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Long chain omega-3 fatty acid dietary content determines escape response efficiency in golden grey mullet

Marie Vagner, Salomé Ducos, Nicolas Graziano, Fabienne Le Grand, Antoine Bideau, Emmanuel Dubillot, Christel Lefrançois

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Dietary long-chain omega-3 fatty acids determine escape response efficiency in golden mullet



Marie VAGNER

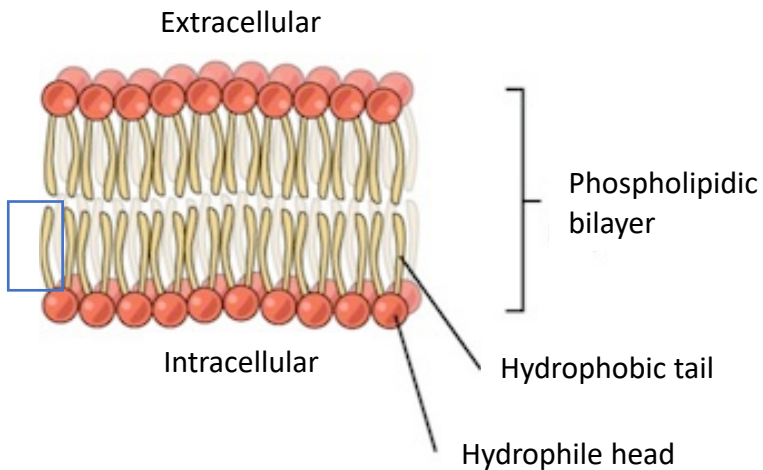
Salomé Ducos, Nicolas Graziano, Fabienne Le Grand, Antoine Bideau,
Emmanuel Dubillot, Christel Lefrançois

UMR LEMAR, Pouzané France

- Lipids and fatty acids (Tocher, 2003)

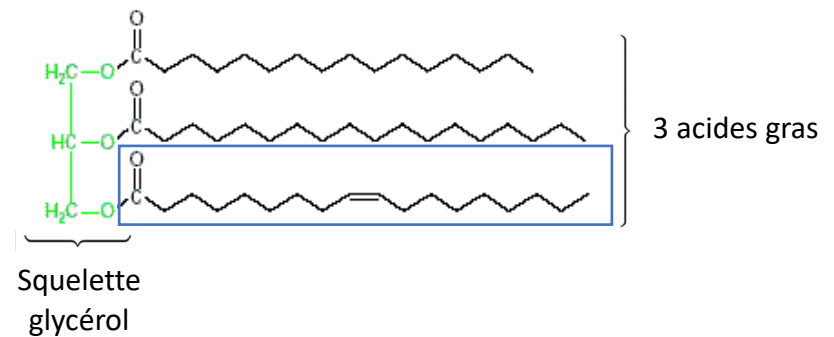
Polar lipids (PL) = Structural lipids

Cell membranes properties



Neutral lipids (NL) = Reserve lipids

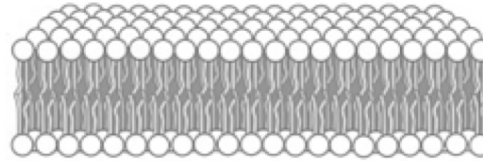
Metabolic energy source



Long chain N-3 polyunsaturated fatty acids (LC omega 3):

Structural components of the cell membranes

- EPA (eicosapentaenoic acid, 20:5n-3)
- DHA (docosahexaenoic acid, 22:6n-3)

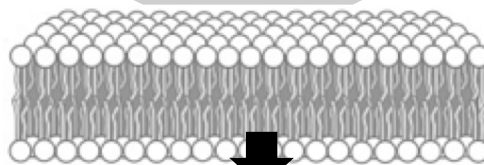


Long chain N-3 polyunsaturated fatty acids (LC omega 3):

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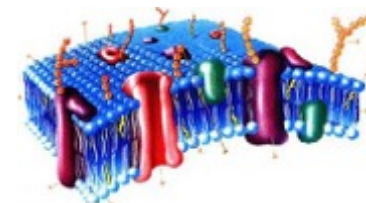
- **DHA** (docosahexaenoic acid, 22:6n-3)



Fluidity and permeability of membranes

Conformation & activity of embedded proteins

Development & functions of cells and tissues

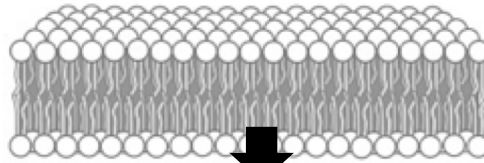


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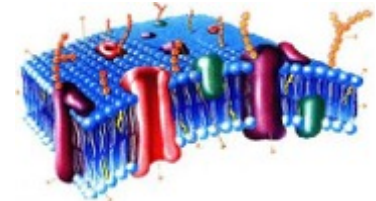
-DHA (docosahexaenoic acid, 22:6n-3)



Fluidity and permeability of membranes

Conformation & activity of embedded proteins

Development & functions of cells and tissues



Individual (growth, locomotion, metabolism, reproduction ...)

Population (reproduction, growth, survival)

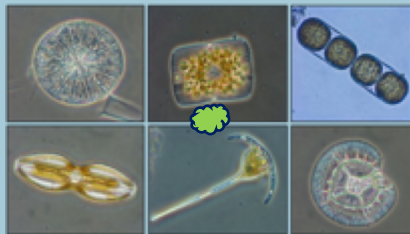
Ecosystem (habitat selection, migration, predator-prey relationships,...)

While necessary to maintain vital functions, LC omega 3 weakly synthesized *de novo* by marine fishes

While necessary to maintain vital functions, LC omega 3 weakly synthesized *de novo* by marine fishes

→ **Must be supplied by food**

Ocean



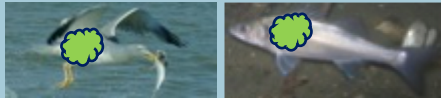
Primary
producers

EPA+DHA

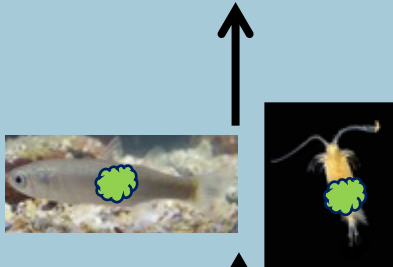


↑ Main vector of LC
omega 3

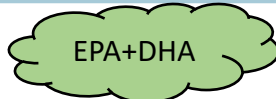
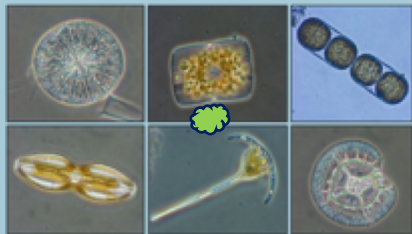
Secondary
consumers



Primary
consumers



Primary
producers

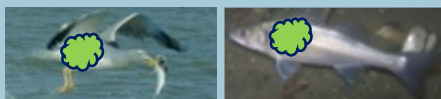




Human

Main vector of LC omega 3

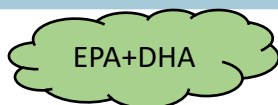
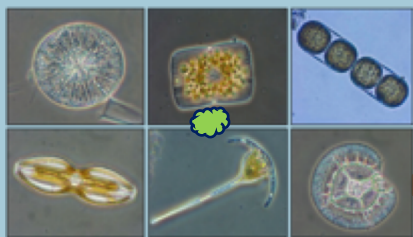
Secondary consumers



