Do green tides affect the trophic ecology of juvenile flatfish ?

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Amédée – 15/11/2018

Coastal zones provide many goods and services…

Beck et al., 2001; Costanza et al., 1997

...but are subject to anthropogenic impacts...

Defeo et al., 2009

...such as eutrophication and green tides...

Charlier et al., 2008; Defeo et al., 2009; Quillien et al., 2015; UE Water Framework Directive; Ye et al., 2011

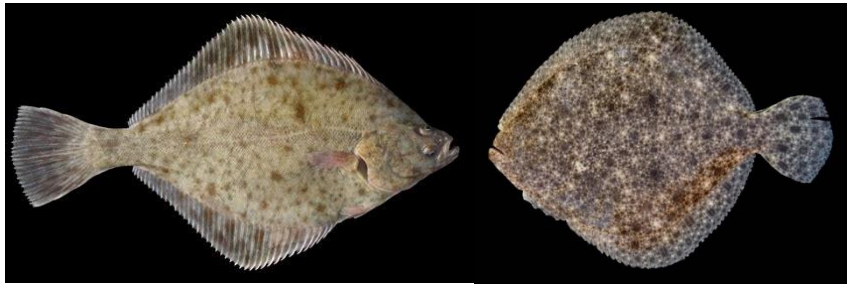
...that affect flatfish species

- Drastic abundance decrease in impacted estuaries (Paumier et al., 2018) and highly impacted sandy bays (Le Luherne et al., 2016)

- Reduction in settlement success of *Pleuronectes platessa* (Pihl et al., 1995; Pihl et al., 2005; Wennhage & Pihl, 1994)

- Decrease in predation efficiency of juvenile *Platichthys flesus* and *Scophthalmus maximus* (Aarnio & Mattila, 2000; Nordstrom &Booth, 2007)

Few studies on the effect of GT on flatfish trophic ecology using in situ data
(Andersen et al., 2005; Pihl et al., 1992)



Problematic

Green tides

⇩

Hypoxic conditions (Cloern, 2001)
Chemical compound release
(Harder et al., 2004)

Problematic

Green tides

Benthic community changes = changes in the potential prey availability

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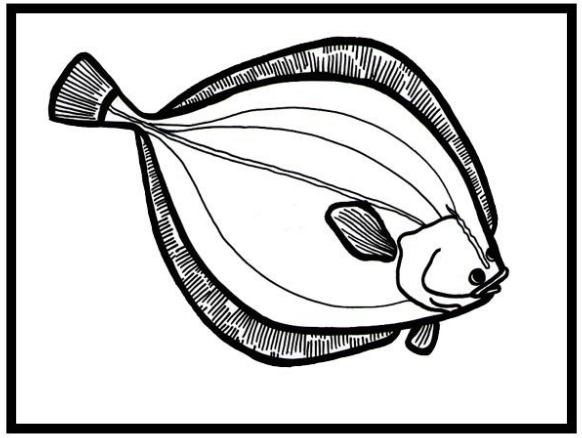
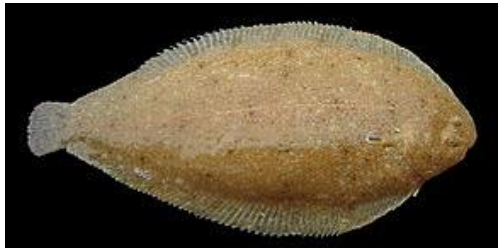


Effect of GT on juvenile flatfish trophic ecology ?

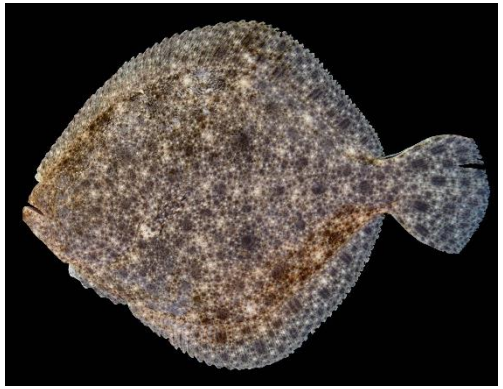
e.g. prey preference, feeding strategy and behaviour

Three flatfish species



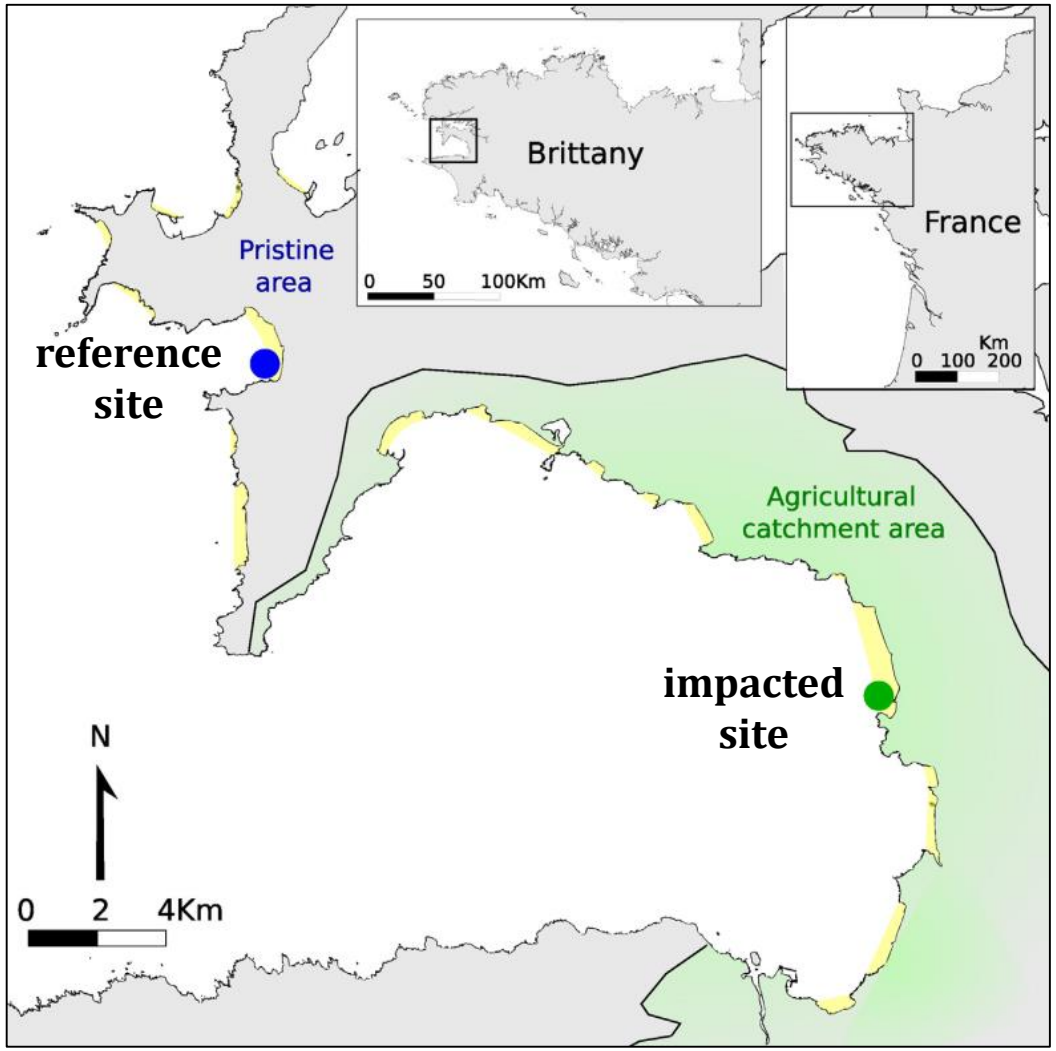
Sand sole (Pegusa lascaris): night-feeder using chemical cues

Plaice (Pleuronectes platessa): day-feeder mainly using visual cues but can also rely on chemical ones



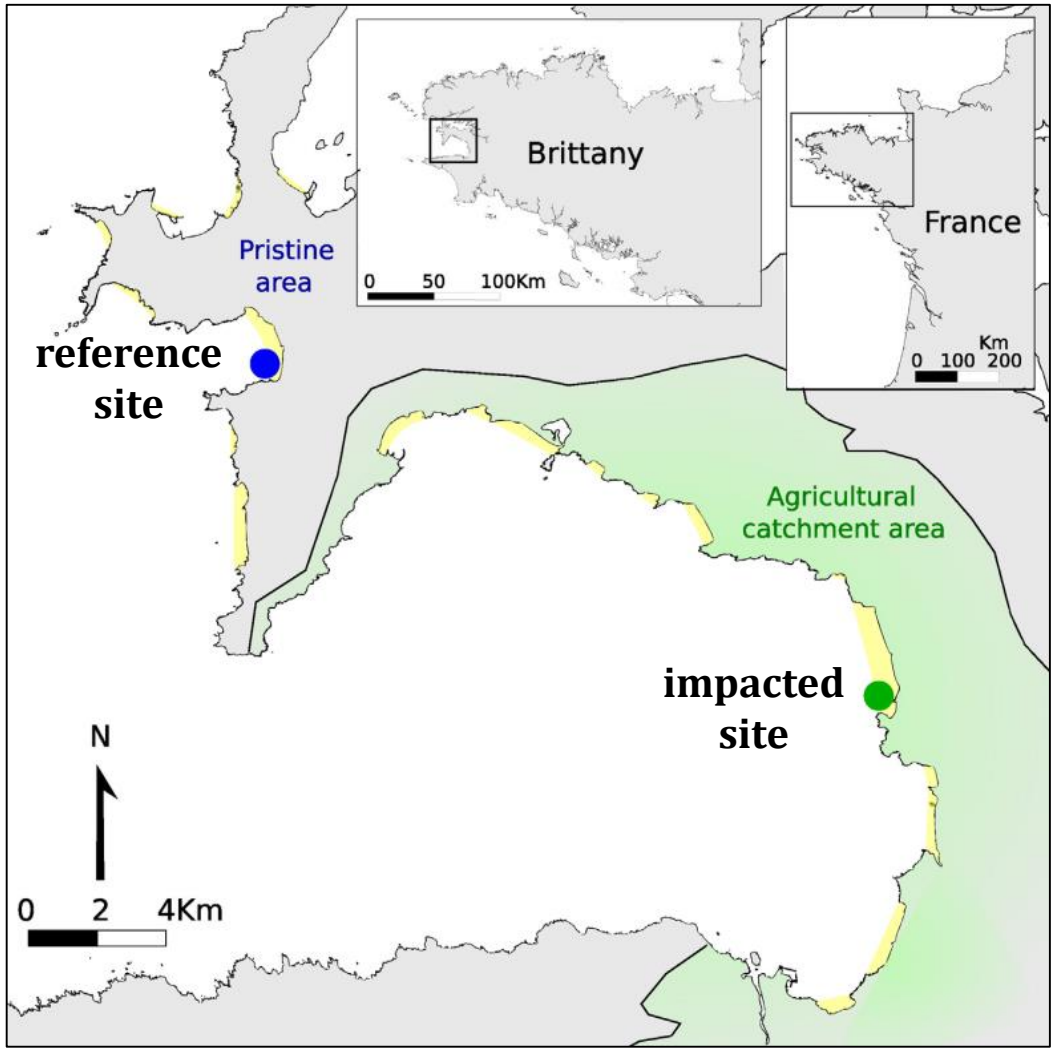
Turbot (Scophthalmus maximus): visual day-feeder

Two contrasted study sites



Quillien et al., 2016

Green tides over time at our impacted site (2012)



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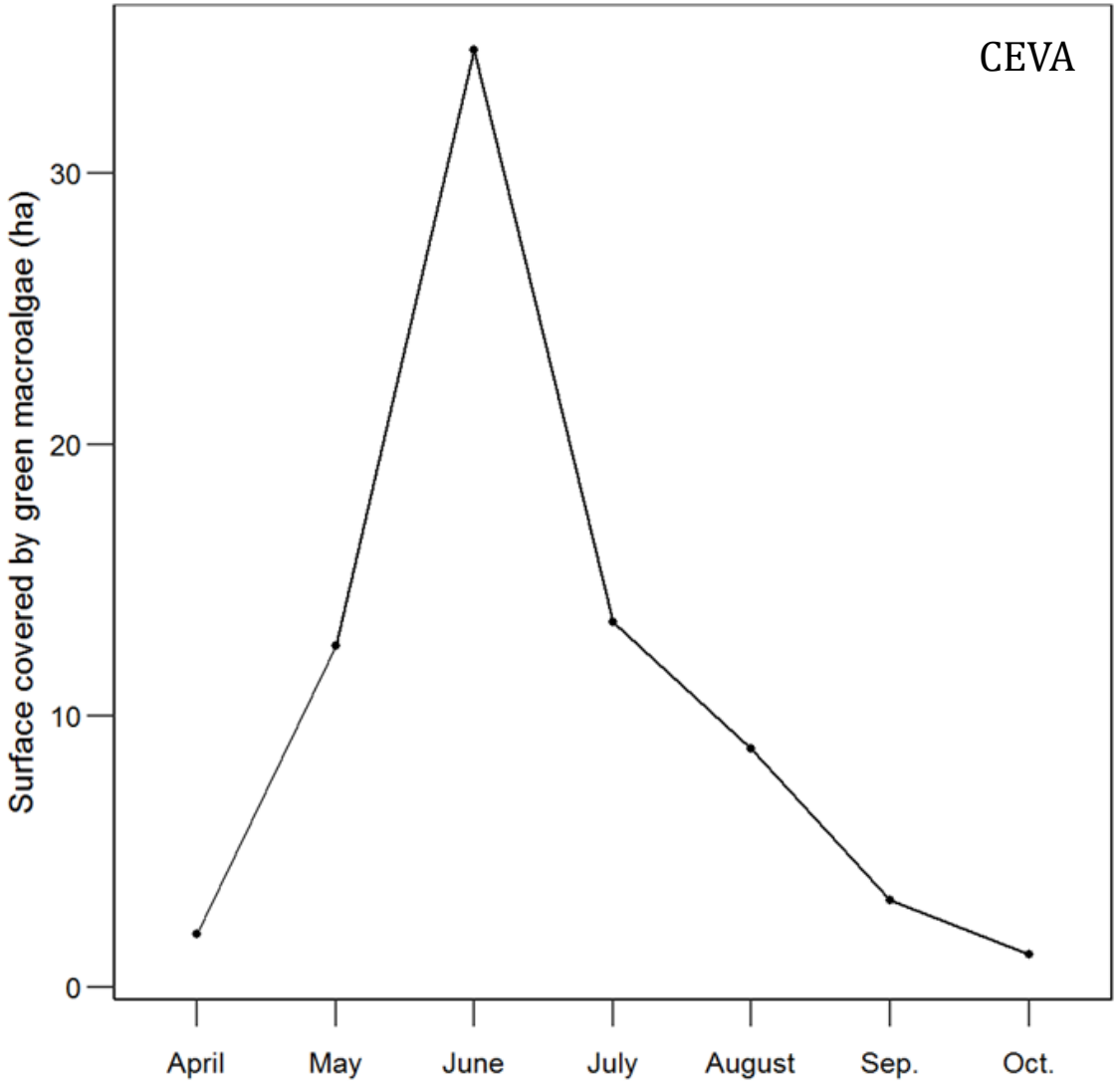

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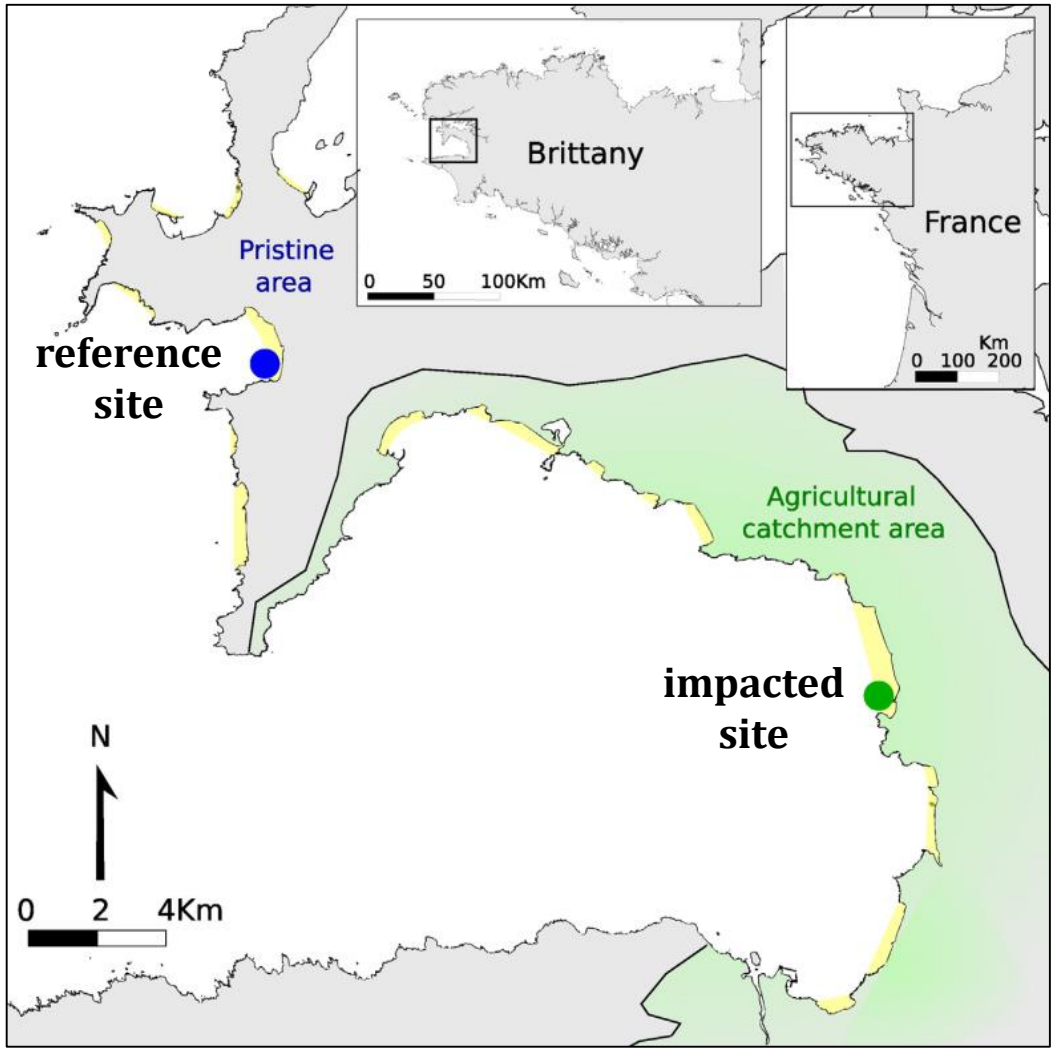

