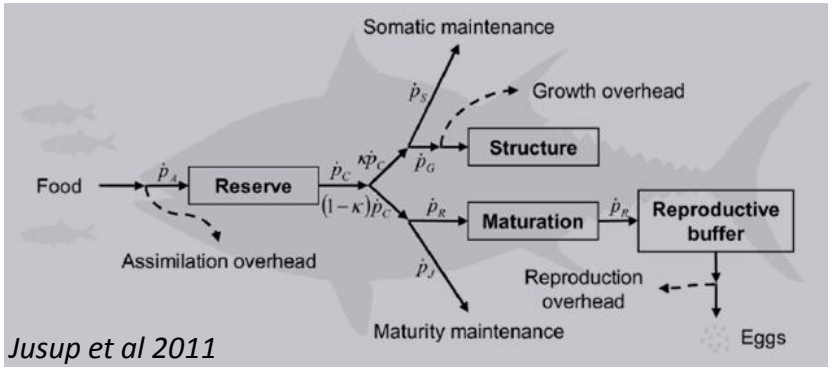
- Tissue fat content slightly lower in immature individuals while differences in lipid class distribution are strongly marked ⇨ predominance of phospholipids probably related to specific energetic requirements for tuna growth

Perspectives

➢ Preliminary study that underlines the importance of lipid studies to better understand the mechanisms of energy acquisition, storage and allocation through tuna life history

➢ Energy allocation and reproduction in tropical tunas from the Indian Ocean
- In SKJ females : PhD of M. Grande
- In YFT females : PhD of I. Zudaire
- In BET females and tropical tunas males: IRD project EMOTION ("Estimation of Maternal effects On the sustainability of large pelagic populaTIONs")

➢ Bioenergetic models for tropical tunas → how an organism acquires and uses energy and essential elements for physiological processes, in addition to how physiological performance is influenced by environmental and anthropogenic pressures
- Bluefin tuna (Jusup et al 2011)
- Skipjack tuna (Dueri et al 2012)



Jusup et al 2011