Primary consumers



Primary producers

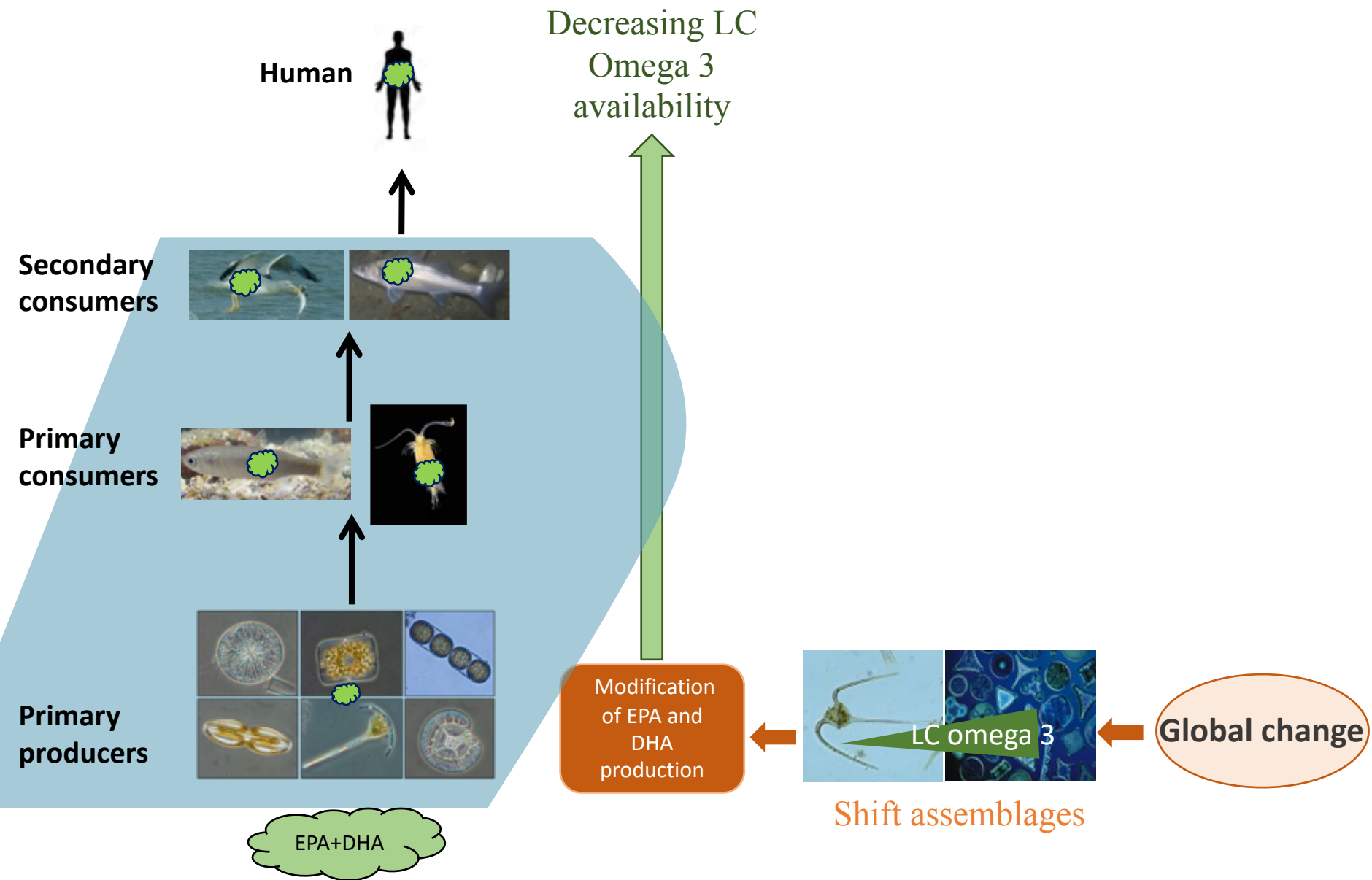


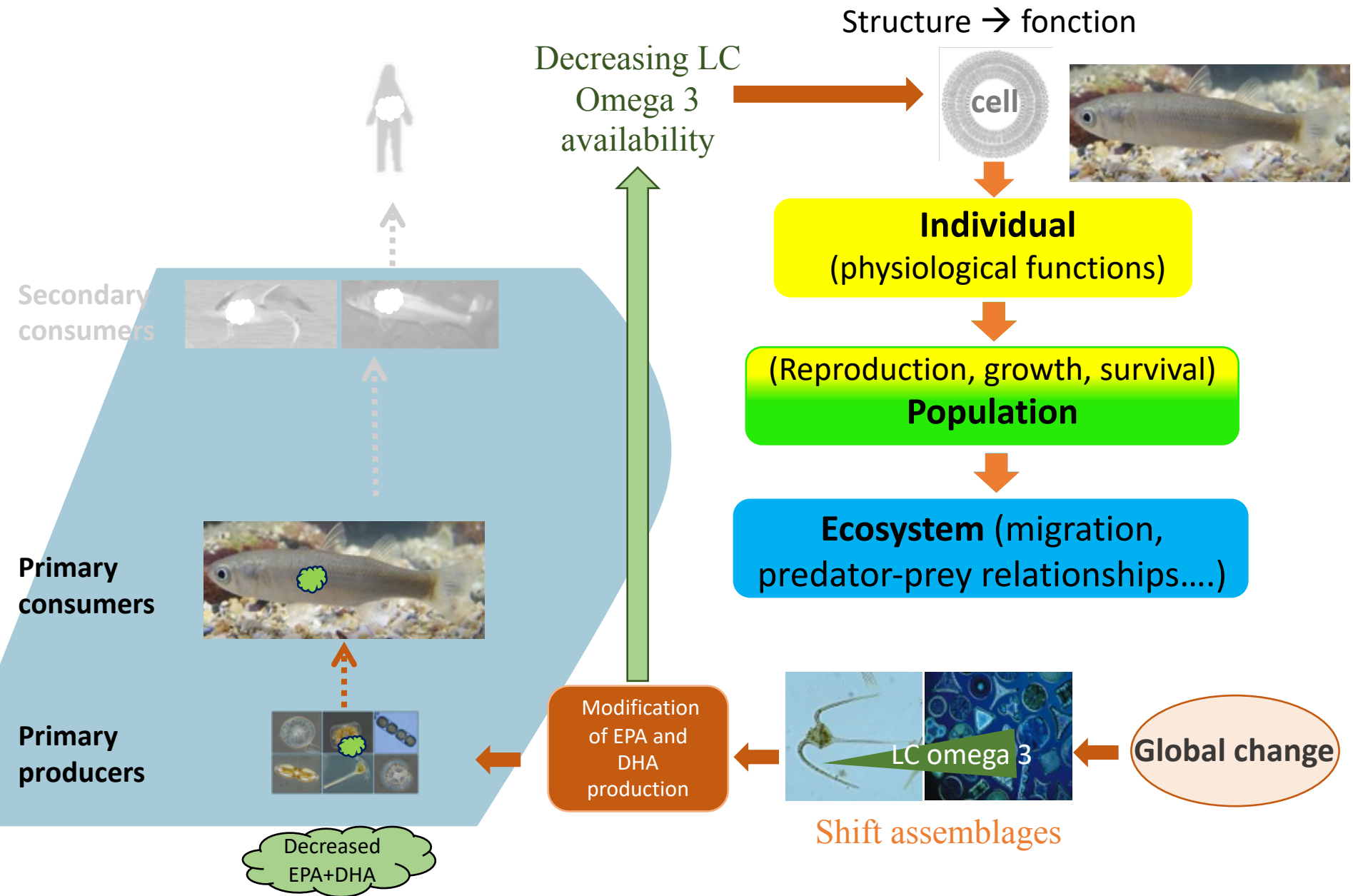
Modification of EPA and DHA production

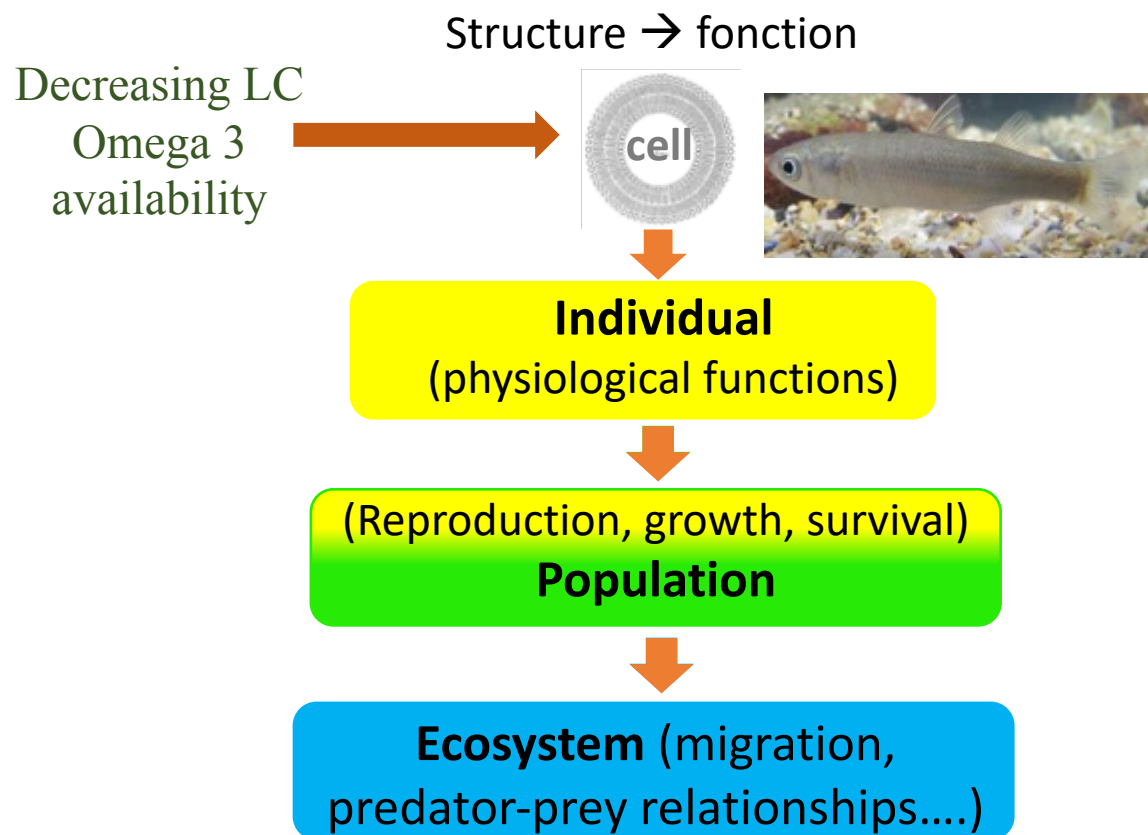


Shift assemblages of communities

Global change

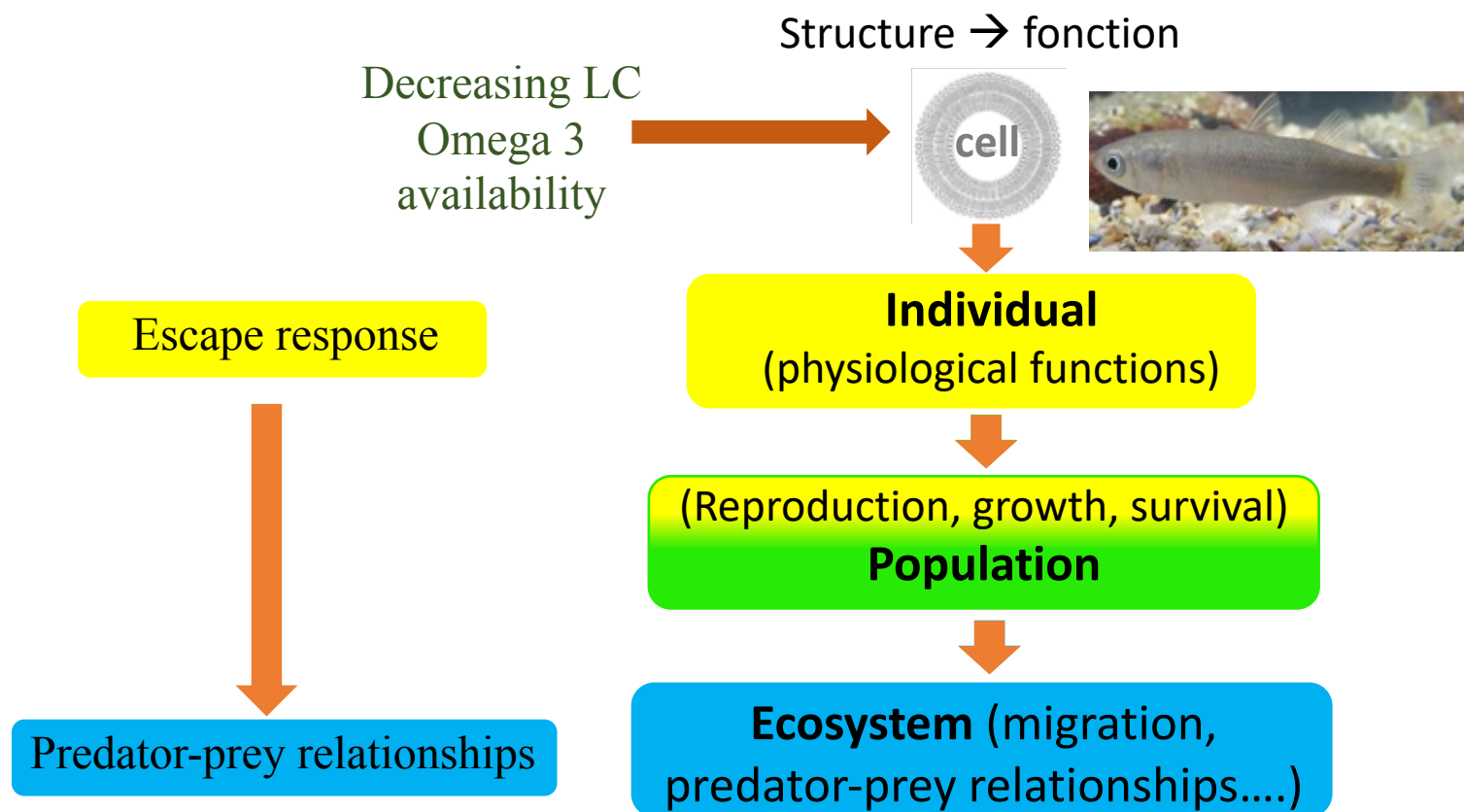






Objective:

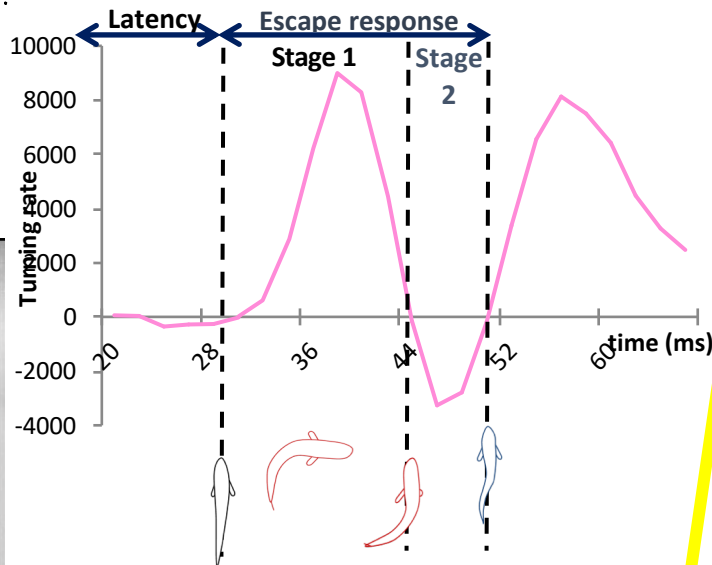
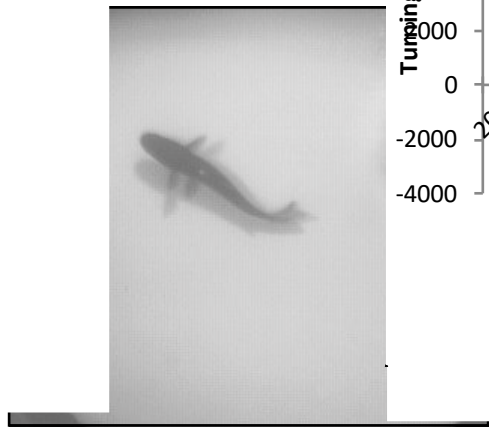
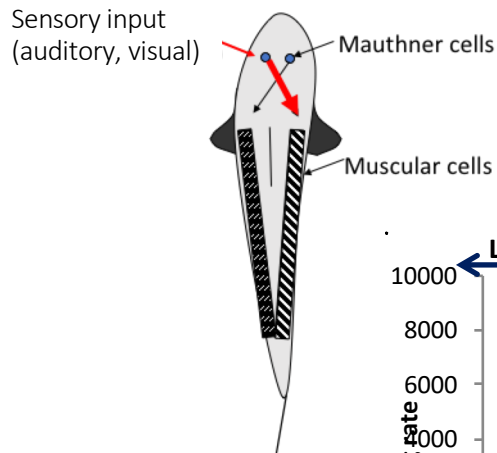
What is the effect of a decreasing LC omega 3 availability on fish individual performance?



Objective:

What is the effect of a decreasing LC omega 3 availability on fish individual performance?

- Reflex response governed by Mauthner cells (brain) and which activate muscle cells
- Essential in prey-predator relationships
- Anaerobically-powered that necessitates a recovery phase which is fueled aerobically



Decreasing LC Omega 3 availability

Structure → fonction



Escape response

Predator-prey relationships

Objective:

To evaluate the effects of depleted LC omega 3 dietary content on escape performance in the golden grey mullet, a grazer of high ecological importance

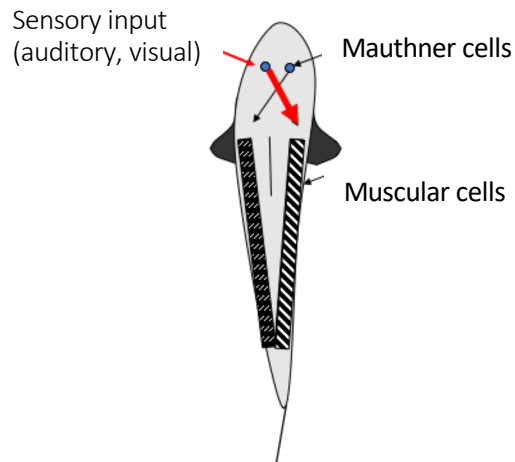


Golden grey mullet
Chelon aurata

- Feed directly on primary producers (microalgae)
- Key compartment in the mudflat ecosystems : the main export pathway of biofilm from tidal flat ecosystems (biotic vector)