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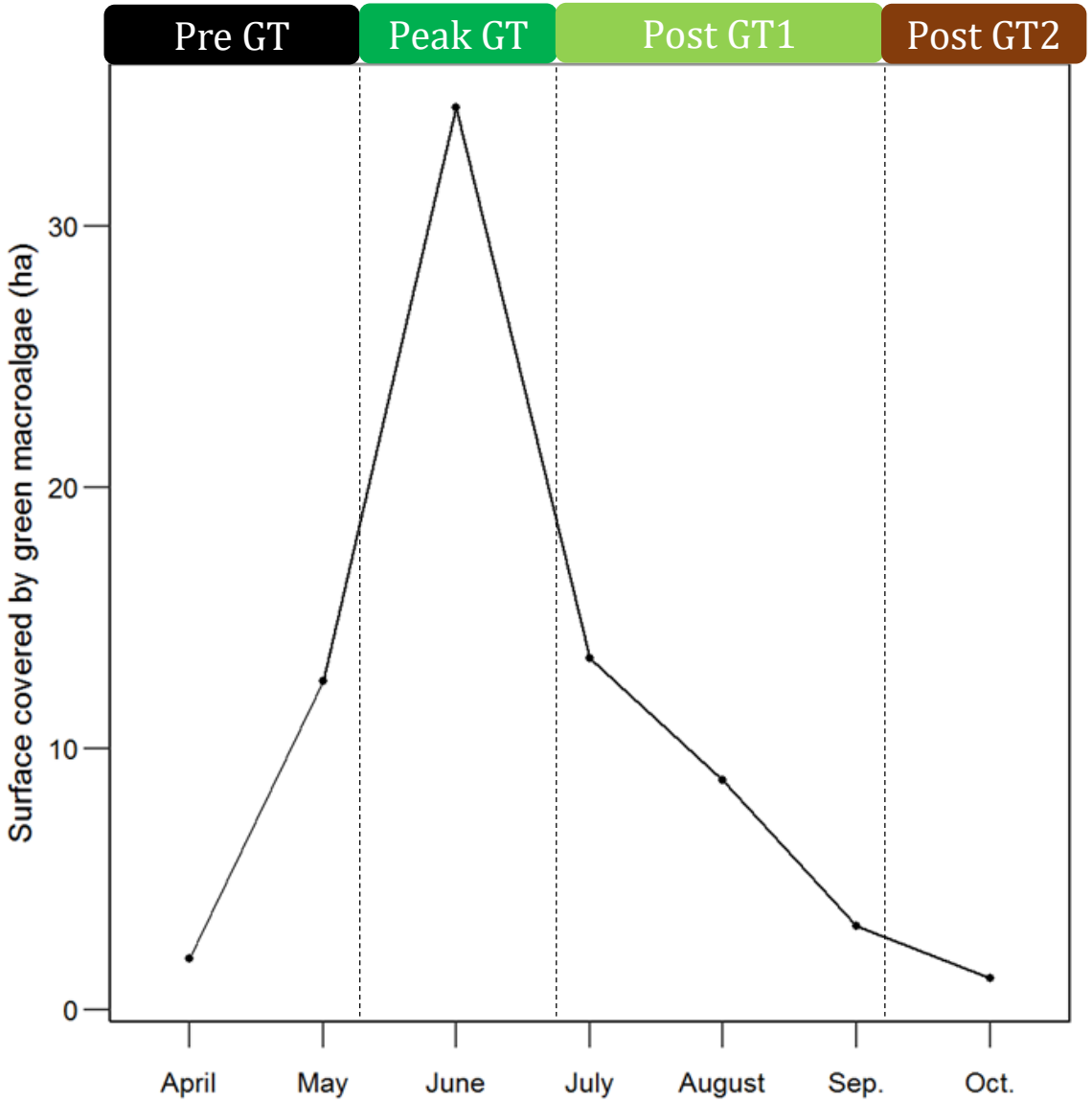
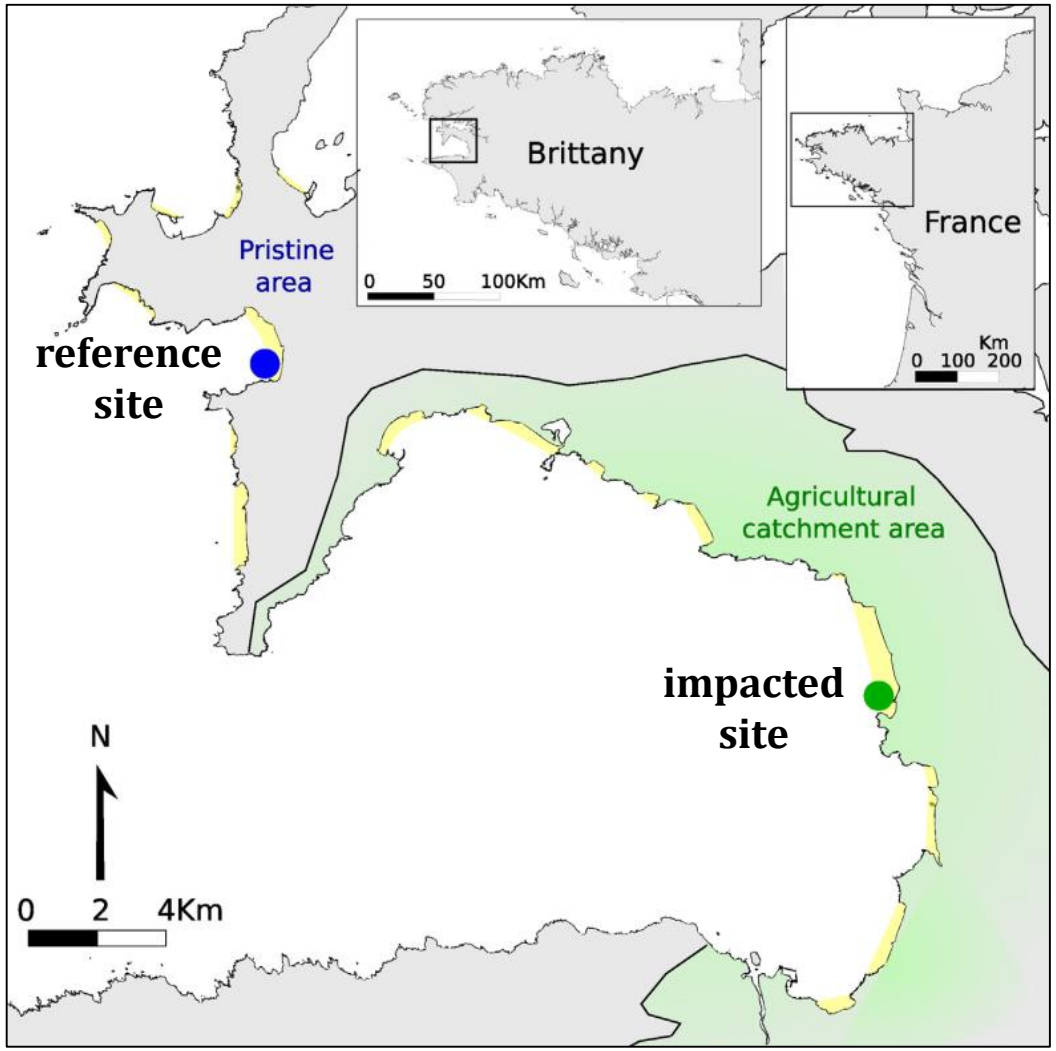


(1) Sampling (2012)



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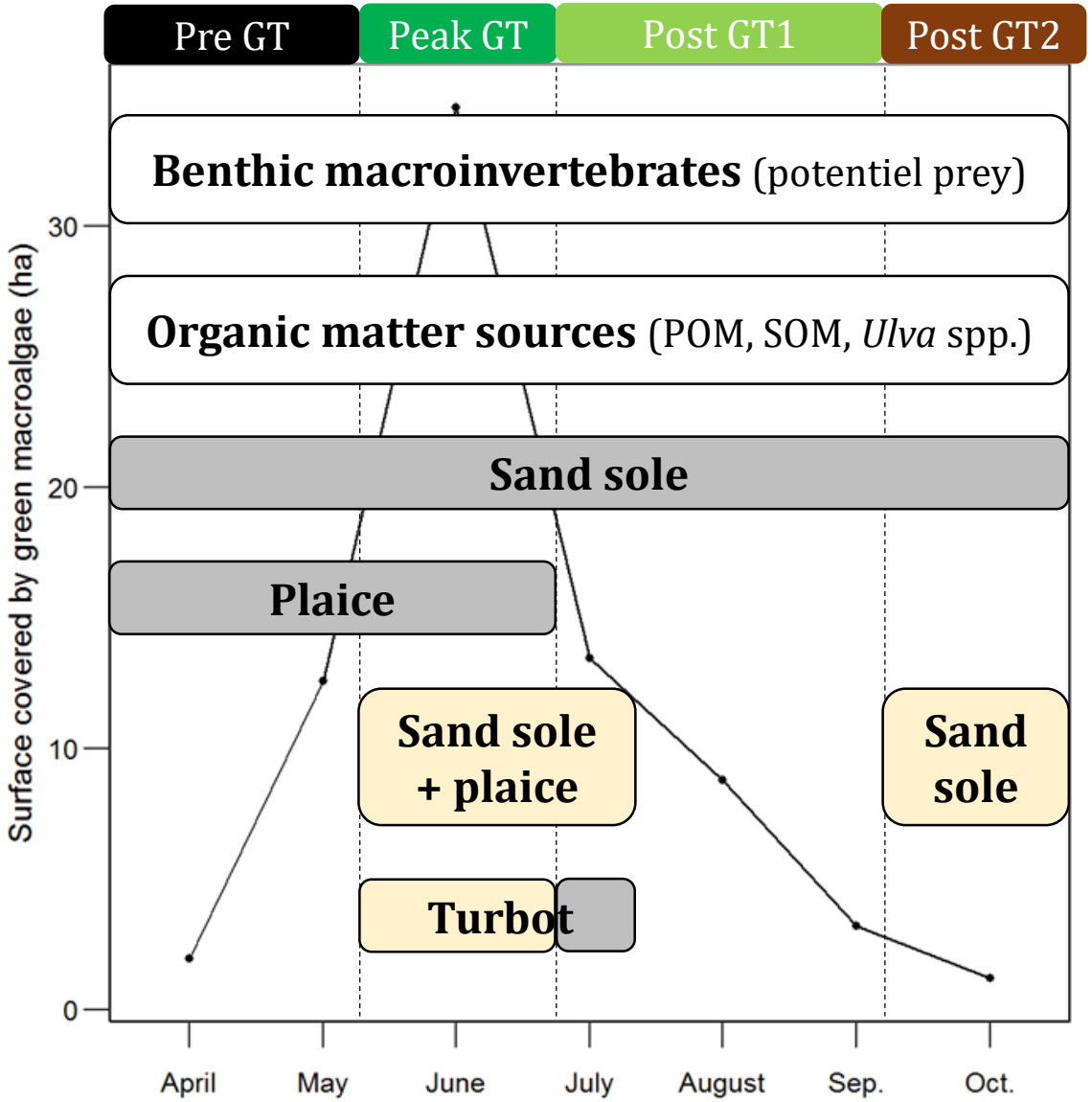
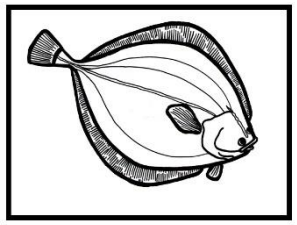


(2) Stable isotope analysis



- Carbon and nitrogen isotope composition (**$\delta^{13}C$ and $\delta^{15}N$**)

✓ **Juvenile flatfish** (isotopic niche, Jackson et al., 2011; Newsome et al., 2007)

Secondary consumers

Trophic level

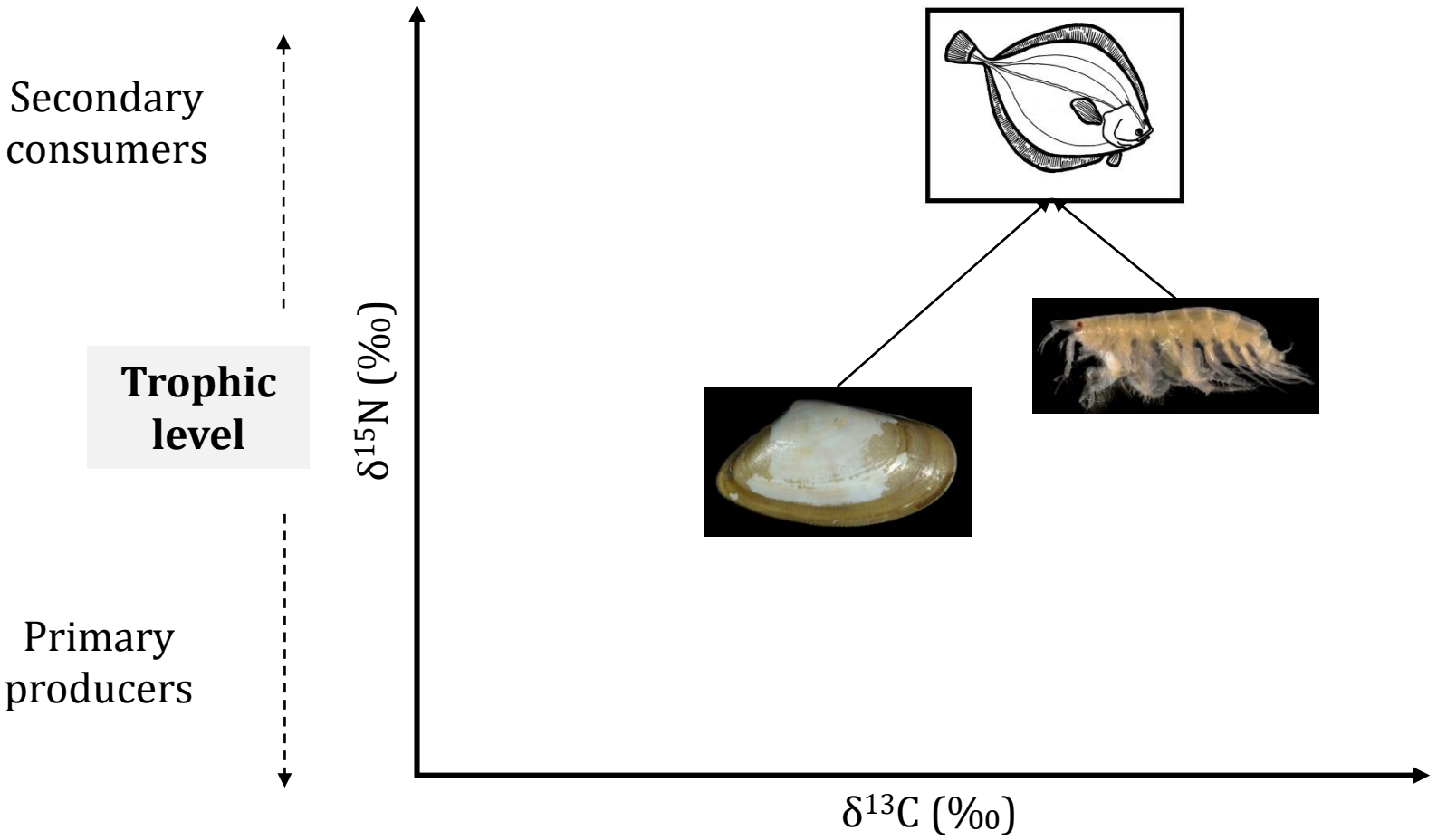
Primary producers

$\delta^{15}N$ (‰)

$\delta^{13}C$ (‰)

Gill, 2003; Quillien et al., 2016; Yeakel et al., 2011

(2) Stable isotope analysis



- Carbon and nitrogen isotope composition (**$\delta^{13}C$ and $\delta^{15}N$**)

✓ **Juvenile flatfish** (isotopic niche, Jackson et al., 2011; Newsome et al., 2007)

✓ **Benthic macroinvertebrates** (tropho-orders) weighted by **relative abundance** and corrected for **trophic discrimination factors** (Hussey et al., 2013; Vander Zanden and Rasmussen, 2001)