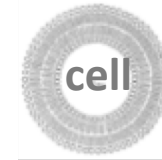
Hypotheses



Decreasing LC
Omega 3
availability



Cell membrane composition in brain
and muscle



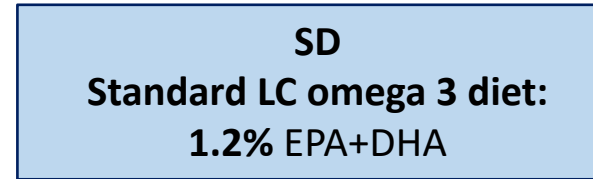
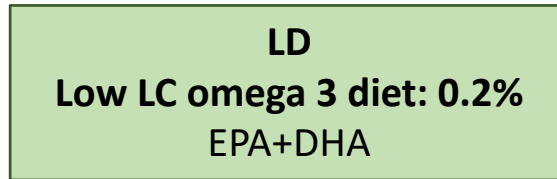
Muscle and brain cell functionality



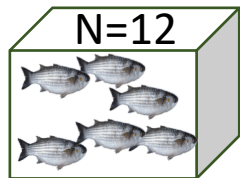
Modification of Escape response

2 Experimental conditions

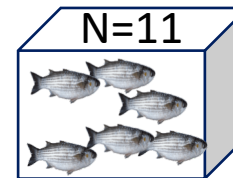
- 2 isolipidic & isoproteic diets contrasted by their LC omega 3 content:



20°C
2 months

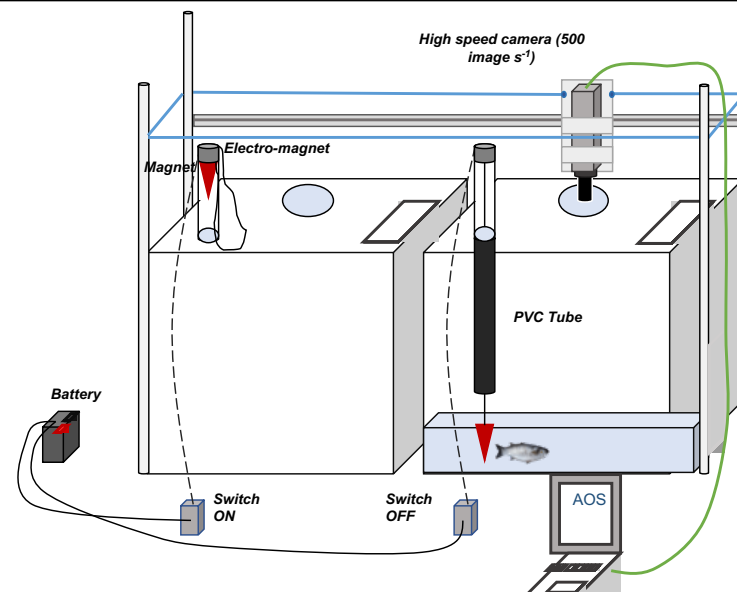


Needs known to be at 0.7%
in European sea bass
juveniles



Biometric analyses

Escape response analyses



On all individuals

Non-locomotion variables
(mainly dependent on brain)



- Responsiveness
- Latency (msec)
- Directionality (towards or away from the stimulus)

Locomotion variables
(mainly dependent on muscle)



- Total duration of escape response (msec)
- Cumulative distance (m)
- Maximum velocity (m s^{-1})
- Maximum acceleration (m s^{-2})
- Turning rate ($^{\circ} \text{msec}^{-1}$)

On all individuals

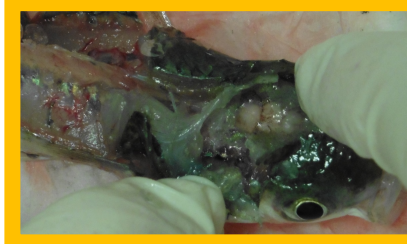
Non-locomotion variables

- Responsiveness
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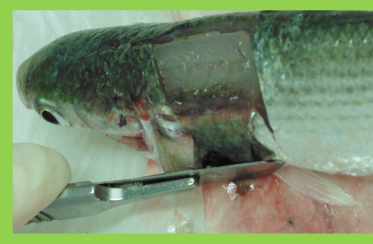
Locomotion variables

- Total duration of escape response (msec)
- Cumulative distance
- Maximum velocity
- Maximum acceleration
- Turning rate ($^{\circ} \text{msec}^{-1}$)

Fatty acid analyses in brain and muscle
(membranes and reserve lipids)



Brain



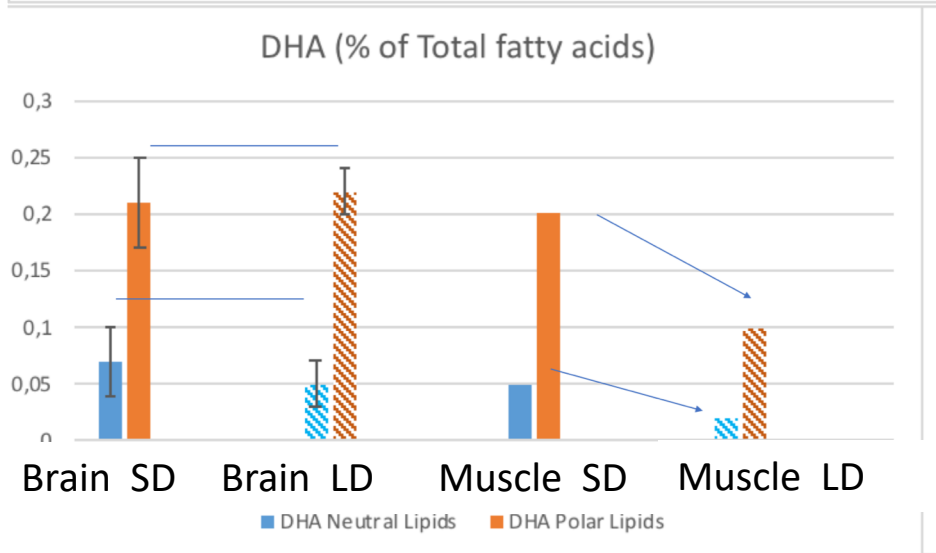
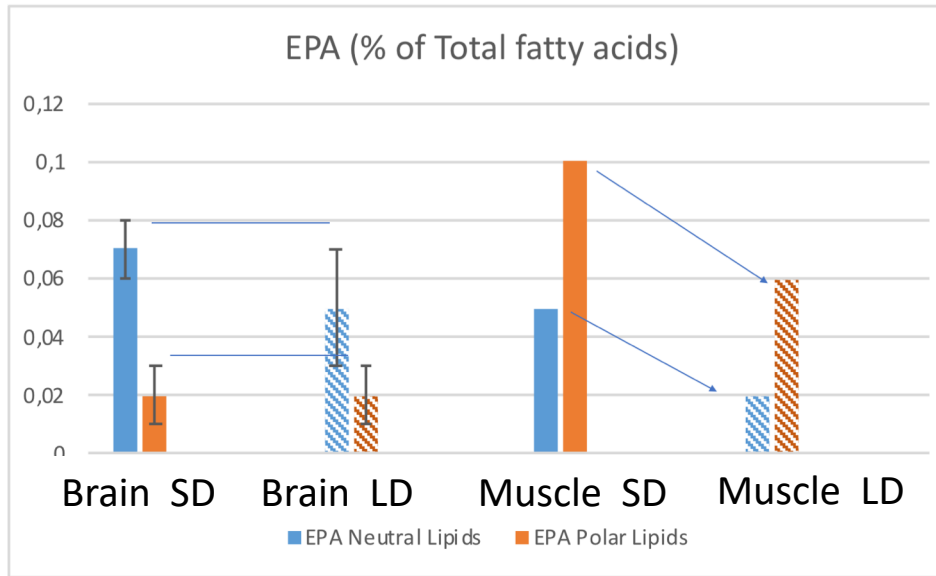
Muscle

Growth performances and condition

| Groups | Weight (g) | Total length (cm) | Fulton index | Hepato-somatic Index |
|-------------------|------------|-------------------|-----------------|----------------------|
| LD | 40.6 ± 1.5 | 16.6 ± 0.2 | 0.0088 ± 0.0001 | 1.6 ± 0.1 |
| SD | 36.4 ± 2.0 | 16.0 ± 0.2 | 0.0089 ± 0.0003 | 1.2 ± 0.1 |
| Statistics | t = 1.66 | t = 2.07 | t = -0.36 | t = 1.84 |
| (t-test) | df = 19 | df = 19 | df = 19 | df = 19 |
| | p = 0.12 | p = 0.05 | p = 0.72 | p = 0.08 |

- No difference in growth performance or body condition

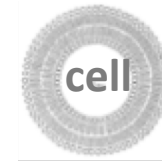
Fatty acid content



Decreasing LC
Omega 3
availability



Cell membrane composition in brain
and muscle



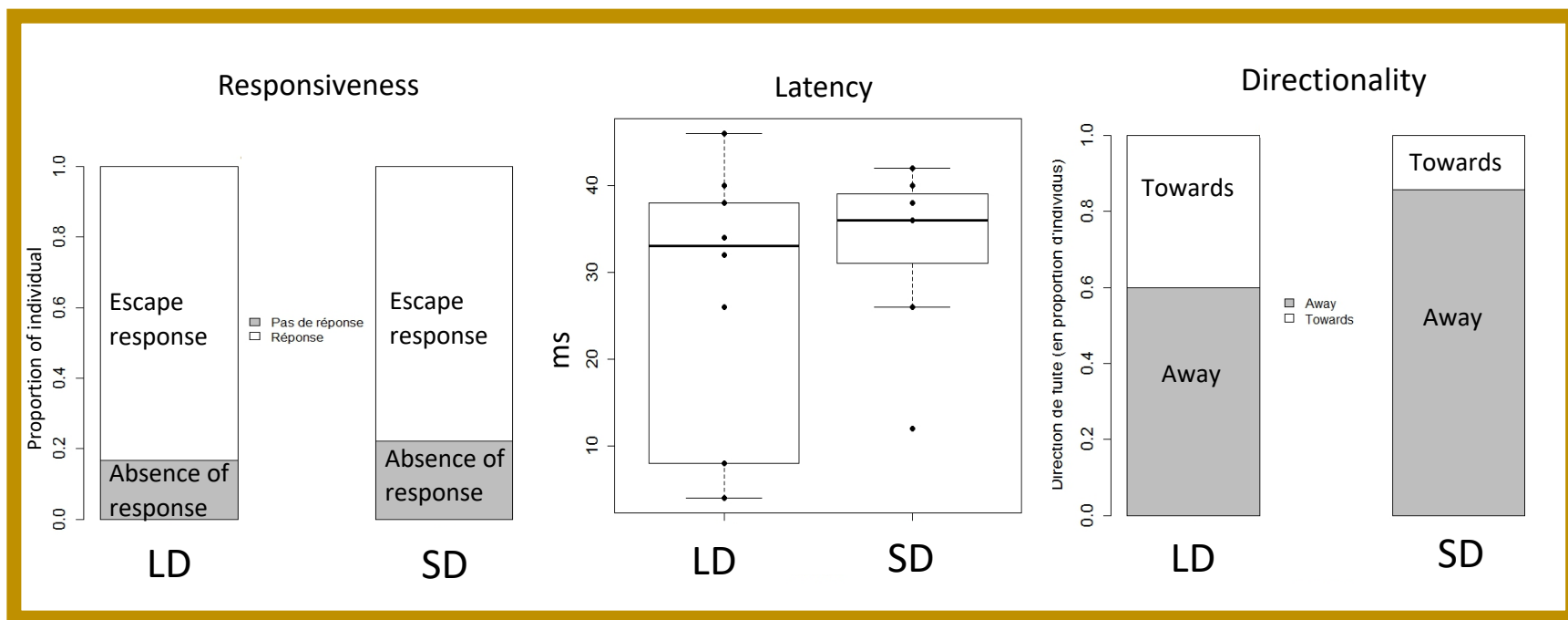
- DHA & EPA reflected diet fatty acid composition in muscle, but not in brain.
- Brain composition preserved in both groups, to maintain cognitive capacity

Non-Locomotion variables (mainly dependant on brain)