Gill, 2003; Quillien et al., 2016; Yeakel et al., 2011

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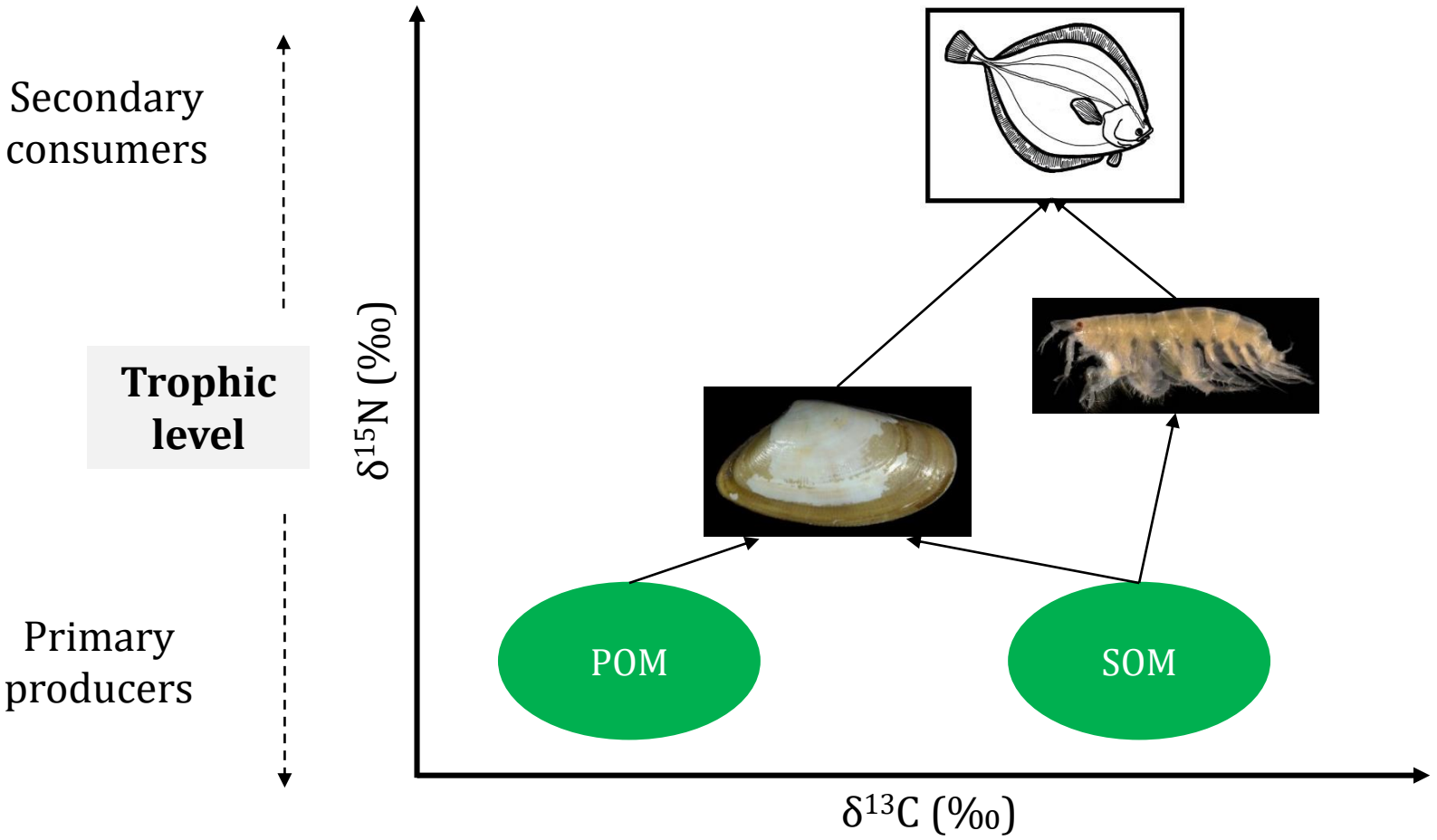

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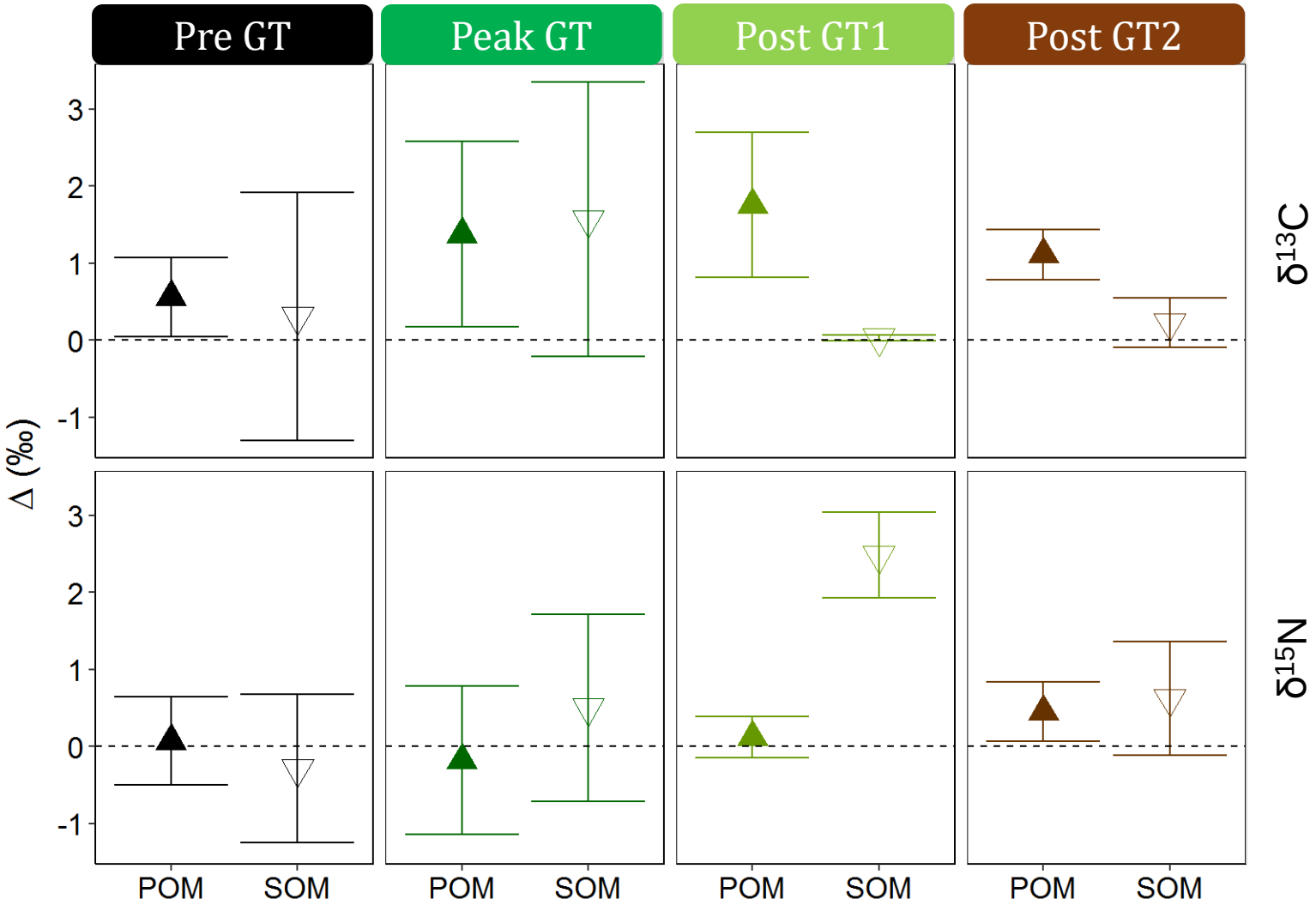
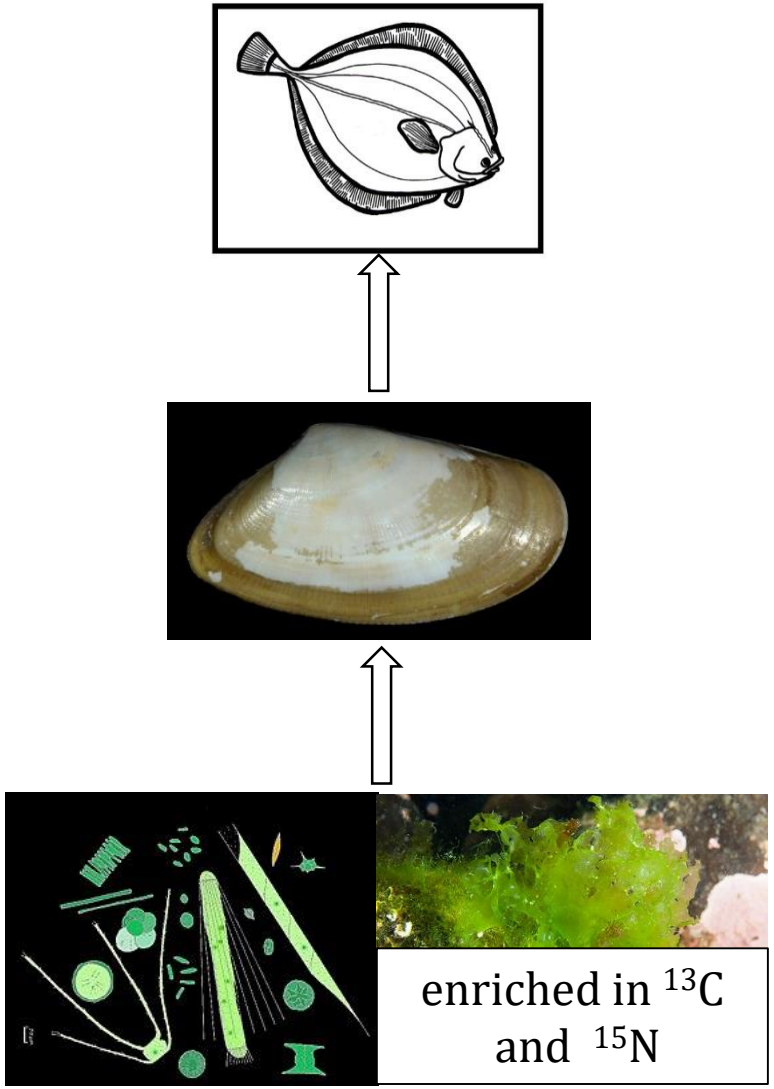
✓ **Organic matter sources** (POM, SOM and *Ulva*)

Gill, 2003; Quillien et al., 2016; Yeakel et al., 2011

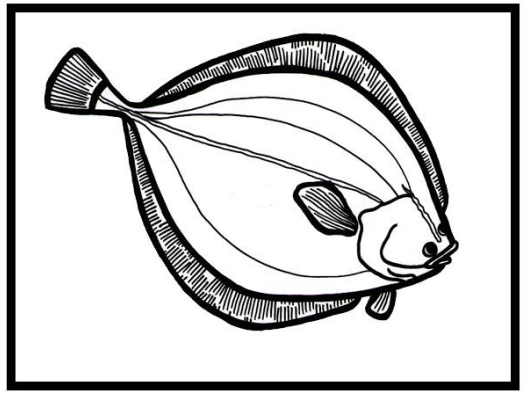
(2) Stable isotope analysis: tracing the bloom

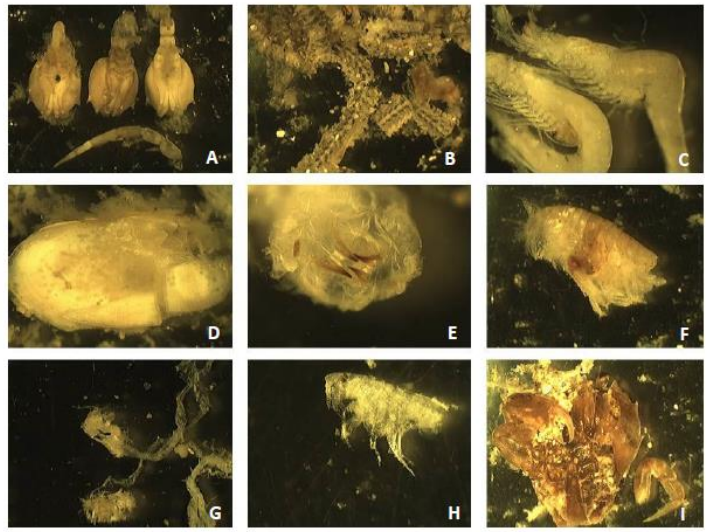




Quillien et al., 2016

(3) Gut content analysis





Prey items grouped in **tropho-orders** (*e.g.* deposit feeding Cumacea)

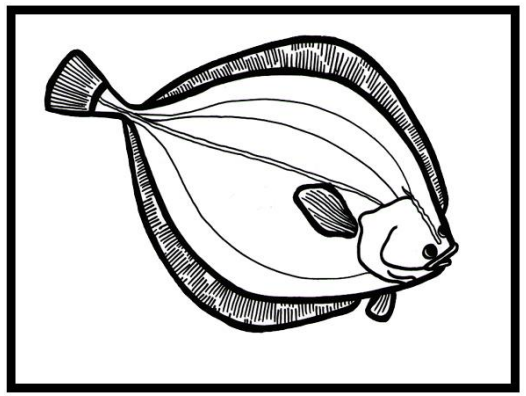
- Gut content

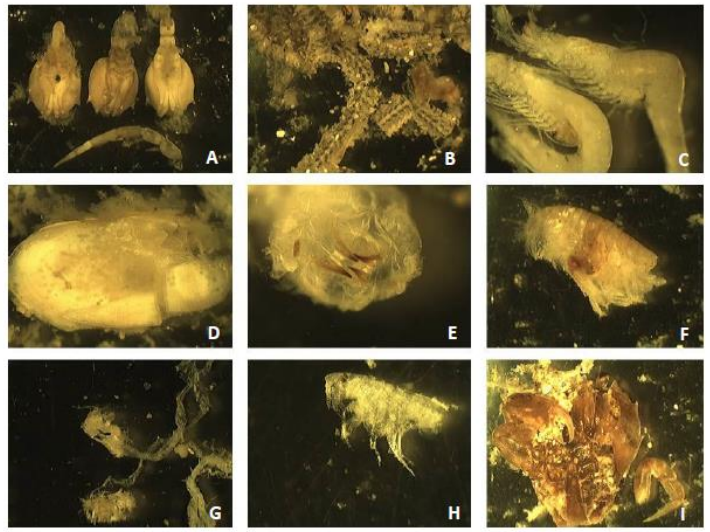
✓ Frequency of occurrence and relative abundance of the prey tropho-orders

✓ **Feeding strategy** using Tokeshi digram (Tokeshi, 1991)

Baker et al., 2014; Hyslop, 1980

(3) Gut content analysis





Prey items grouped in **tropho-orders** (*e.g.* deposit feeding Cumacea)

- Gut content

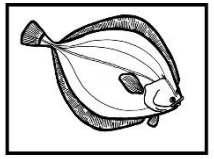
✓ Frequency of occurrence and relative abundance of the prey tropho-orders

✓ **Feeding strategy** using Tokeshi digram (Tokeshi, 1991)

- **Degree of opportunism** and **feeding behavior** using the overlap between gut content and macrofauna (Schoener, 1970)

Baker et al., 2014; Hyslop, 1980

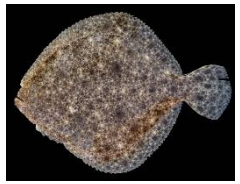
Juvenile flatfish trophic ecology



- ✓ Specialized feeding strategy and selective feeding behavior

- ✓ Diet = suspension-feeding bivalves (SF-Ven.), small deposit-feeding crustaceans (DF-Cum. And DF-Amp.) and polychaetes (deposit-feeding and carnivorous)

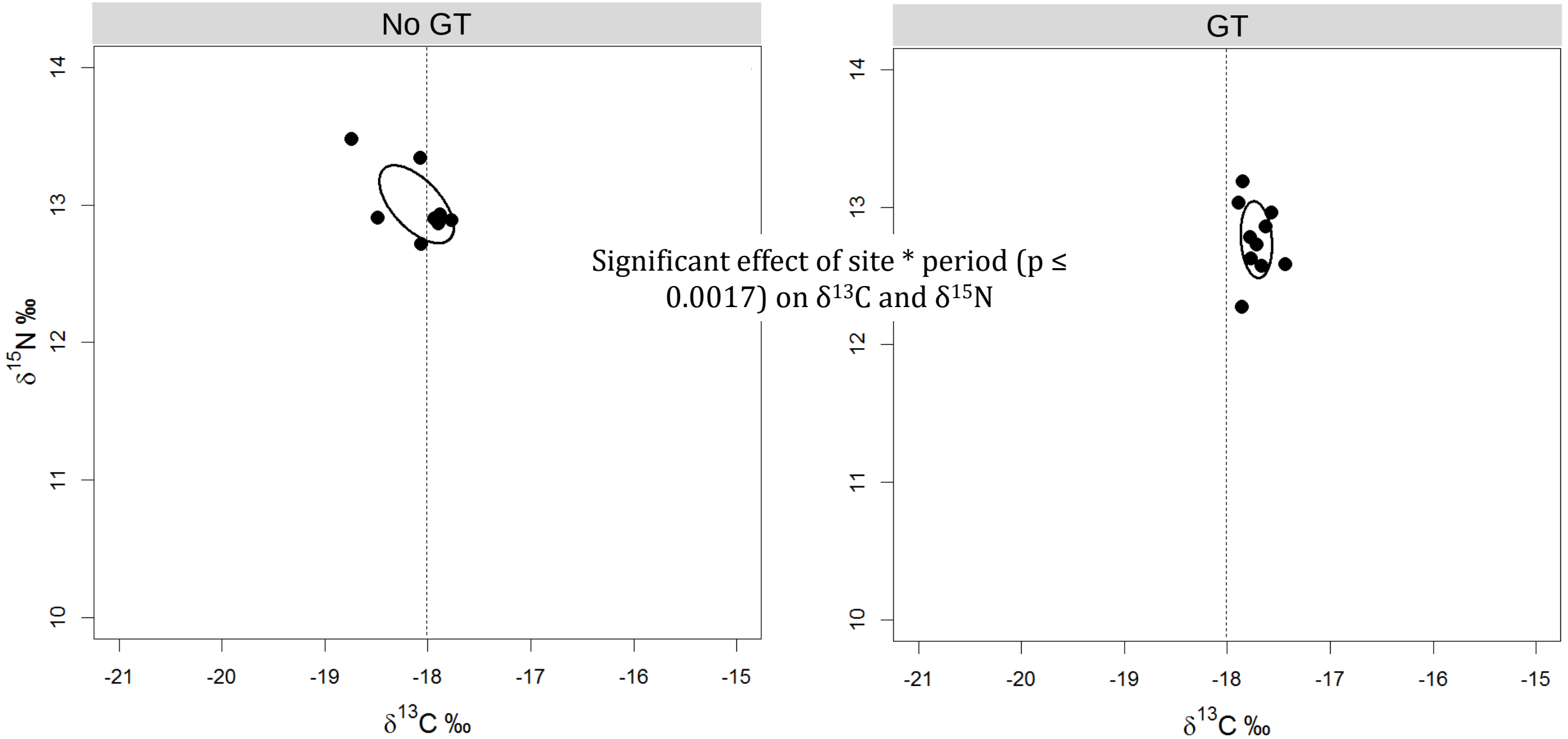
- ✓ Diet = mainly suspension-feeding bivalves (SF-Ven.) and some small deposit-feeding crustaceans (DF-Cum.)