NS

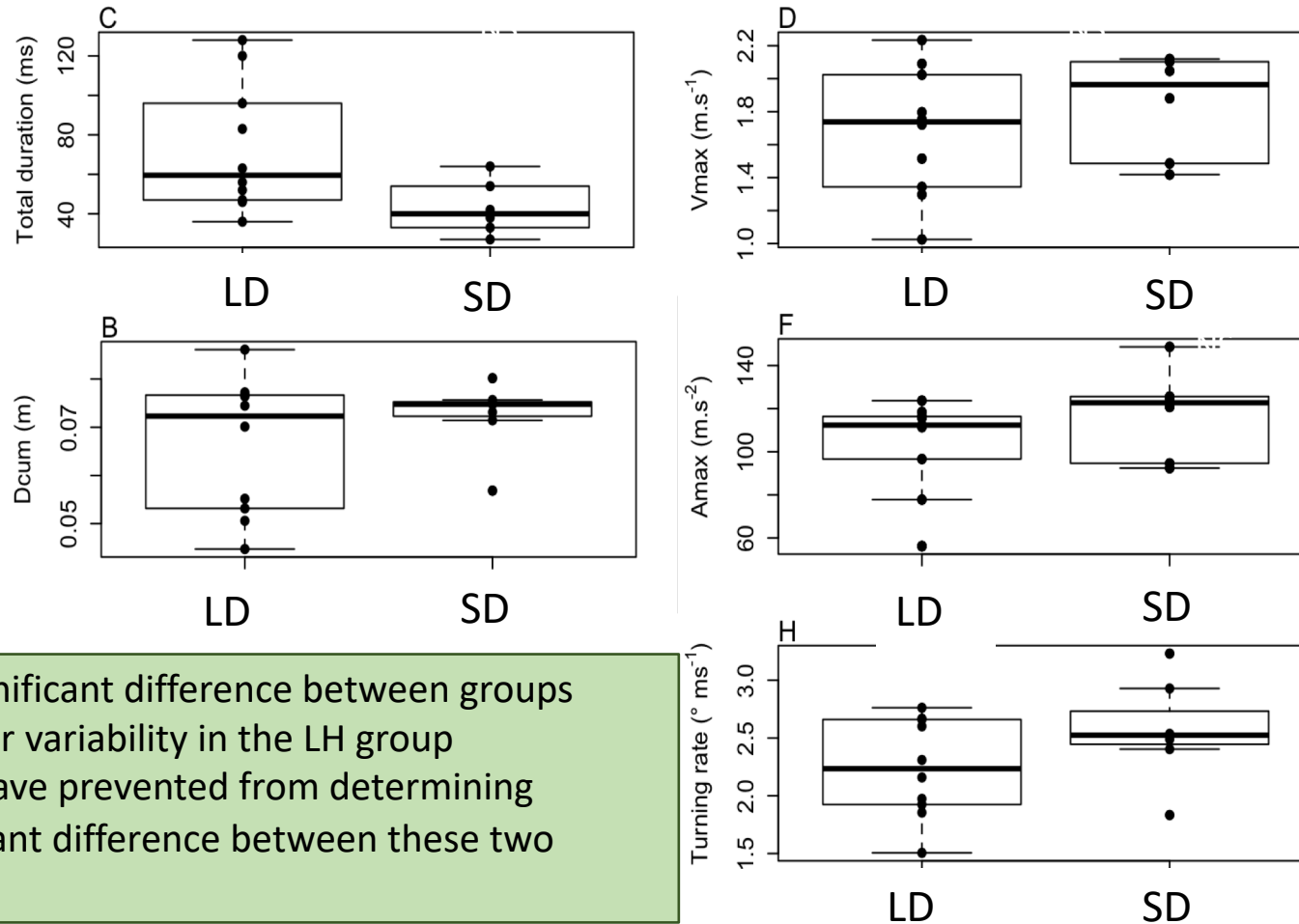
NS

NS

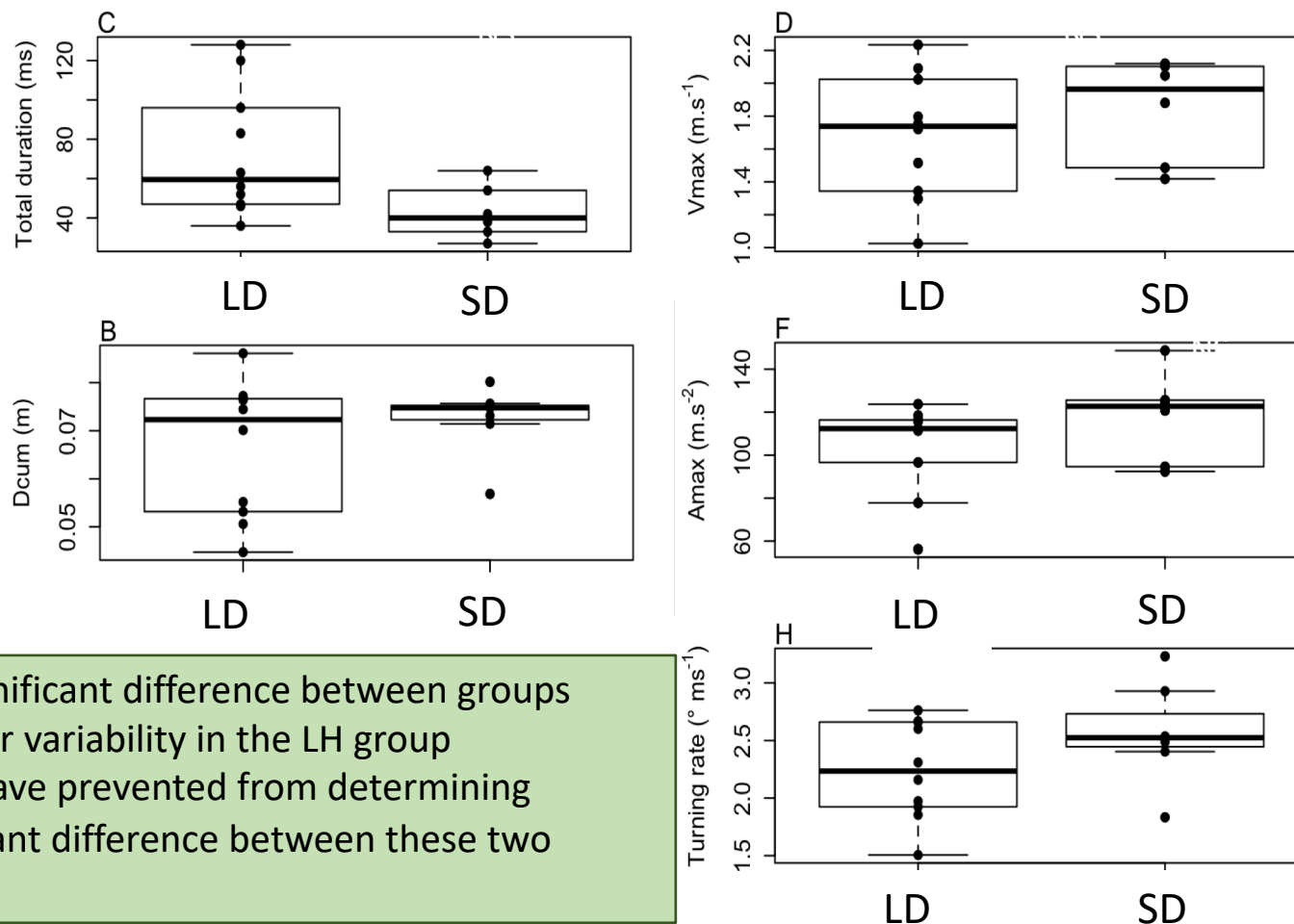


- No difference in responsiveness, latency, directionality between dietary groups

Locomotion variables (Mainly dependent on muscle)

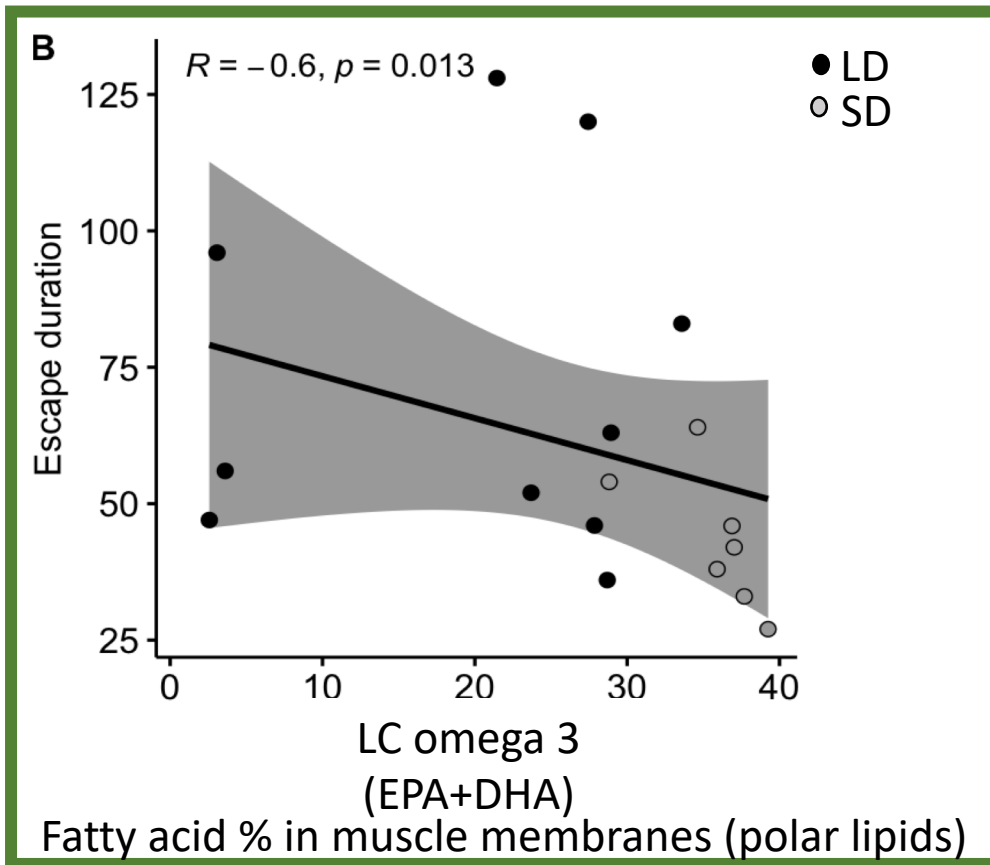
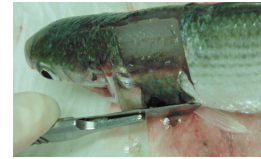


Locomotion variables (Mainly dependent on muscle)



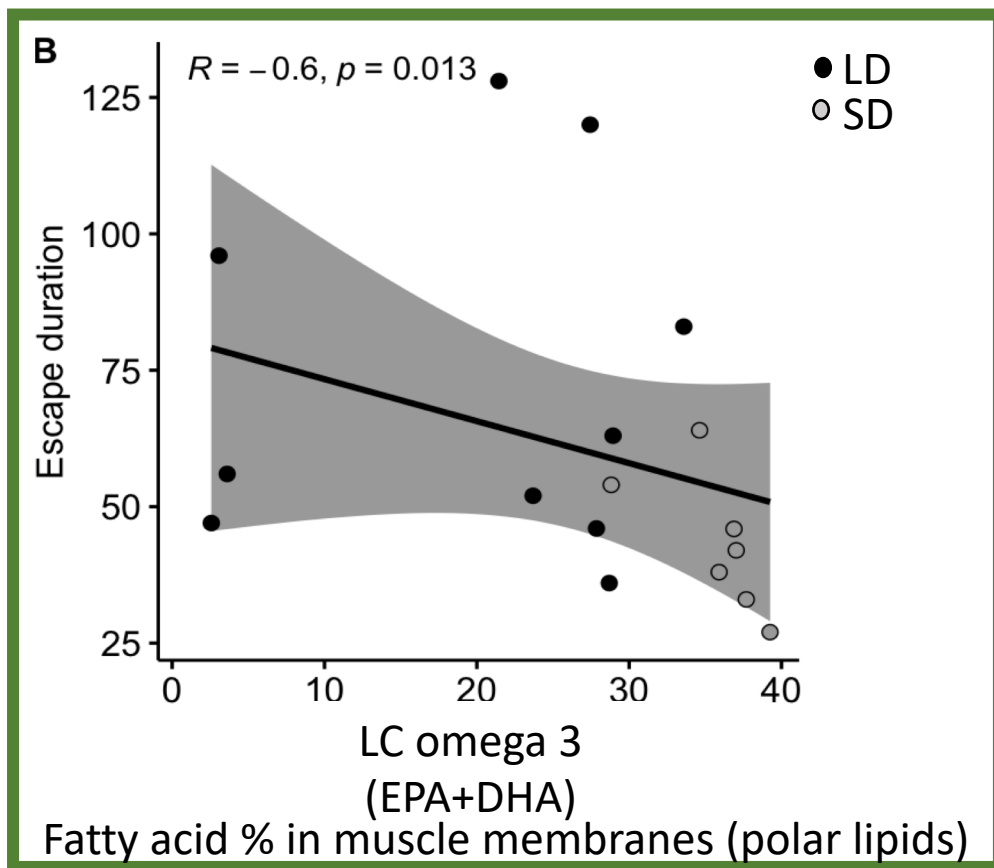
Are there any correlations between LC omega 3 muscle content and locomotion variables?

Locomotion variables



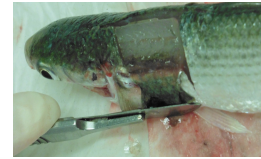
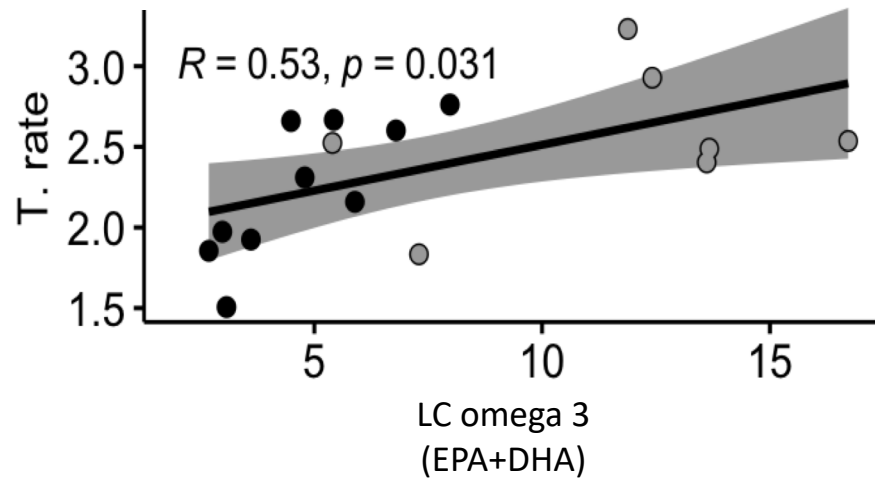
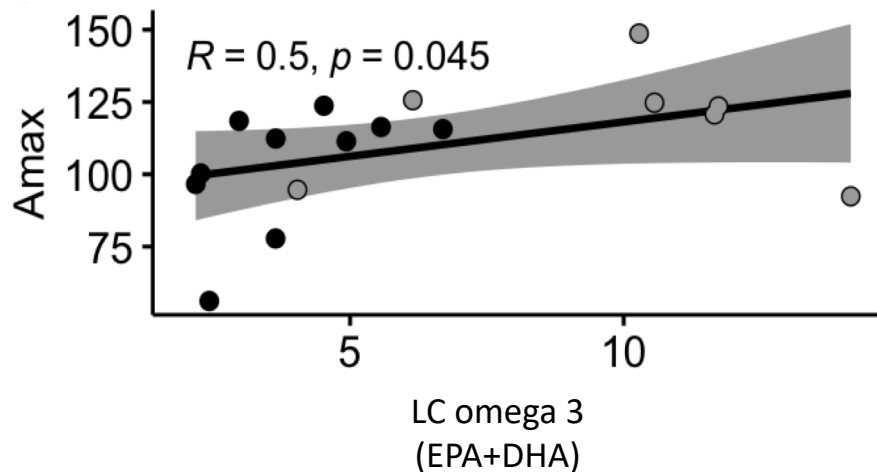
- A lower LC omega 3 content (including EPA and DHA) in muscle membranes, tend to be correlated with a longer escape response.

Locomotion variables



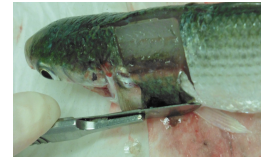
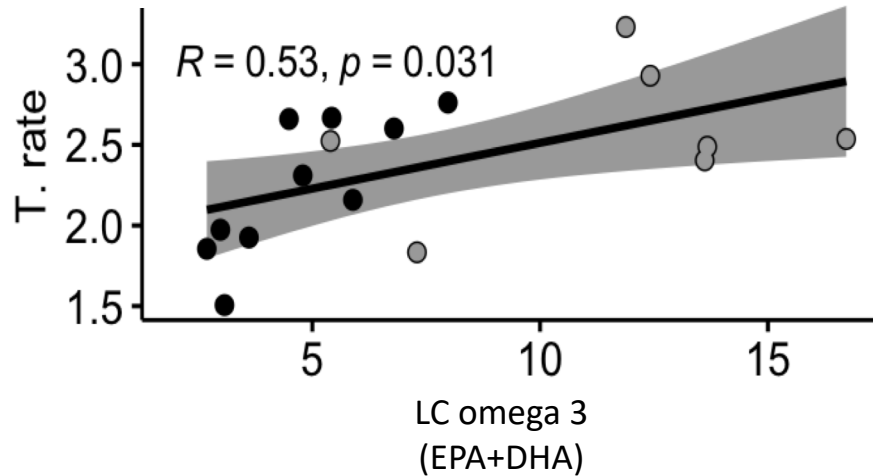
- A lower LC omega 3 content (including EPA and DHA) in muscle membranes, tend to be correlated with a longer escape response.
- A longer response may increase the energetic cost required for an individual to escape from a predator.

Fatty acid % in lipid reserve of muscle

Turning rate ($^{\circ} \text{msec}^{-1}$)● LD
○ SDMaximum Acceleration (m s^{-2})

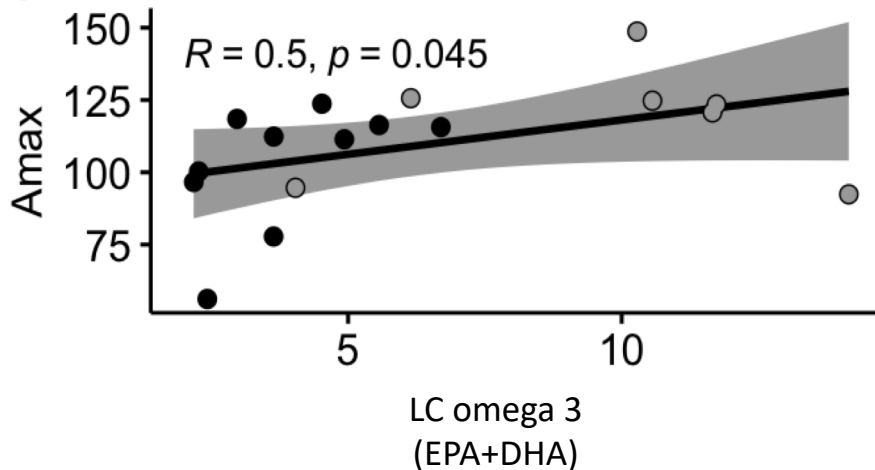
A lower LC omega 3 (including EPA+DHA) content in lipid reserves of muscle tend to be correlated with decreased turning rates and maximum acceleration

Fatty acid % in lipid reserve of muscle

Turning rate ($^{\circ} \text{msec}^{-1}$)

● LD
○ SD

↑ Better survival

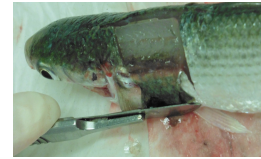
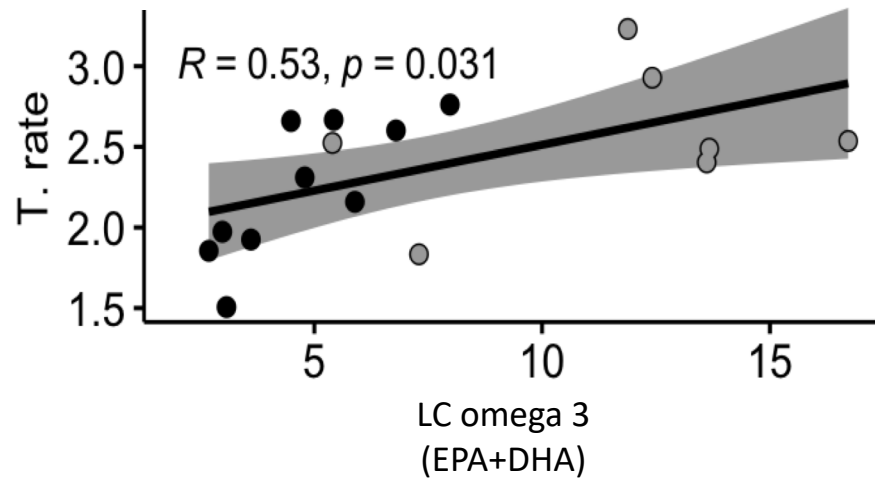
Maximum Acceleration (m s^{-2})

A lower LC omega 3 (including EPA+DHA) content in lipid reserves of muscle tend to be correlated with decreased turning rates and maximum acceleration