- ✓ Diet = suspension-feeding bivalves (SF-Ven.), small deposit-feeding crustaceans (DF-Cum. And DF-Amp.), larger crustaceans (Mysida) and carnivorous polychaetes

Tracing the *Ulva* bloom

Pre GT

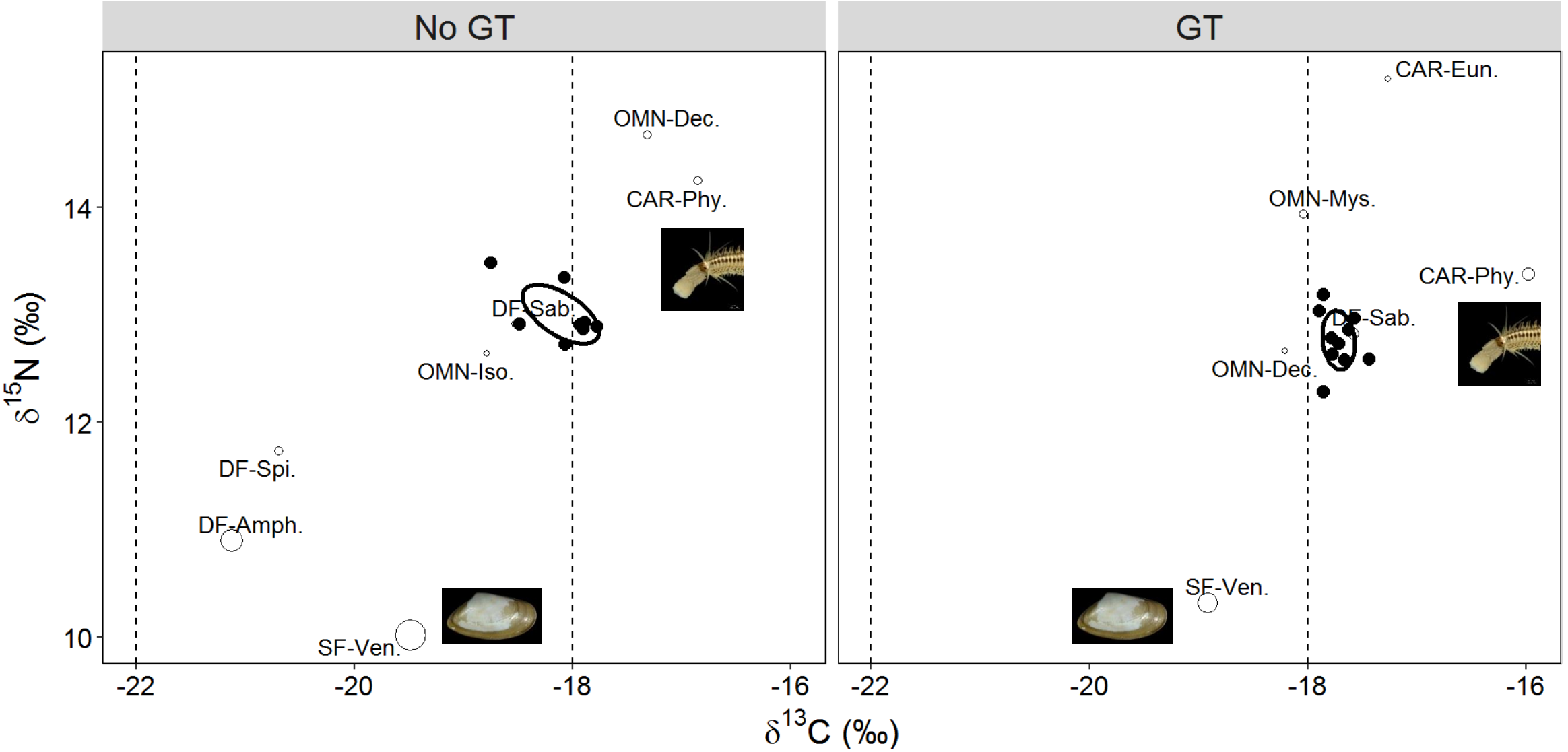


Significant effect of site * period ($p \leq 0.0017$) on $\delta^{13}C$ and $\delta^{15}N$

Tracing the *Ulva* bloom

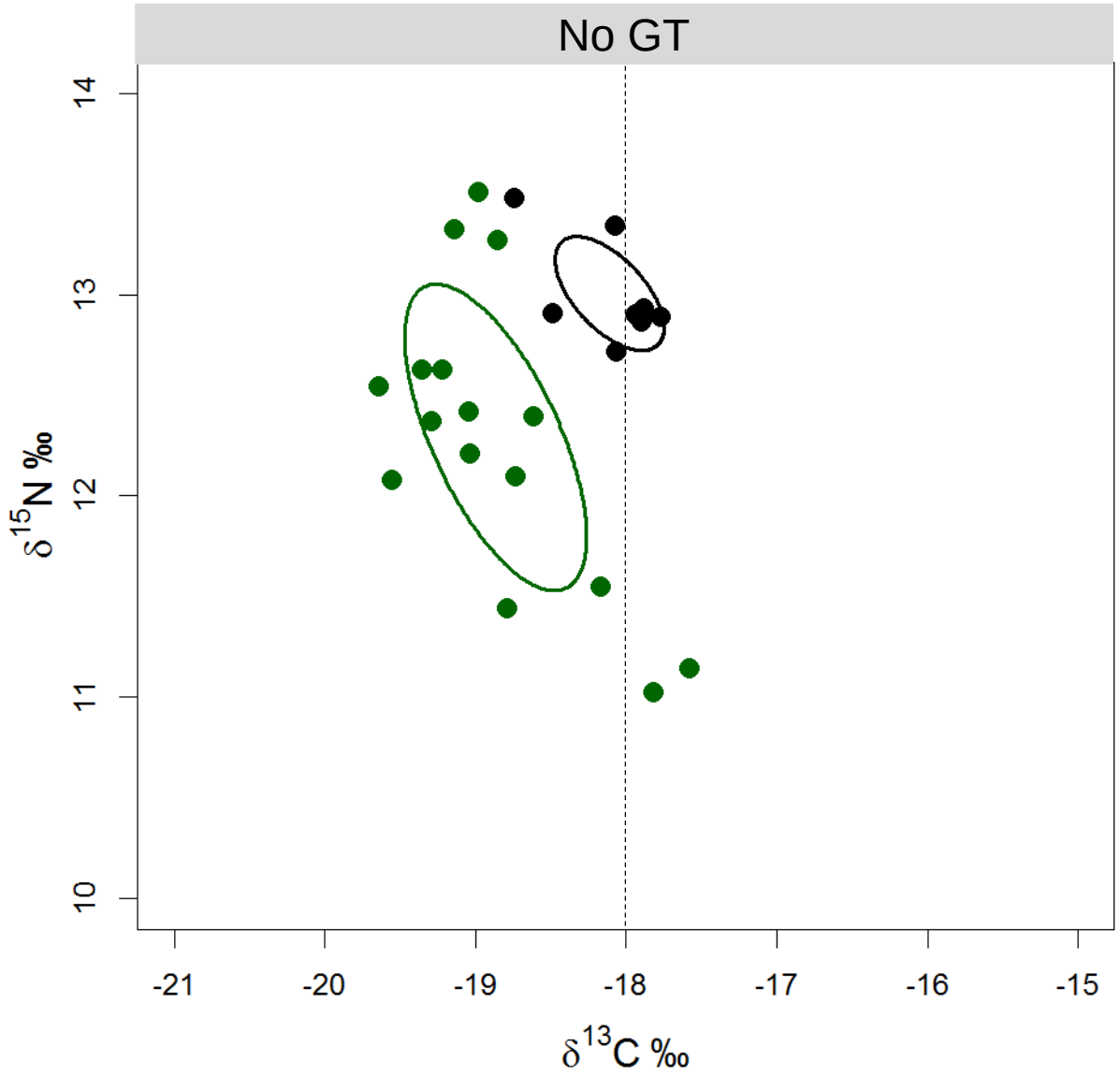
Pre GT

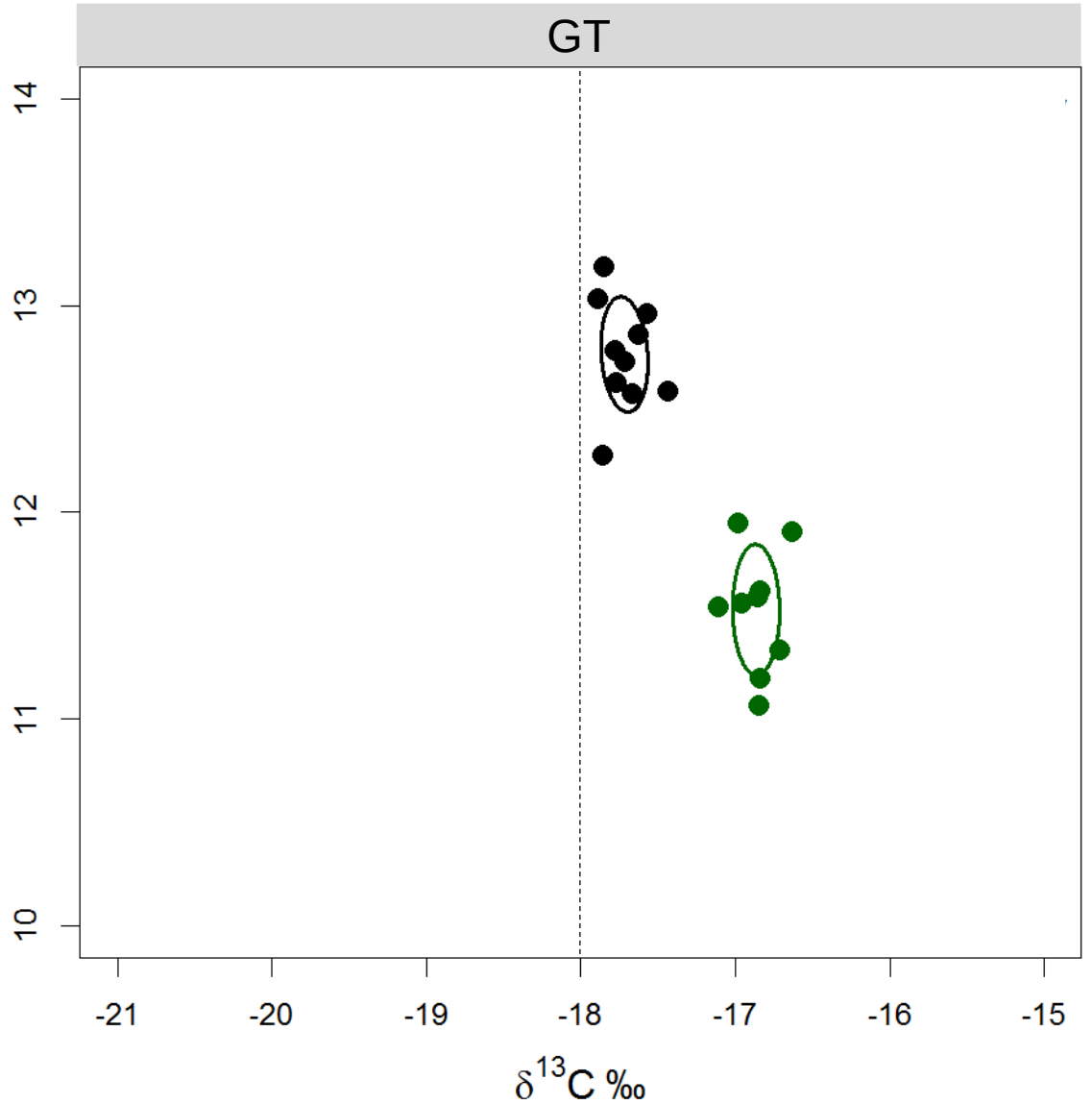
Residual 2011 GT signal



Tracing the *Ulva* bloom

Pre GT | GT peak

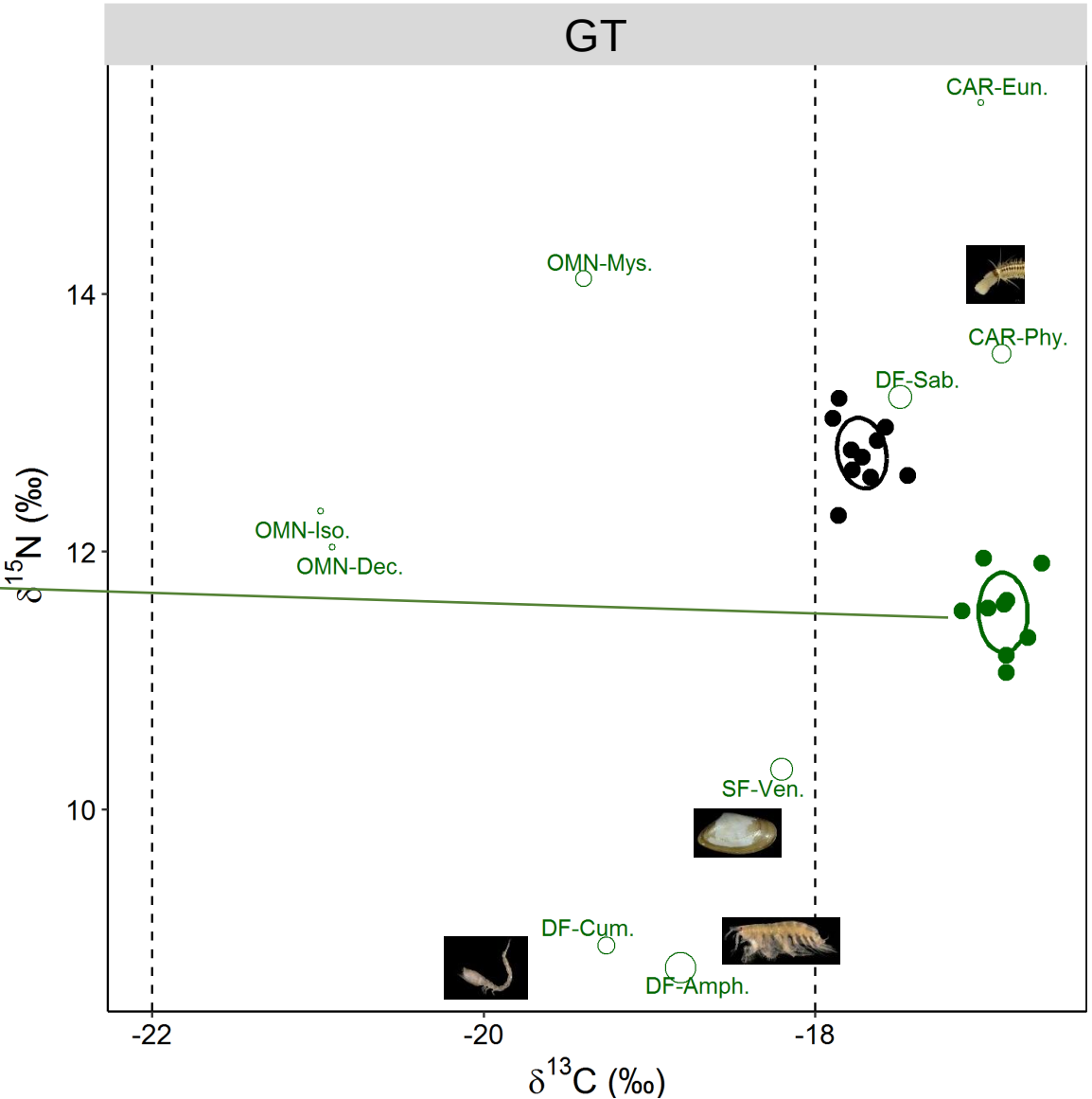




Tracing the *Ulva* bloom

Pre GT | GT peak

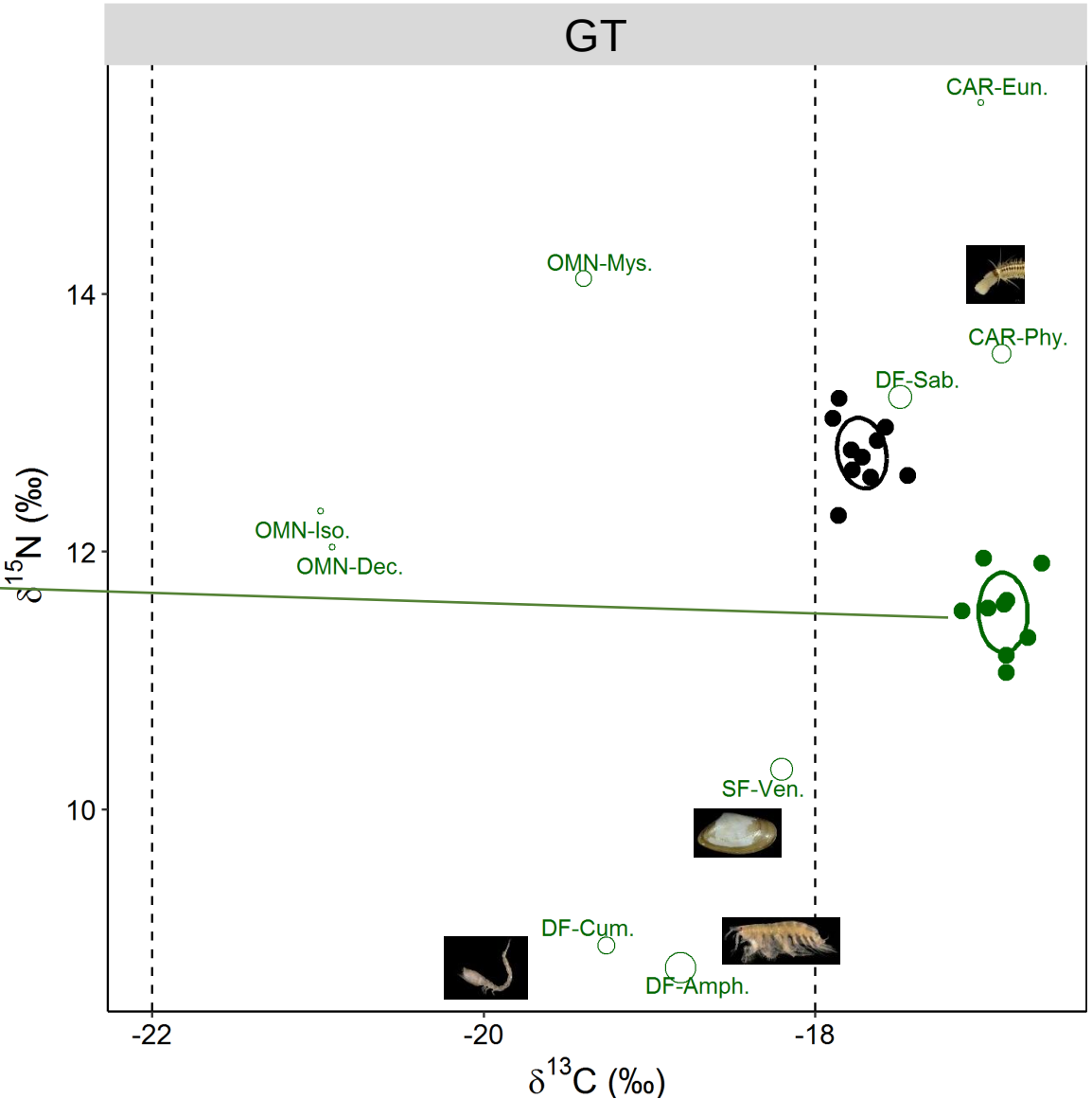
generalist feeding strategy and opportunistic feeding behavior