Both variables contributes to better chances to escape from the predator

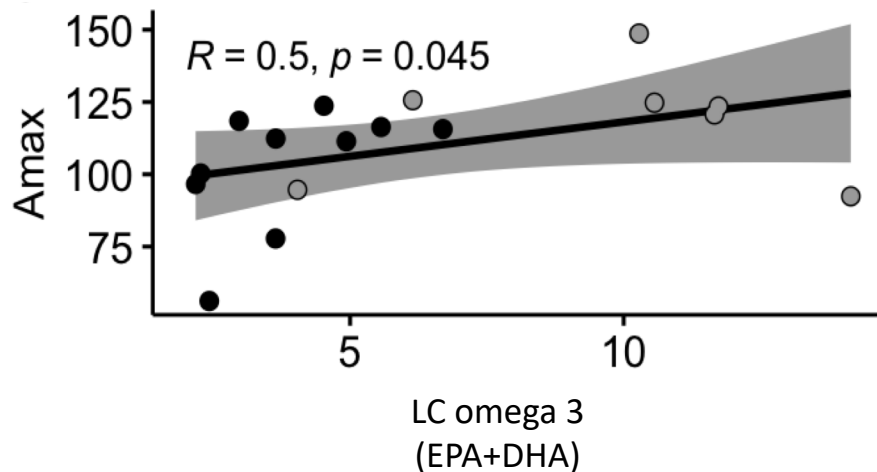
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A lower LC omega 3 (including EPA+DHA) content in lipid reserves of muscle tend to be correlated with decreased turning rates and maximum acceleration

Maximum Acceleration (m s^{-2})

Both variables contributes to better chances to escape from the predator

Lower LC omega 3 tend to decrease the chances to escape from a predator

- Growth rate and escape responses variables were similar in both dietary groups

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Decreasing LC
Omega 3
availability



Structure → fonction



- Tissue composition modified by diet in both PL and NL of muscle
- But not in the brain, certainly to preserve cognitive capacities

- Growth rate and escape responses variables were similar in both dietary groups

Decreasing LC
Omega 3
availability



Structure → fonction



Escape response

- Tissue composition modified by diet in both PL and NL of muscle
- But not in the brain, certainly to preserve cognitive capacities

- A greater variability in escape response variables in LC omega 3 depleted group compared to control group may have prevented from determining significant difference between these two groups.

- Growth rate and escape responses variables were similar in both dietary groups

Decreasing LC
Omega 3
availability



Structure → fonction



Some correlations may exist between escape response variables and LC omega 3 content in muscle

Escape response

- Allonging response duration
- Reducing maximum acceleration and turning rate

Decreasing LC
Omega 3
availability



Structure → fonction



Some correlations may exist between escape response variables and LC omega 3 content in muscle

Escape response

- Allonging response duration
- Reducing maximum acceleration and turning rate



Higher energetic cost

Decreasing LC
Omega 3
availability



Structure → fonction



Some correlations may exist between escape response variables and LC omega 3 content in muscle

Escape response

- Allonging response duration
- Reducing maximum acceleration and turning rate



Higher energetic cost



May be compensated by

These results may suggest some effects of EPA and DHA dietary changes on the predator-prey relationships, in the context of global change

Further studies required to examine these effects

- the interindividual variability
- The effect of LC omega 3 dietary depletion on the energetic cost of escape response



Nicolas Graziano, IUT



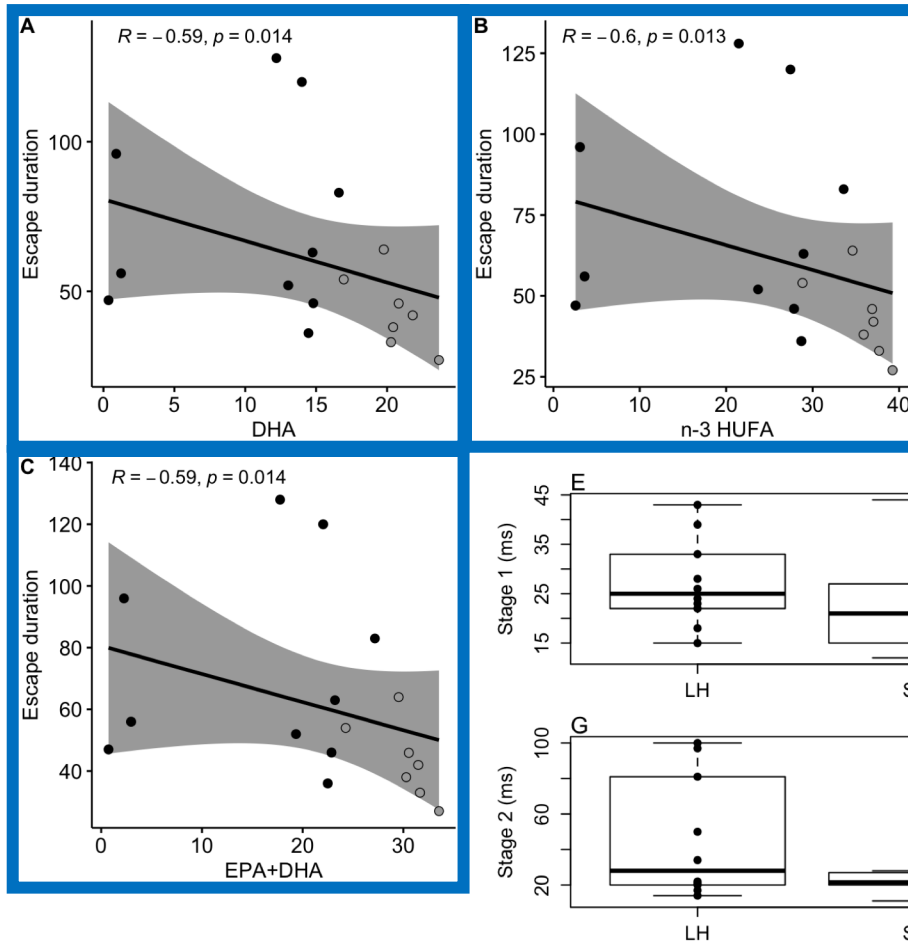
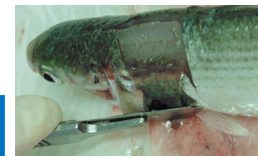
Salomé Ducos, Master 1



Merci de votre attention

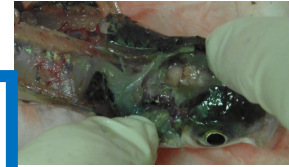
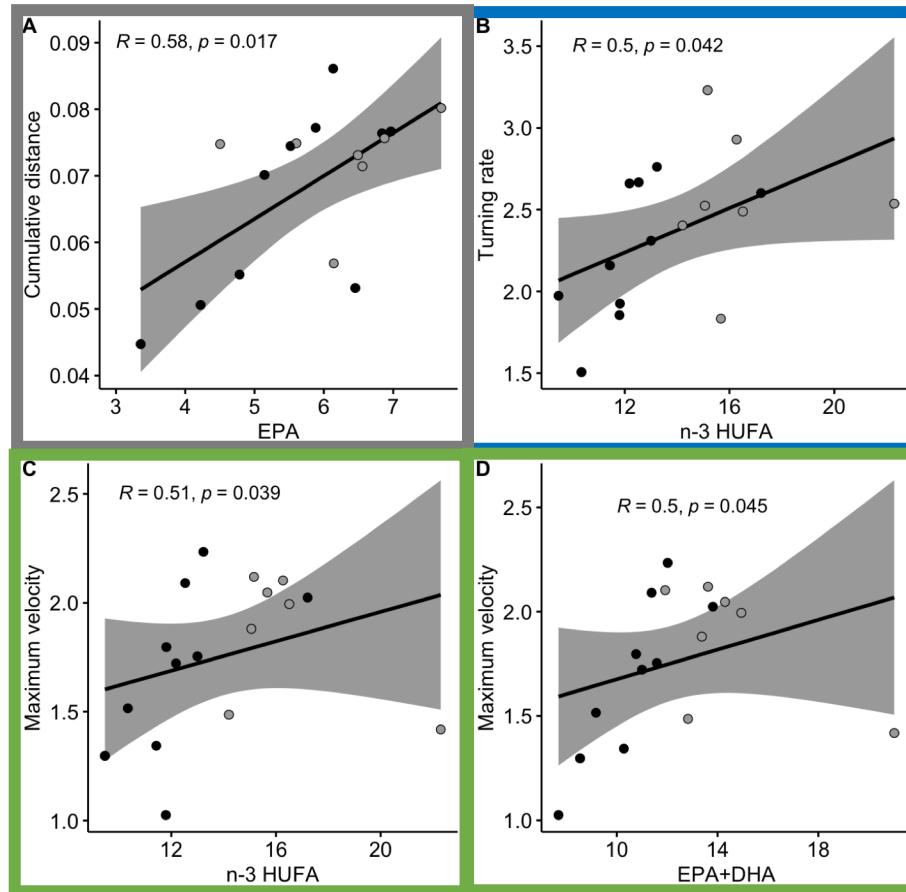
This work is a contribution to the project ECONAT Axe 1 - Ressources Marines Littorales: qualité et éco-valorisation, funded by the Contrat de Plan Etat-Région and the CNRS and the European Regional Development Fund.

Fatty acid % in muscle membranes (polar lipids)



in muscle use.