Tracing the *Ulva* bloom

Pre GT | GT peak

generalist feeding strategy and opportunistic feeding behavior



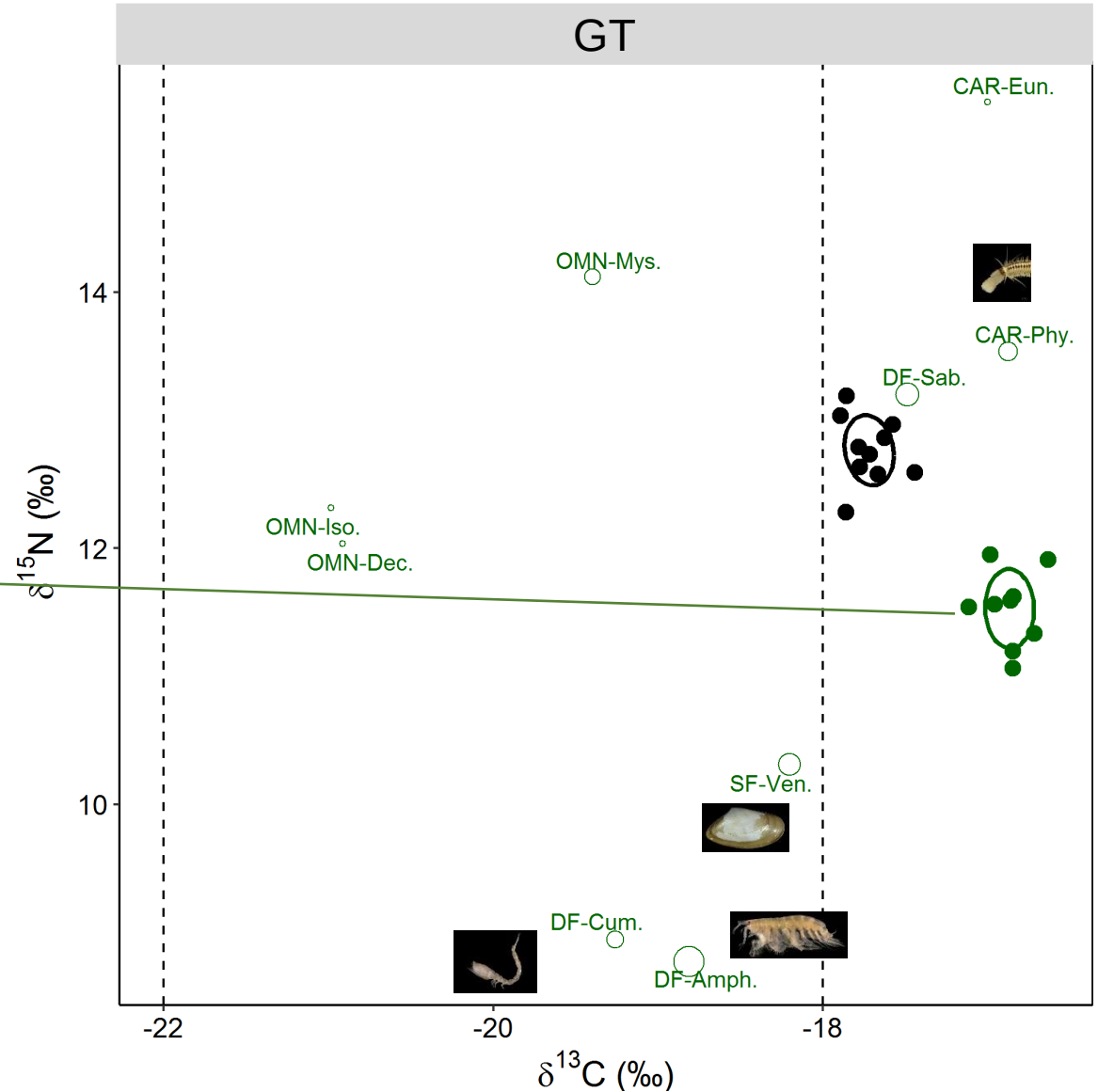
Tracing the *Ulva* bloom

Pre GT | GT peak

generalist feeding strategy and opportunistic feeding behavior

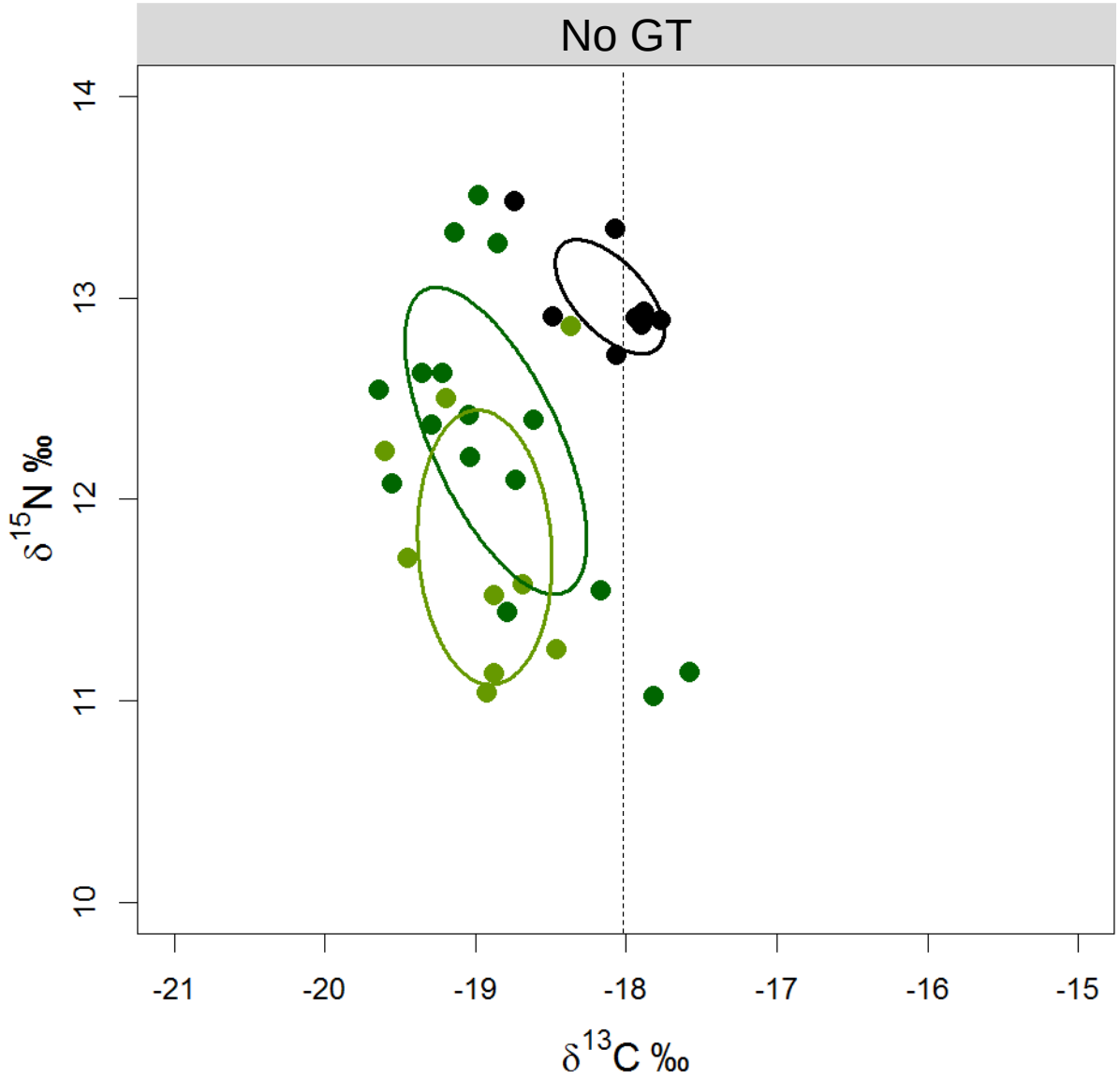
Strong integration of the GT isotopic signal

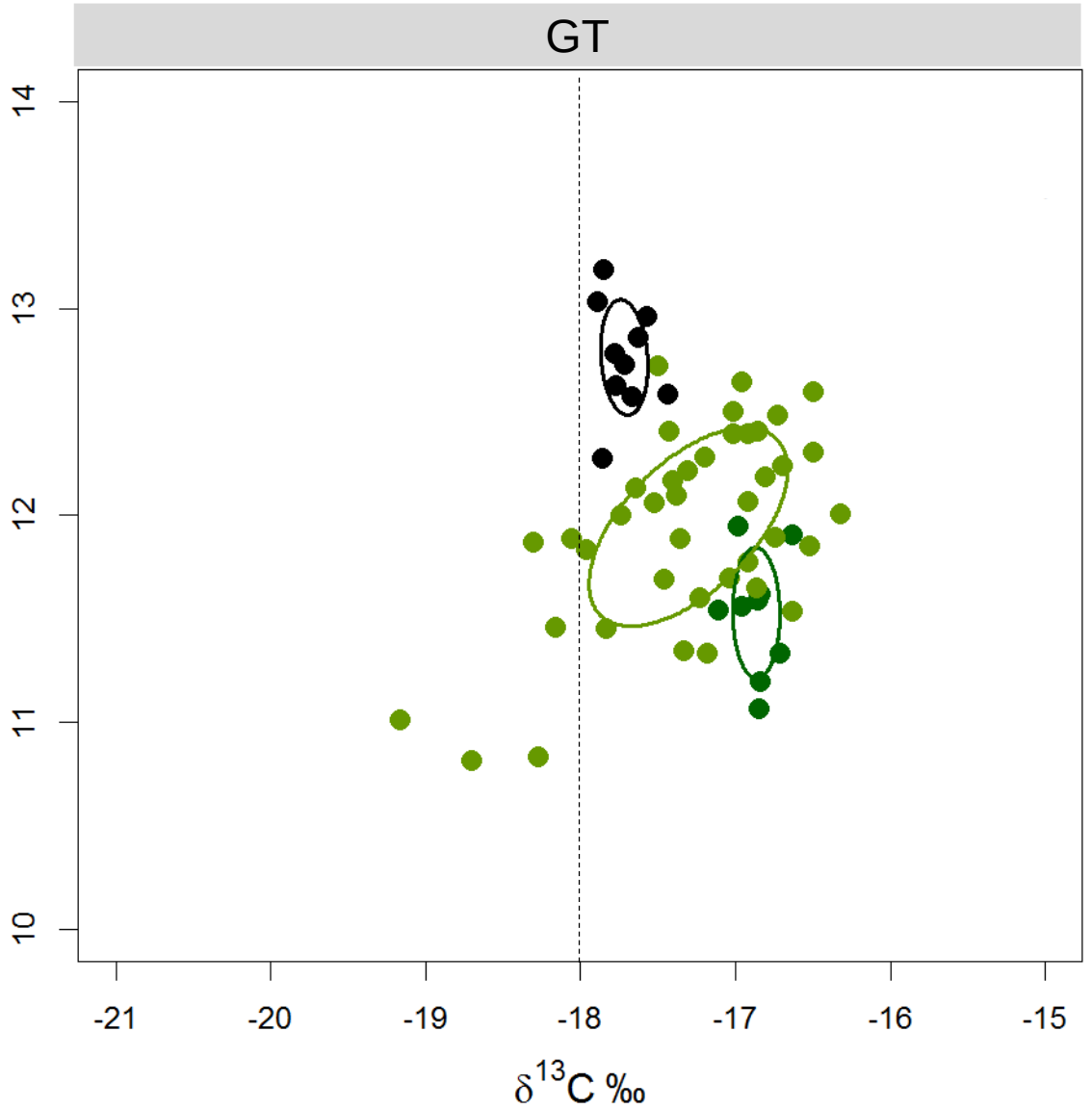
Trophic plasticity (forages on abundant macrofauna)



Tracing the *Ulva* bloom

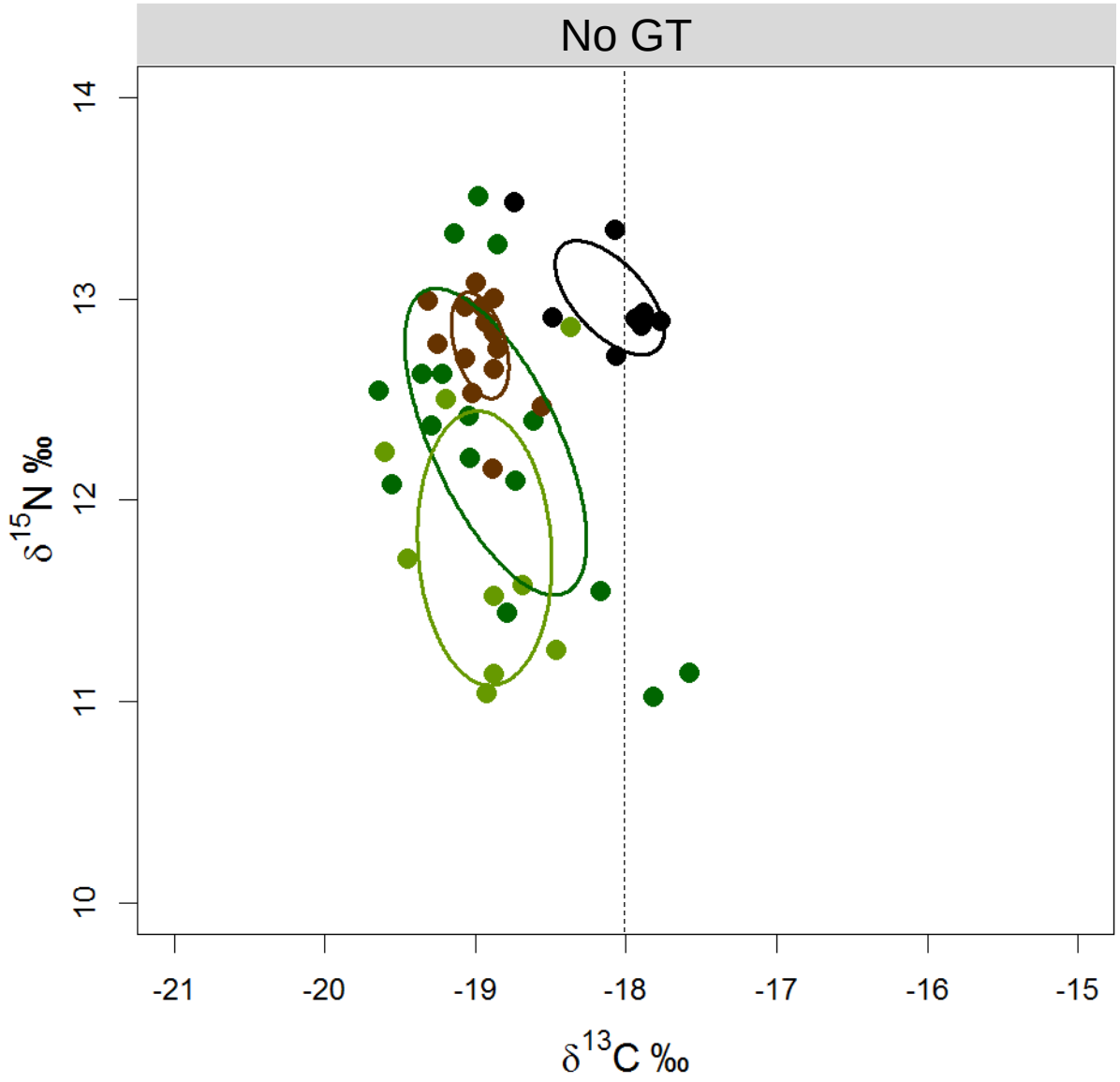
Pre GT | GT peak | Post GT1

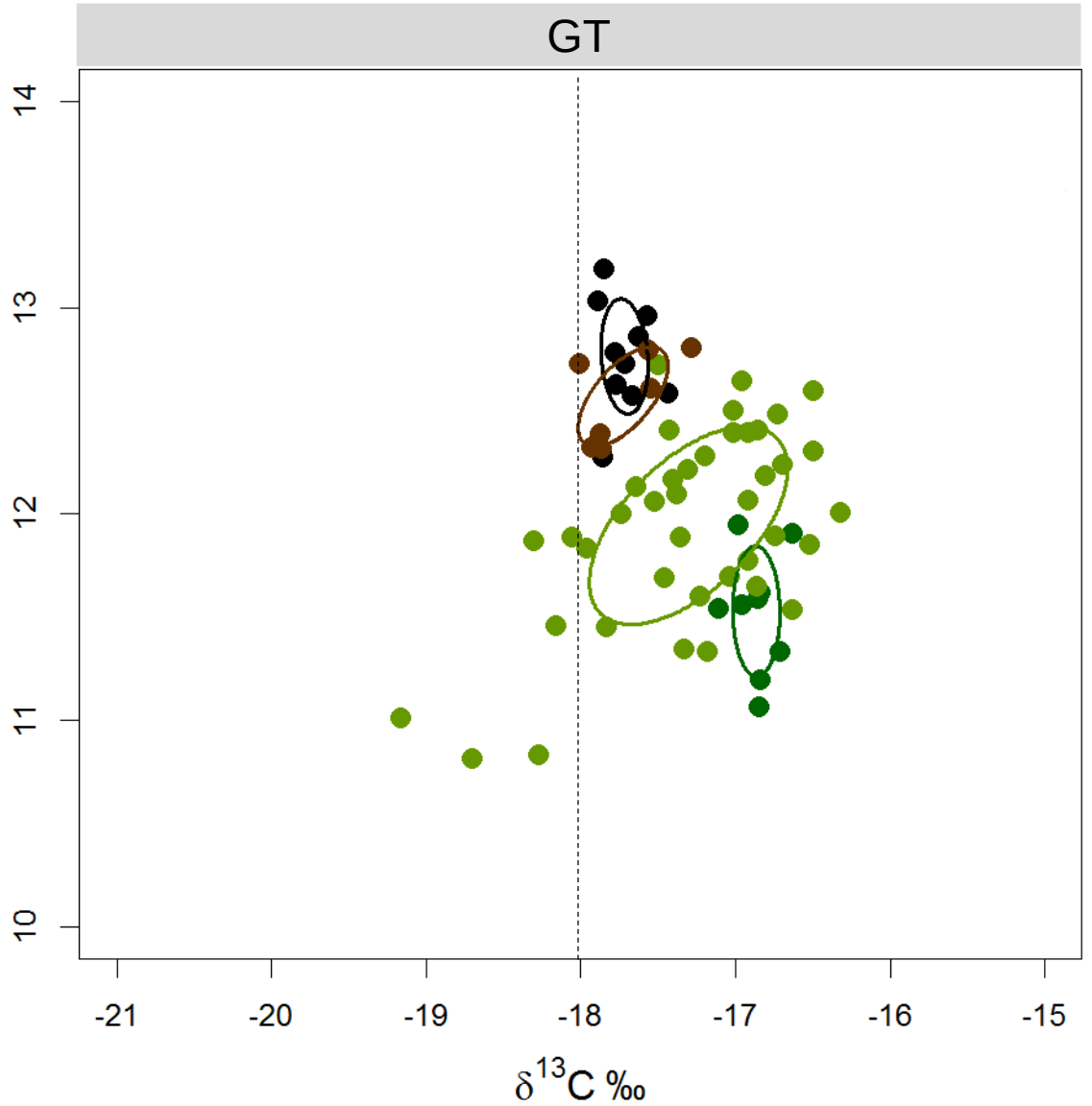




Tracing the *Ulva* bloom

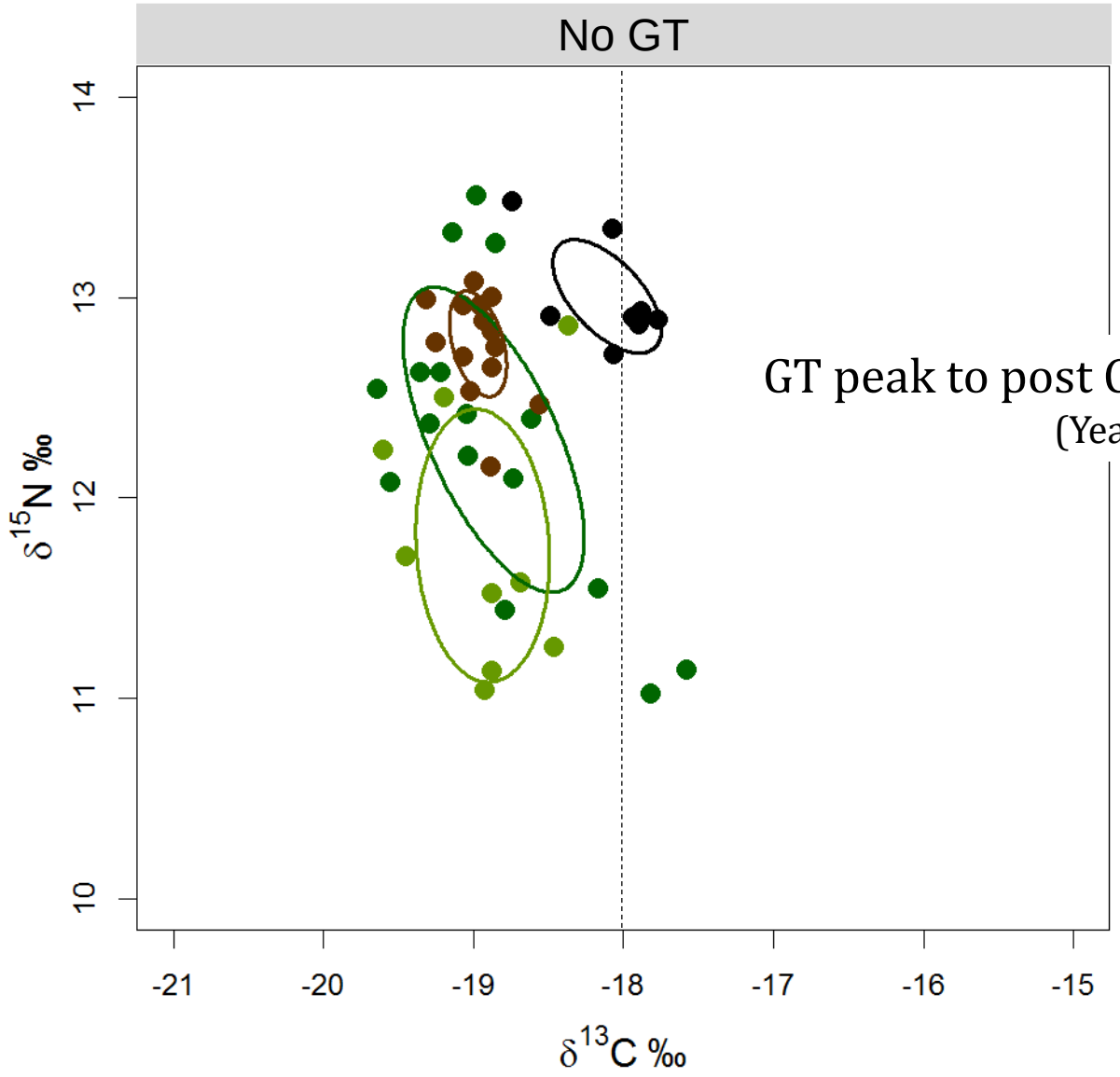
Pre GT | GT peak | Post GT1 | Post GT2



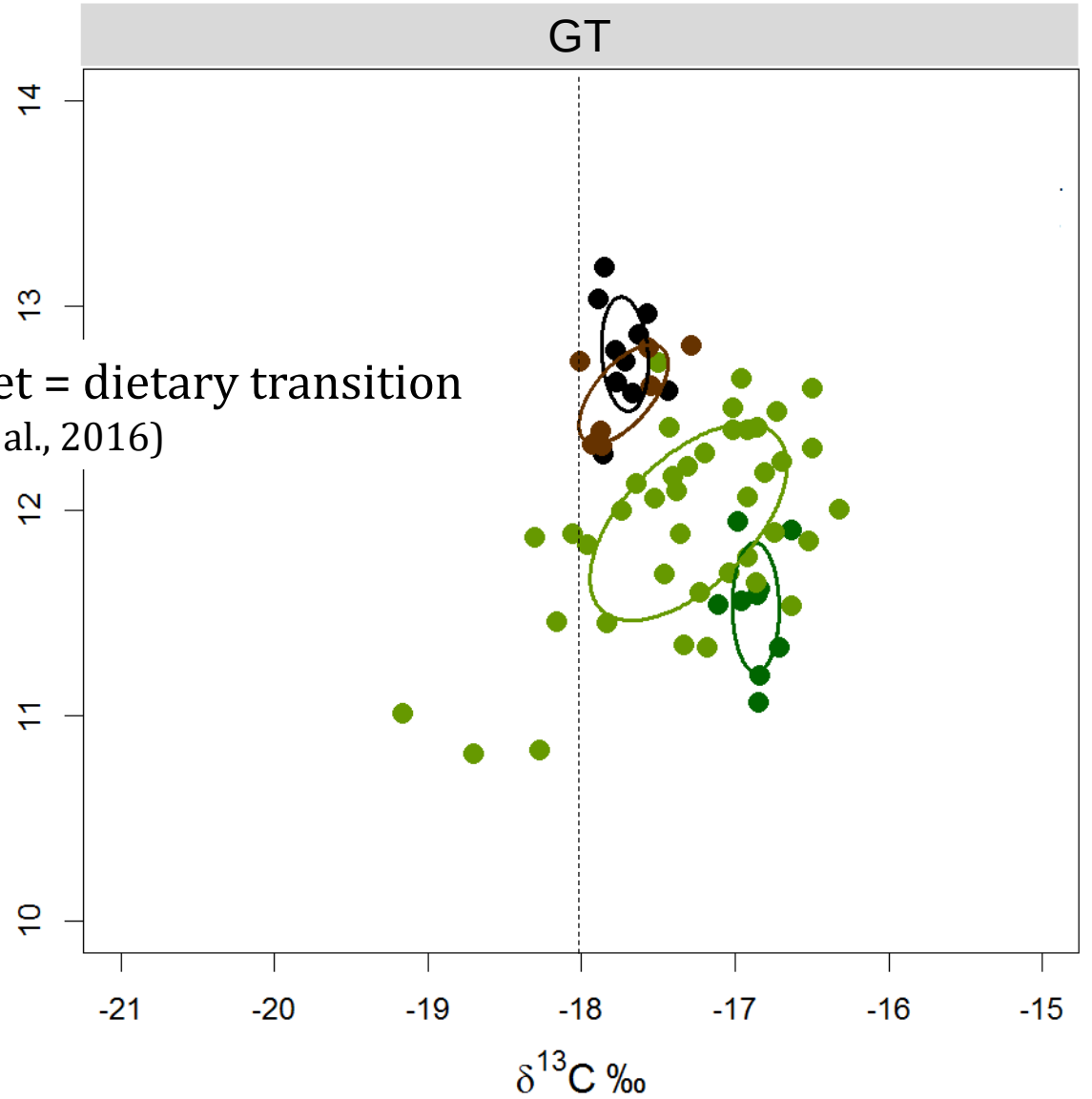


Tracing the *Ulva* bloom

Pre GT | GT peak | Post GT1 | Post GT2



GT peak to post GT diet = dietary transition
(Yeakel et al., 2016)

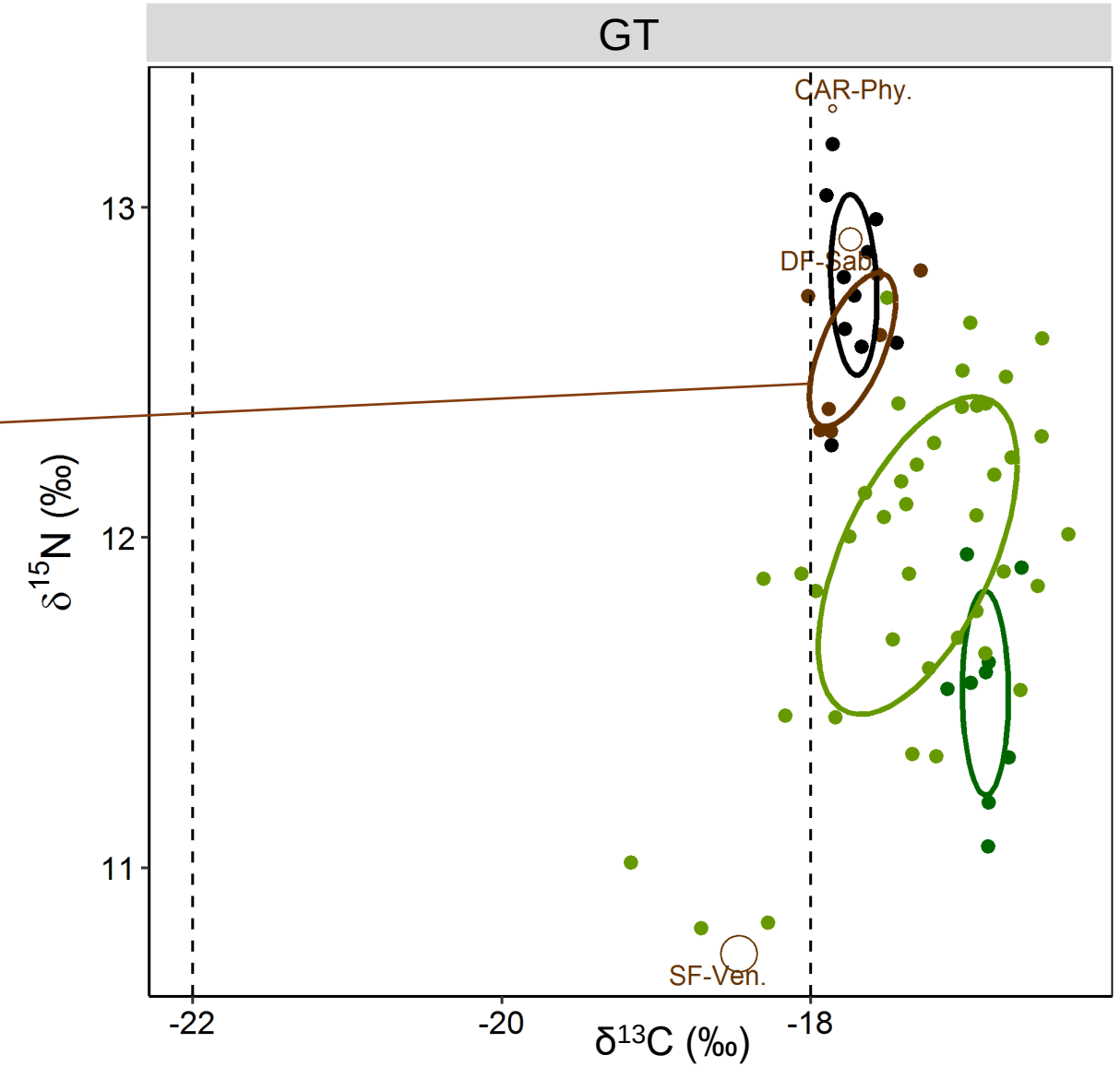


Tracing the *Ulva* bloom

Pre GT | GT peak | Post GT1 | Post GT2

highly specialized feeding strategy

similar diet to reference site



Tracing the *Ulva* bloom

Pre GT | GT peak | Post GT1 | Post GT2

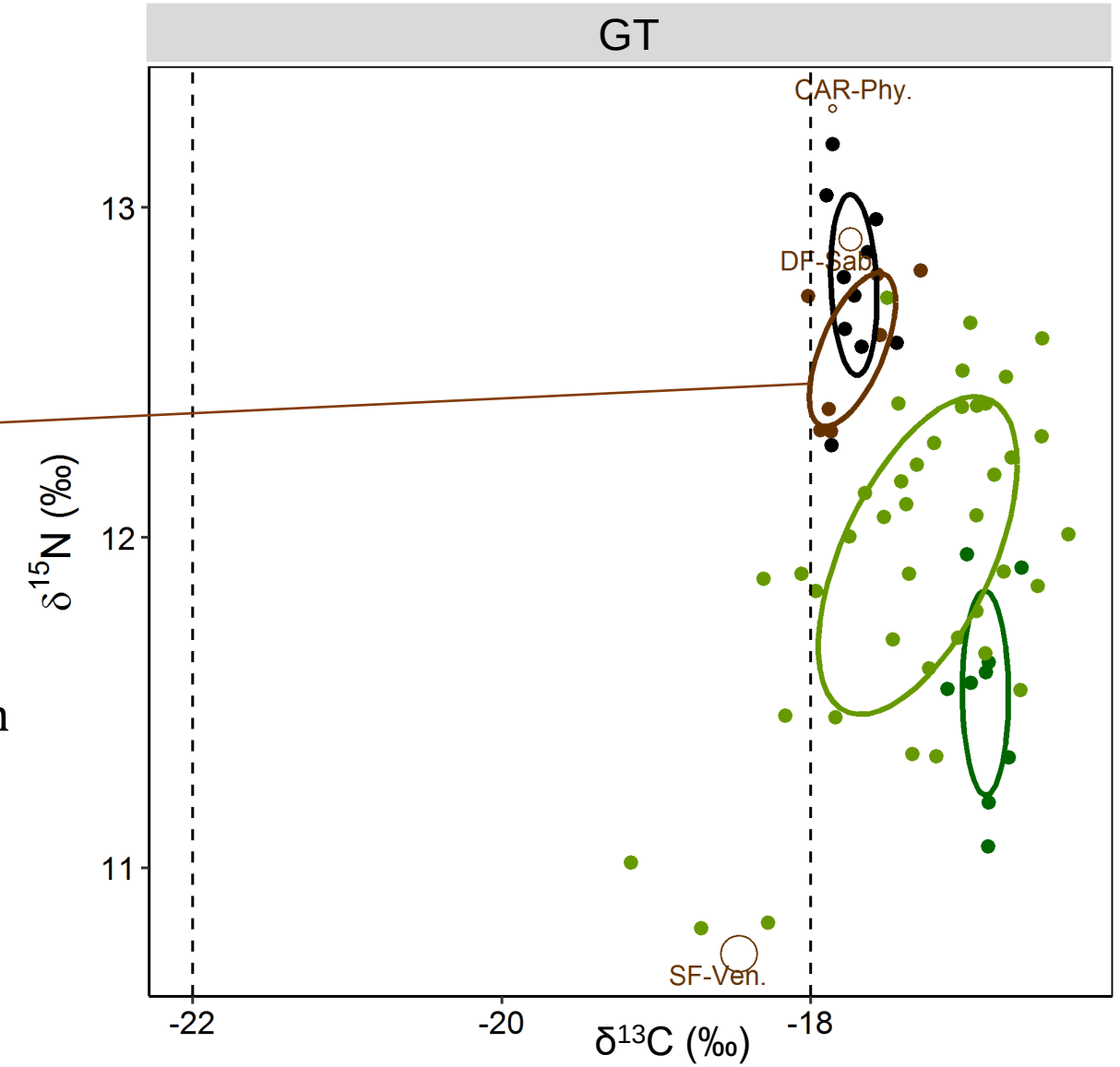
highly specialized feeding strategy

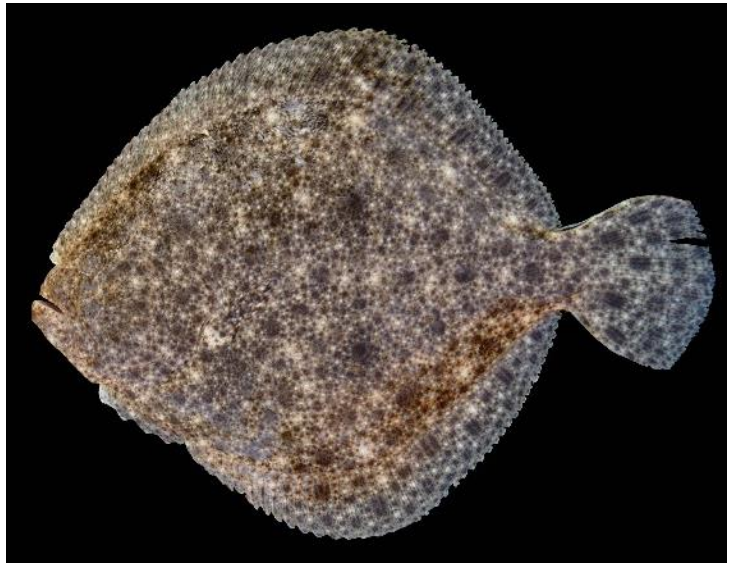
similar diet to reference site

Strong GT signal from the sampling year (integration of decaying *Ulva*)