Fatty acid % in brain lipid reserves (neutral lipids)



- A brief reflex (30-100 ms) that allows the animal to escape from danger
- Very short latency (~ 10-50 ms vs 100 ms in mammals/ cf sprinter)
- Reaches a speed of around 10-20 body lengths s^{-1}
- Very high acceleration (around $100 m s^{-2}$, i.e. 10 g).
- Very high angular velocity (around $5-10^{\circ} ms^{-1}$, i.e. the fish can cover $\sim 90^{\circ}$ in ~ 10 ms)



Decreasing LC
Omega 3
availability

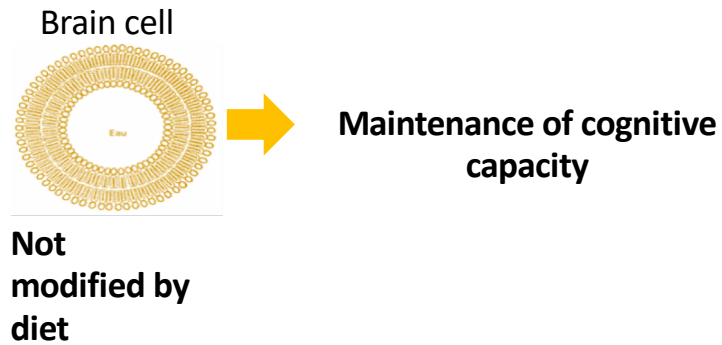
Structure \rightarrow fonction



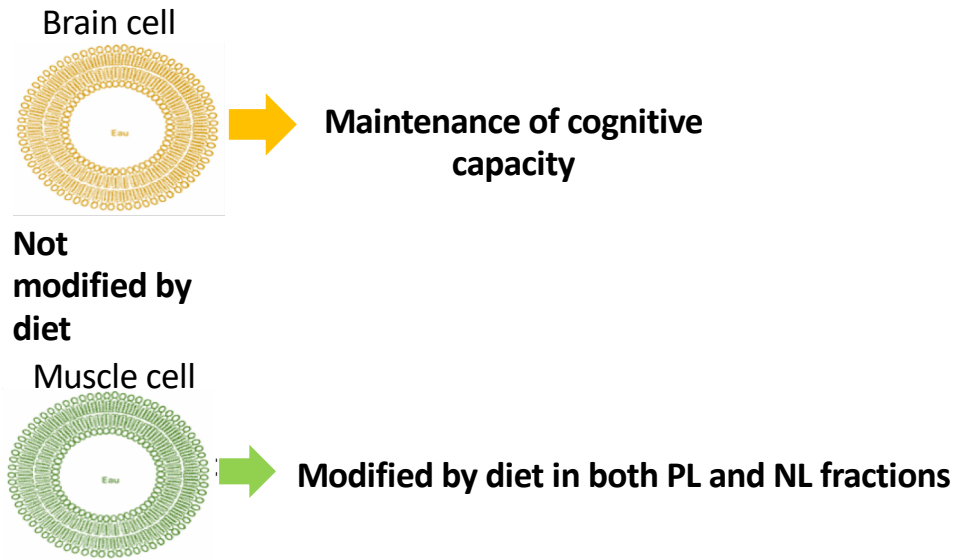
Escape response

Predator-prey relationships

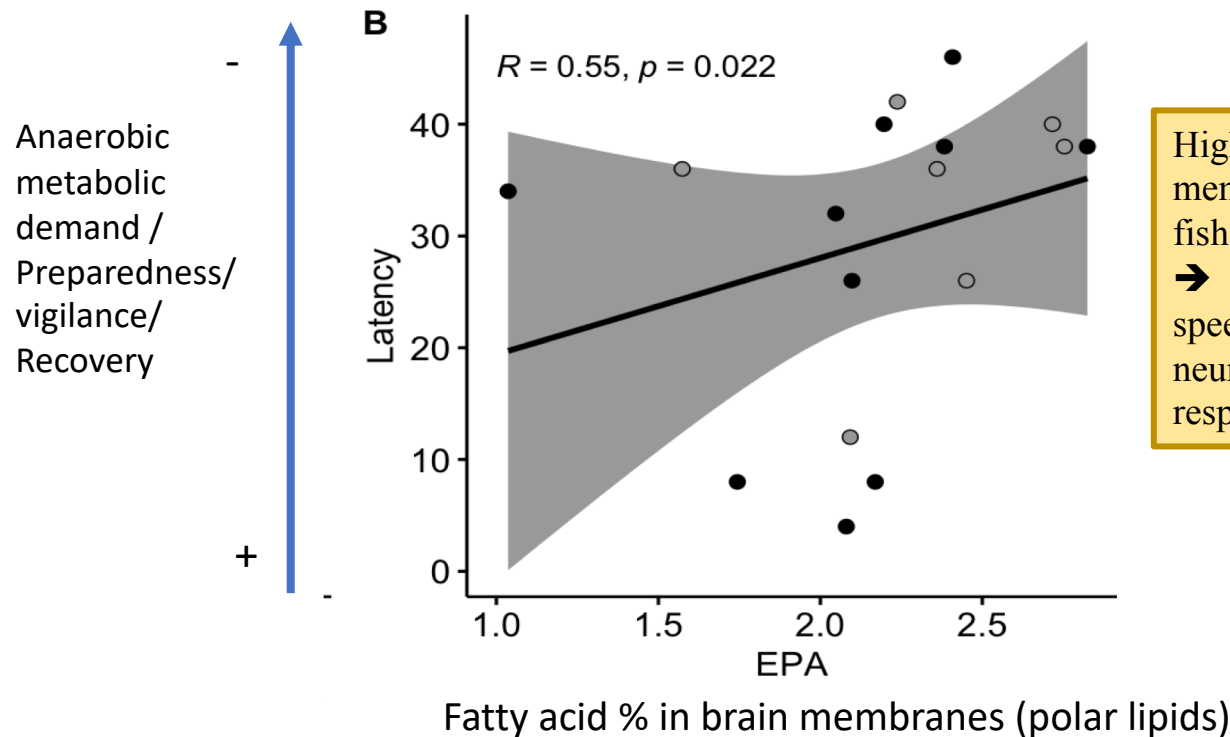
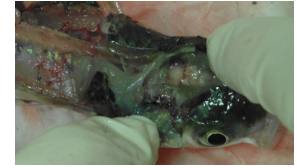
Conclusions



Conclusions



Non-Locomotion variables



Higher the EPA content in brain membranes, slower the reactivity of fish to the stimulus
 → Would be related to a lower speed in the translation of the neural signal to activate escape response.

Short response latency → high preparedness to escape (vigilance) → high metabolic demand → longer recovery times in fast reactors. (Killen et al. 2015)

→ It exists a trade-off between the increased vigilance and metabolic demand

EPA → longer latency → lower vigilance → lower metabolic demand → shorter aerobic recovery times after escaping

- Strong correlations exist between some escape response variables and LC omega 3 content in fish tissue:

Decreasing LC
Omega 3
availability



Structure → fonction



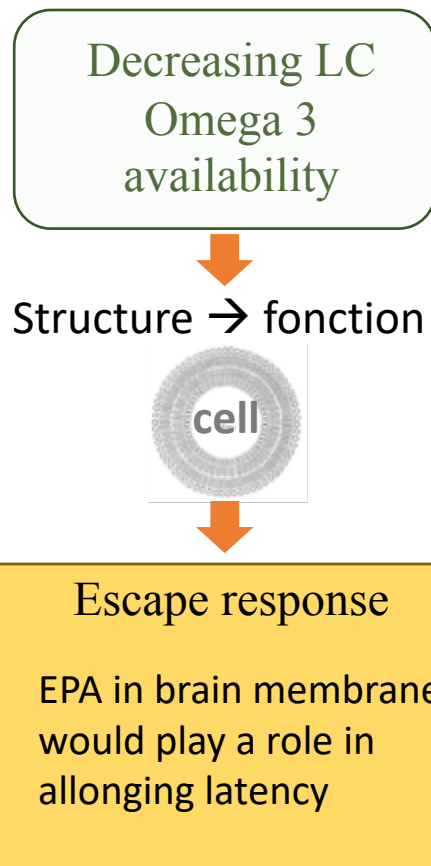
Escape response

- EPA in brain membrane would play a role in allonging latency



Could further participate to reduce recovery times

- Growth rate and escape responses variables were similar in both dietary groups
- A greater variability in escape response variable measured in LC omega 3 depleted group compared to the control group,
 - May have prevented from determining significant difference between these two groups.



- Strong correlations exist between some escape response variables and LC omega 3 content in fish tissue:
 - that could further participate to reduce recovery times
 - Allonging its duration
 - Reducing maximum acceleration and turning rate

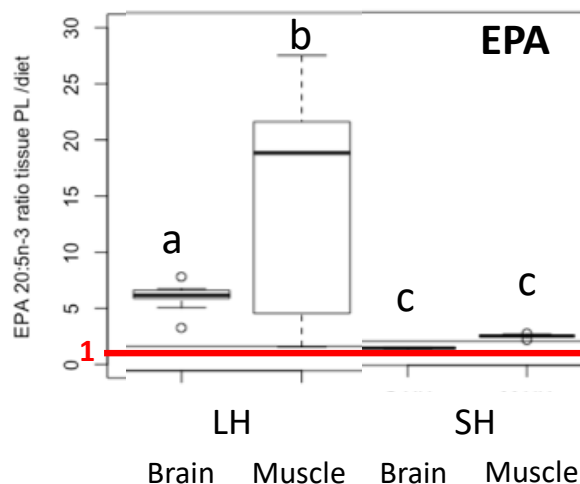
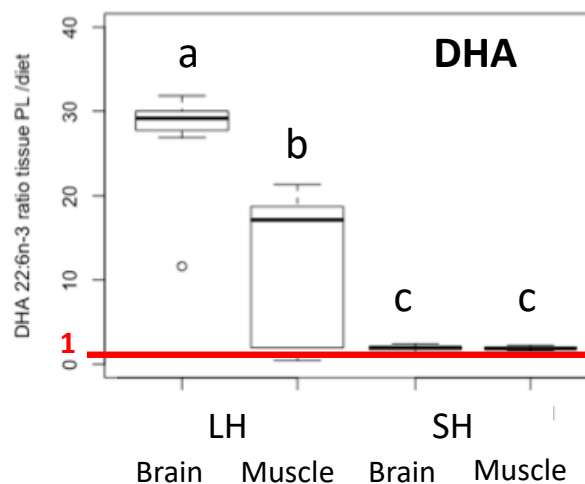
could further participate to reduce recovery times

When looking at FA composition in membranes of both muscle and brain.....

EPA → longer latency → lower vigilance → lower metabolic demand → shorter aerobic recovery times after escaping

- Higher the LC omega 3 content (including EPA and DHA) in muscle membranes, shorter the response.
- A shorter response may reduce the energetic cost required for an individual to escape from a predator.

.....Our result suggest that higher EPA and DHA in membranes would reduce energetic cost of escape response



Selective retention => deficiency in the tissue

Absence of retention => Fatty acid supplied by diet correspond to the needs

- DHA and EPA more stored in LH fish than in SH fish, probably to face their low dietary availability