High site fidelity during and after the *Ulva* bloom

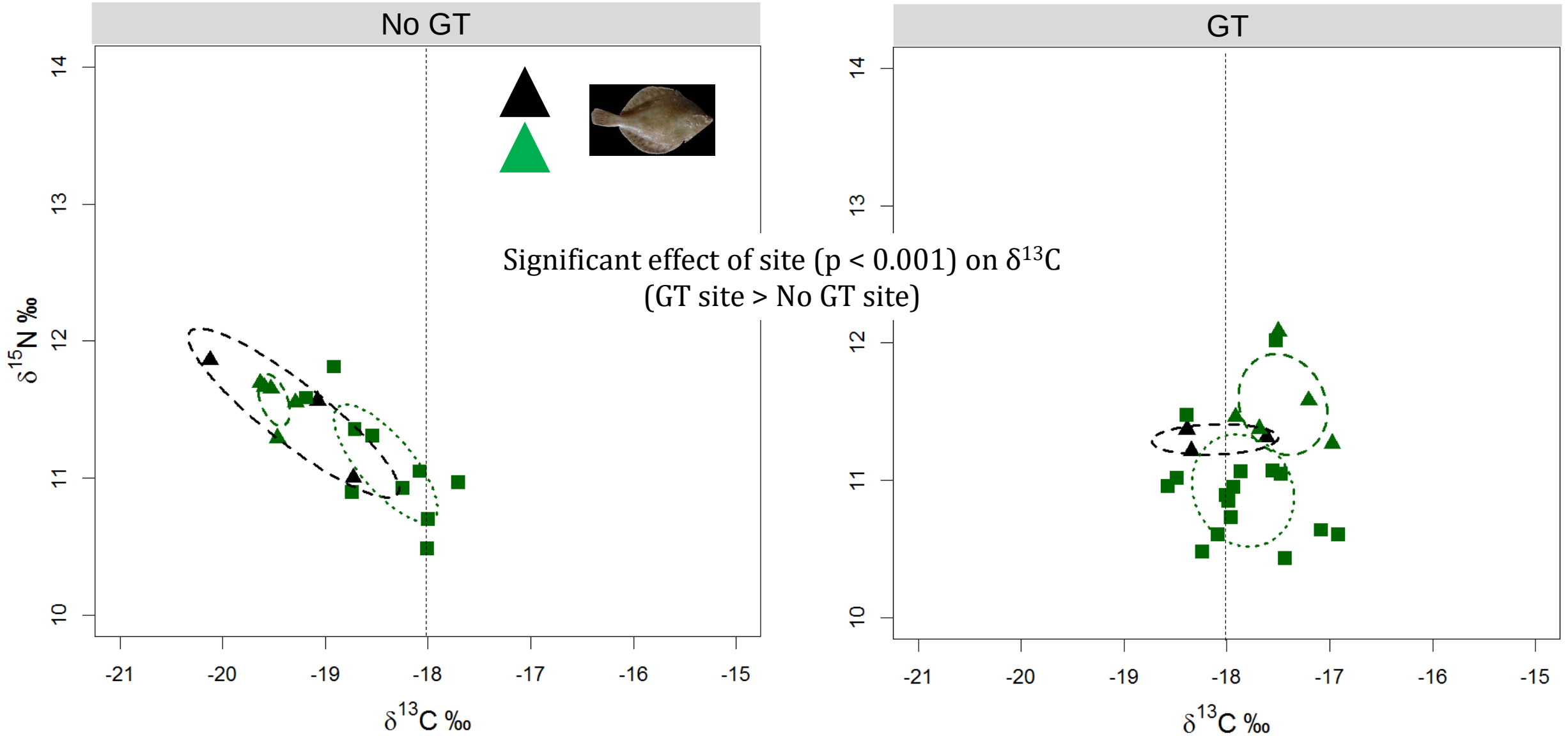
Dietary resilience





GT effect on plaice

Pre GT

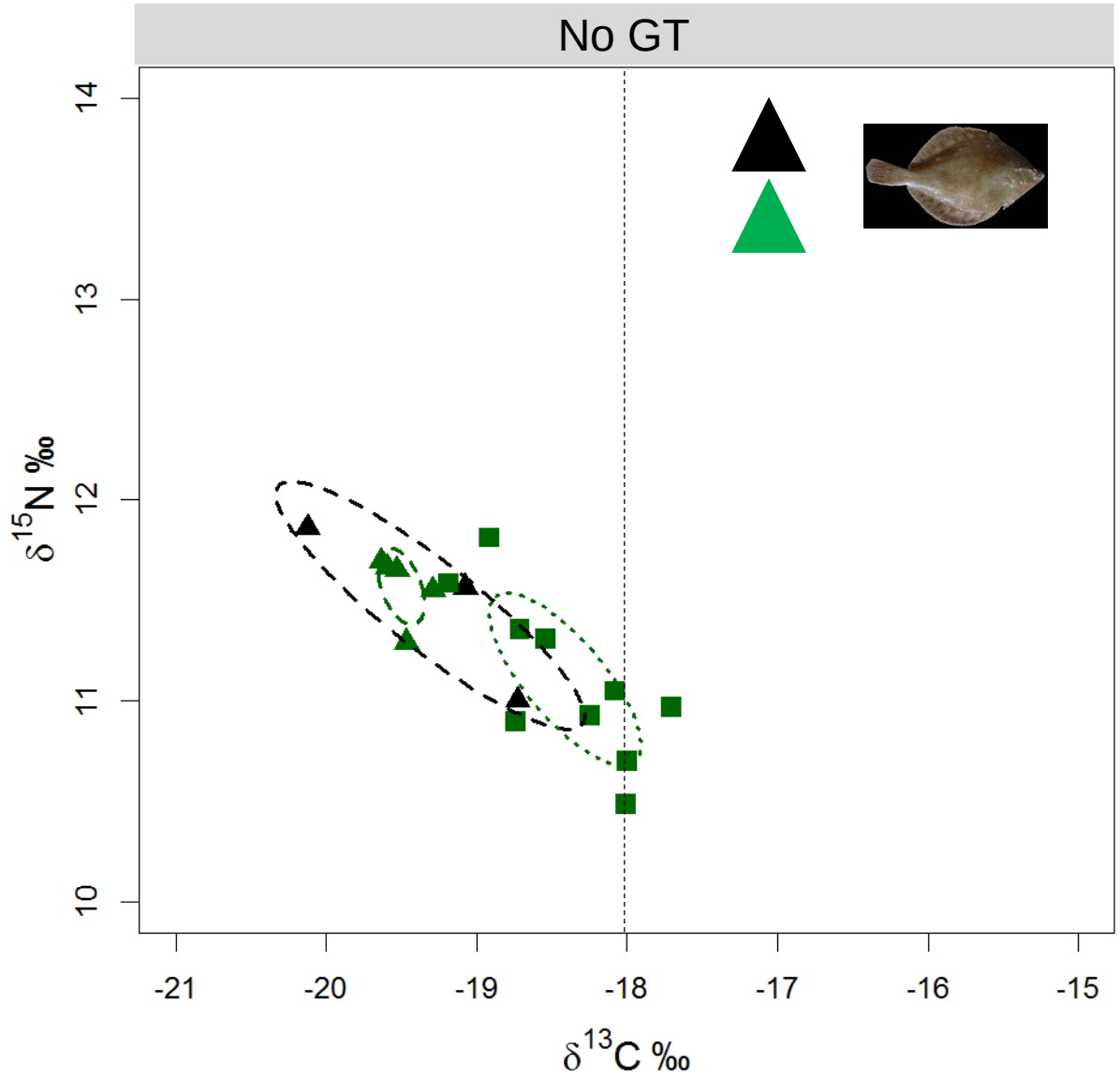


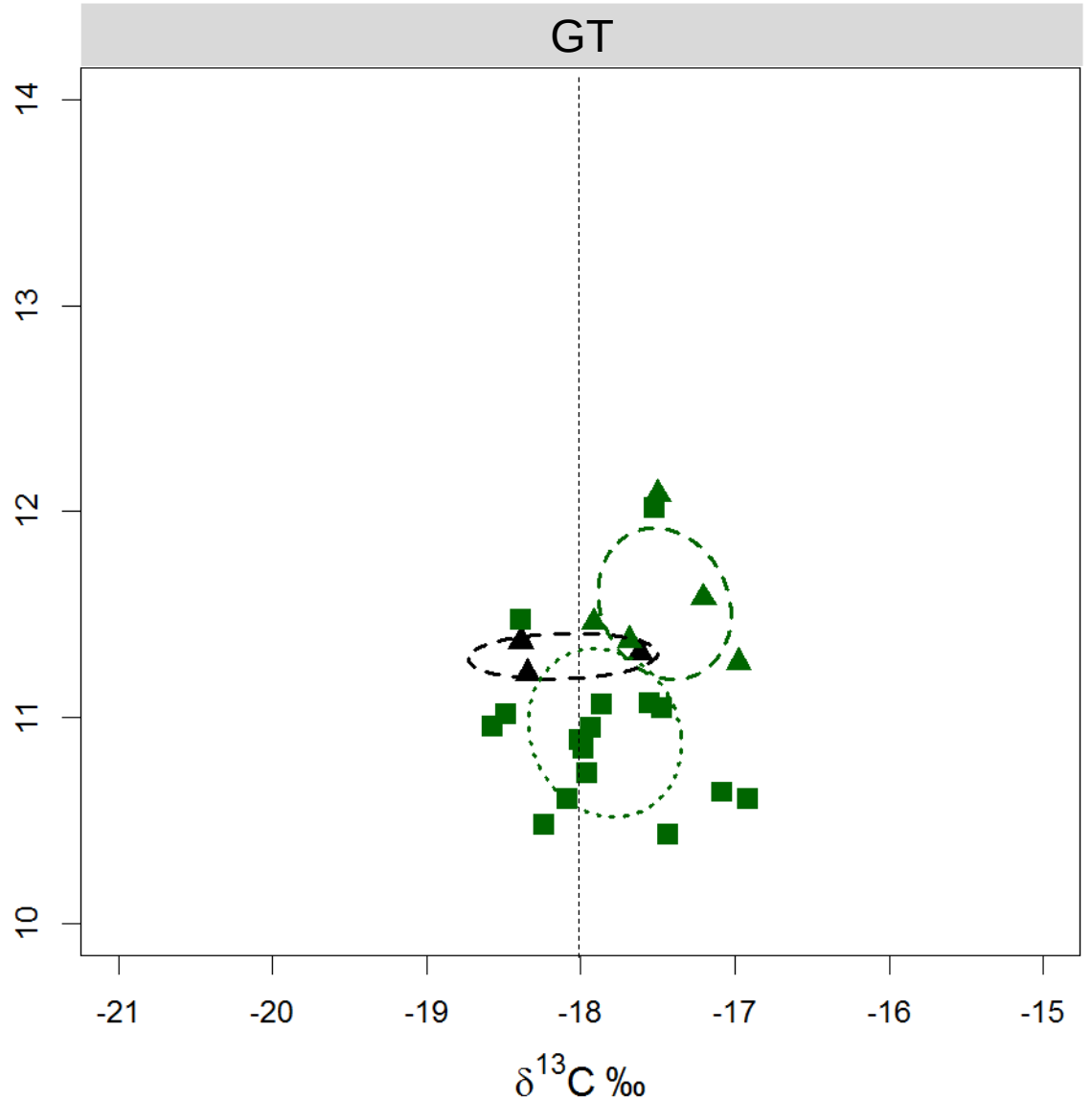
Significant effect of site ($p < 0.001$) on $\delta^{13}C$
(GT site > No GT site)

GT effect on plaice

Pre GT

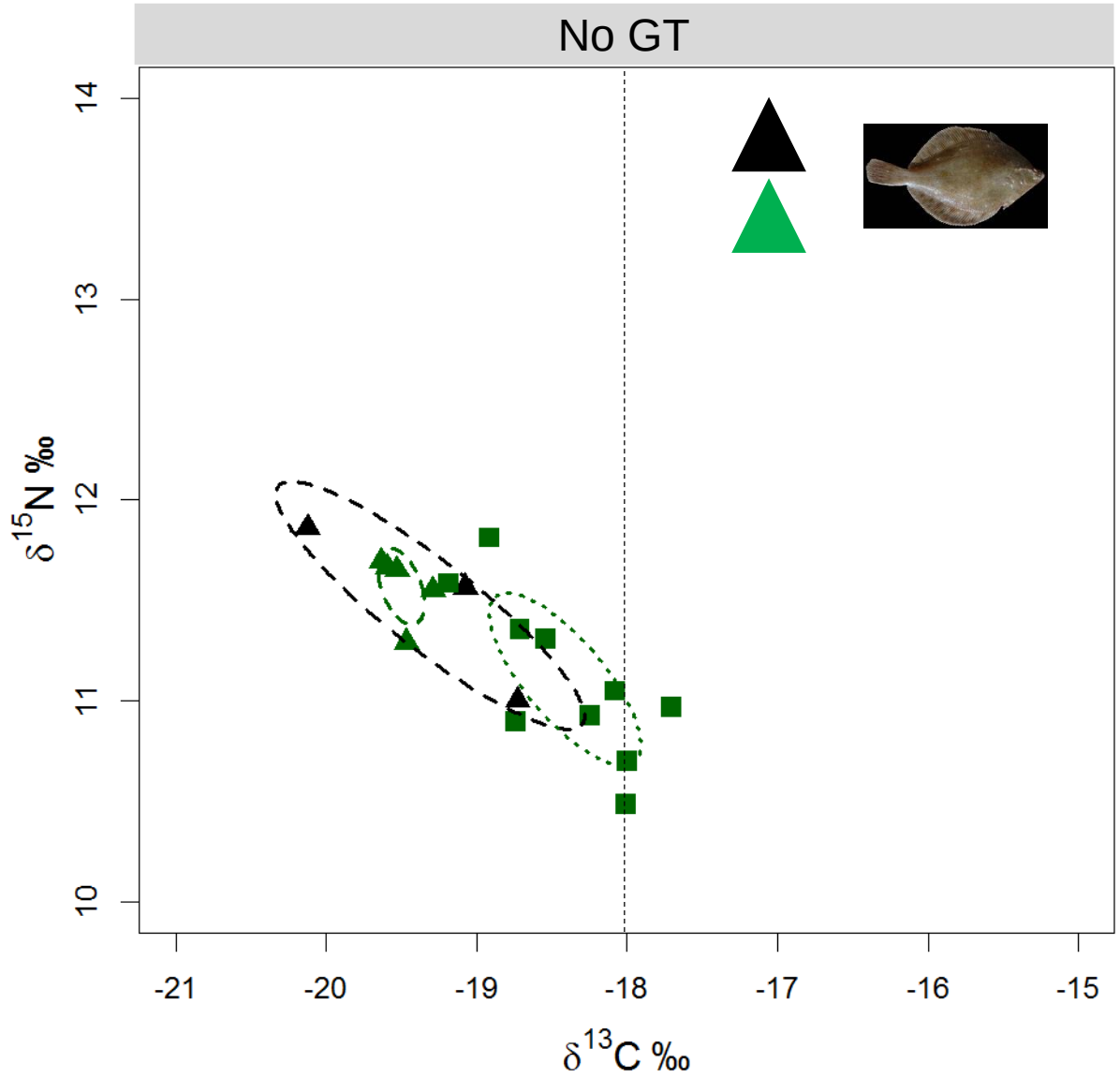
Residual 2011 GT signal

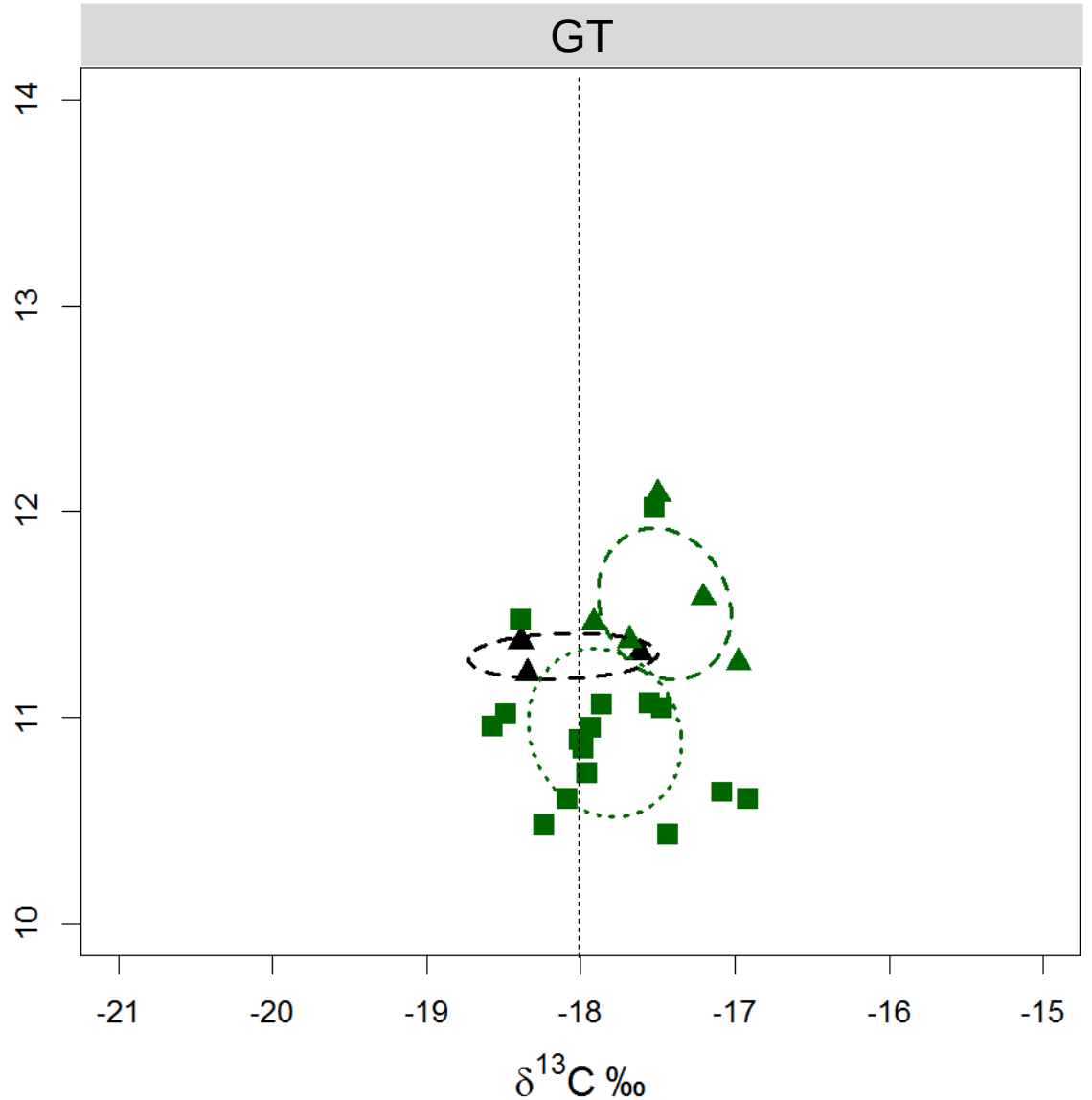




GT effect on plaice

Pre GT | GT peak

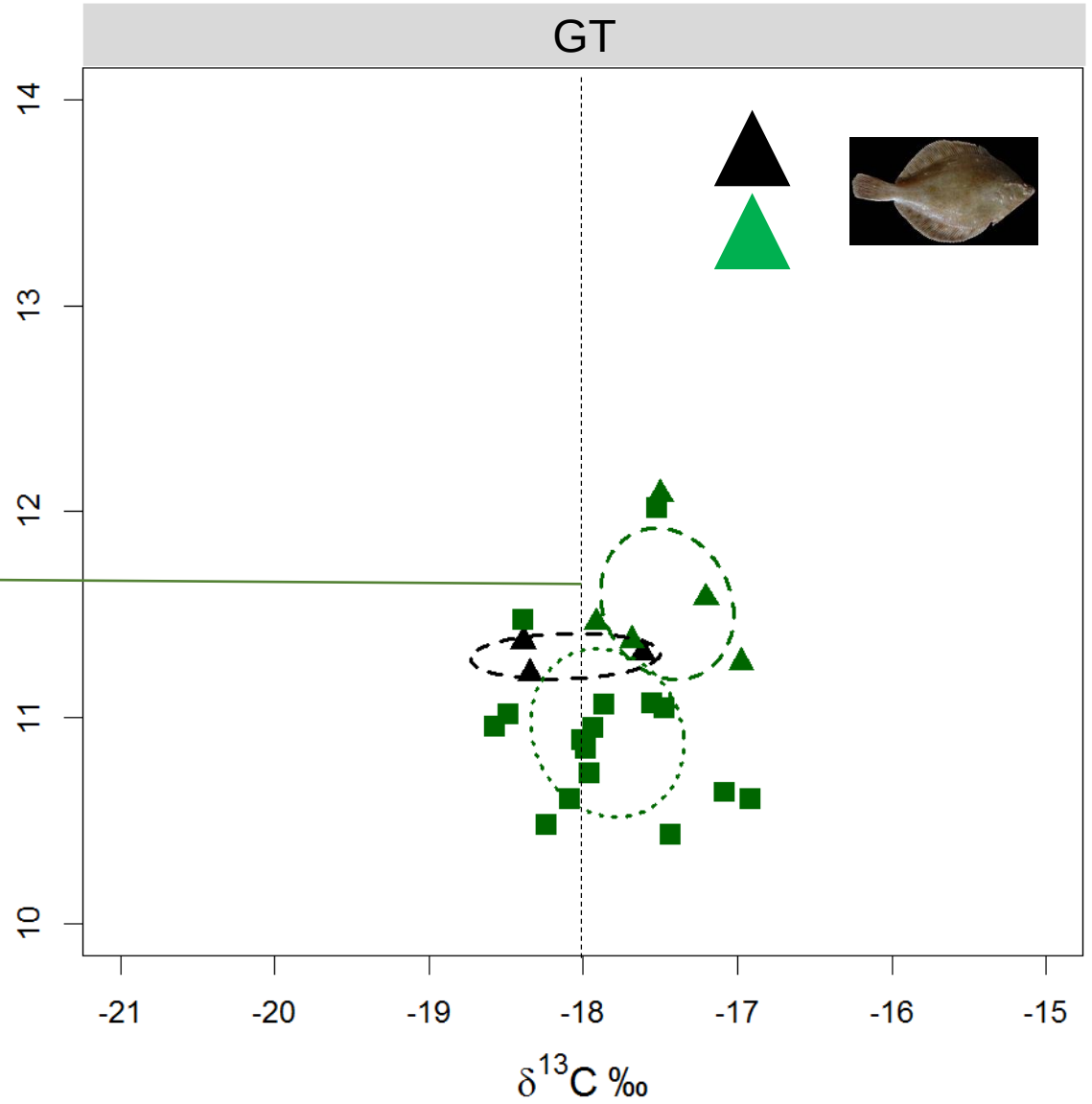




GT effect on plaice

Pre GT | GT peak

generalist feeding strategy and opportunistic feeding behavior



GT effect on plaice

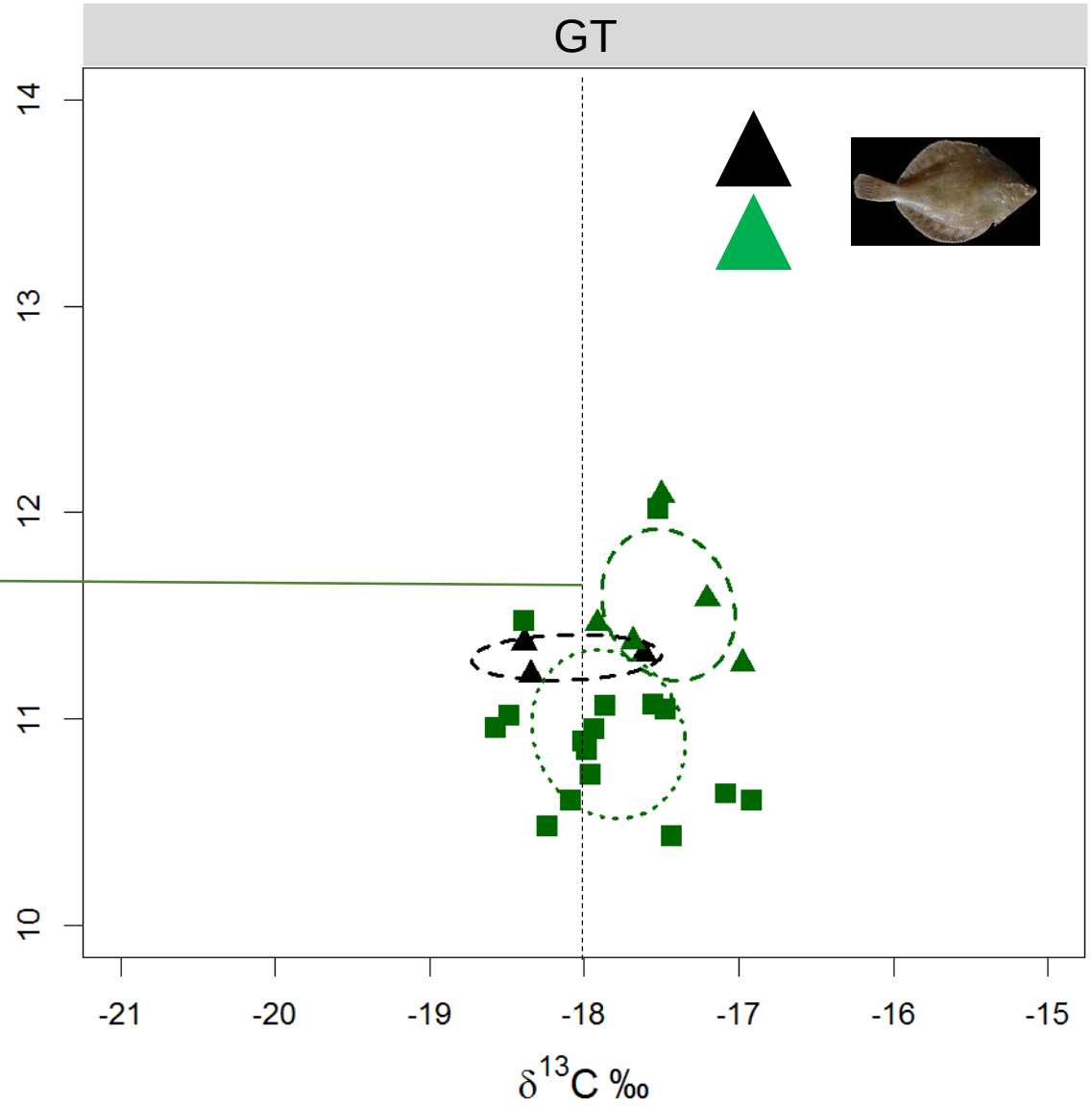
Pre GT | GT peak

generalist feeding strategy and opportunistic feeding behavior

Integration of the GT isotopic signal

Presence of subtidal prey in gut contents

Trophic plasticity



GT effect on plaice

generalist feeding strategy but more selective feeding behavior

Integration of the GT isotopic signal

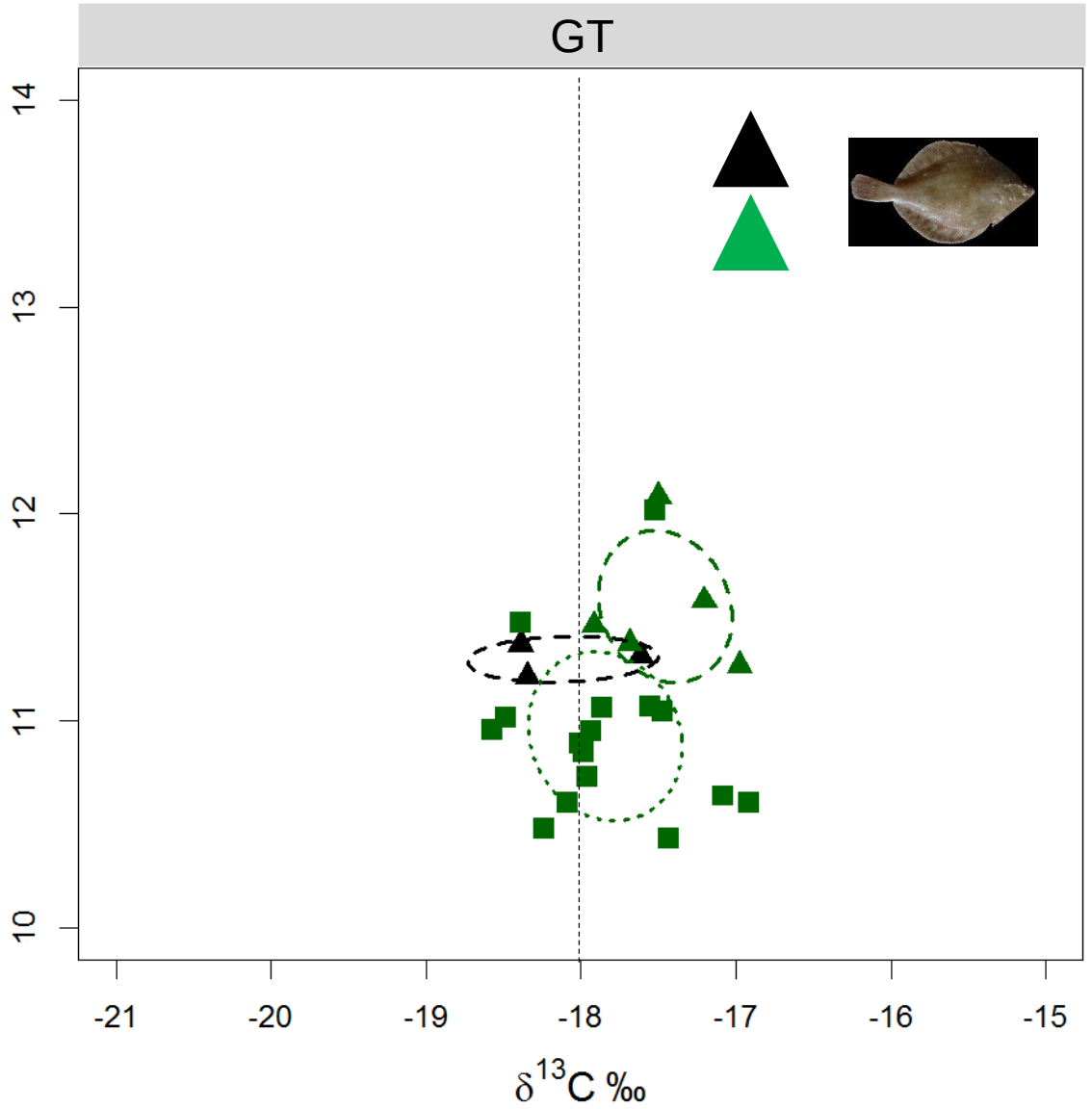
Presence of subtidal prey in gut contents

Trophic plasticity

Less dietary resilience than sand sole

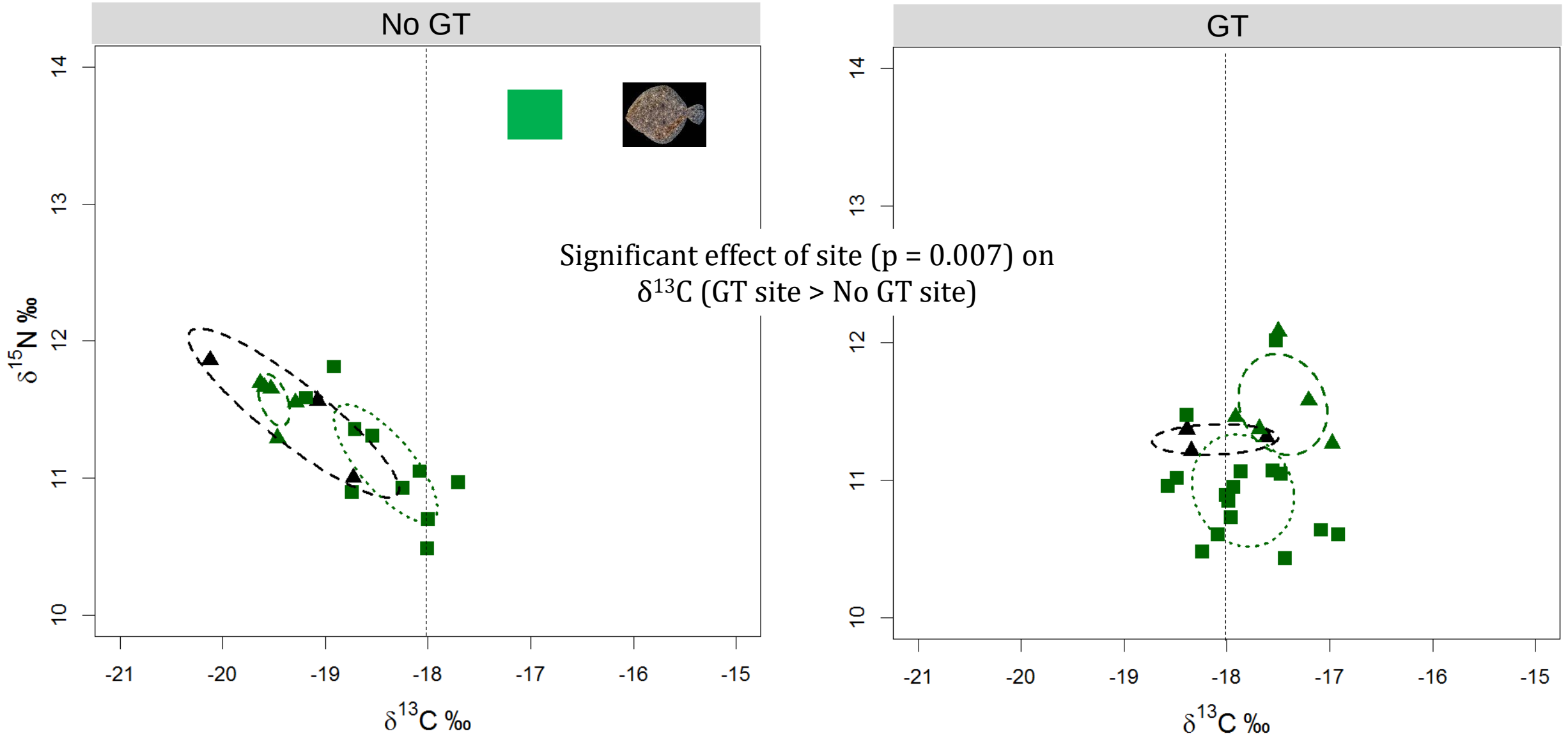
Pre GT | GT peak

Just after the GT peak (July)



GT effect on turbot

GT peak



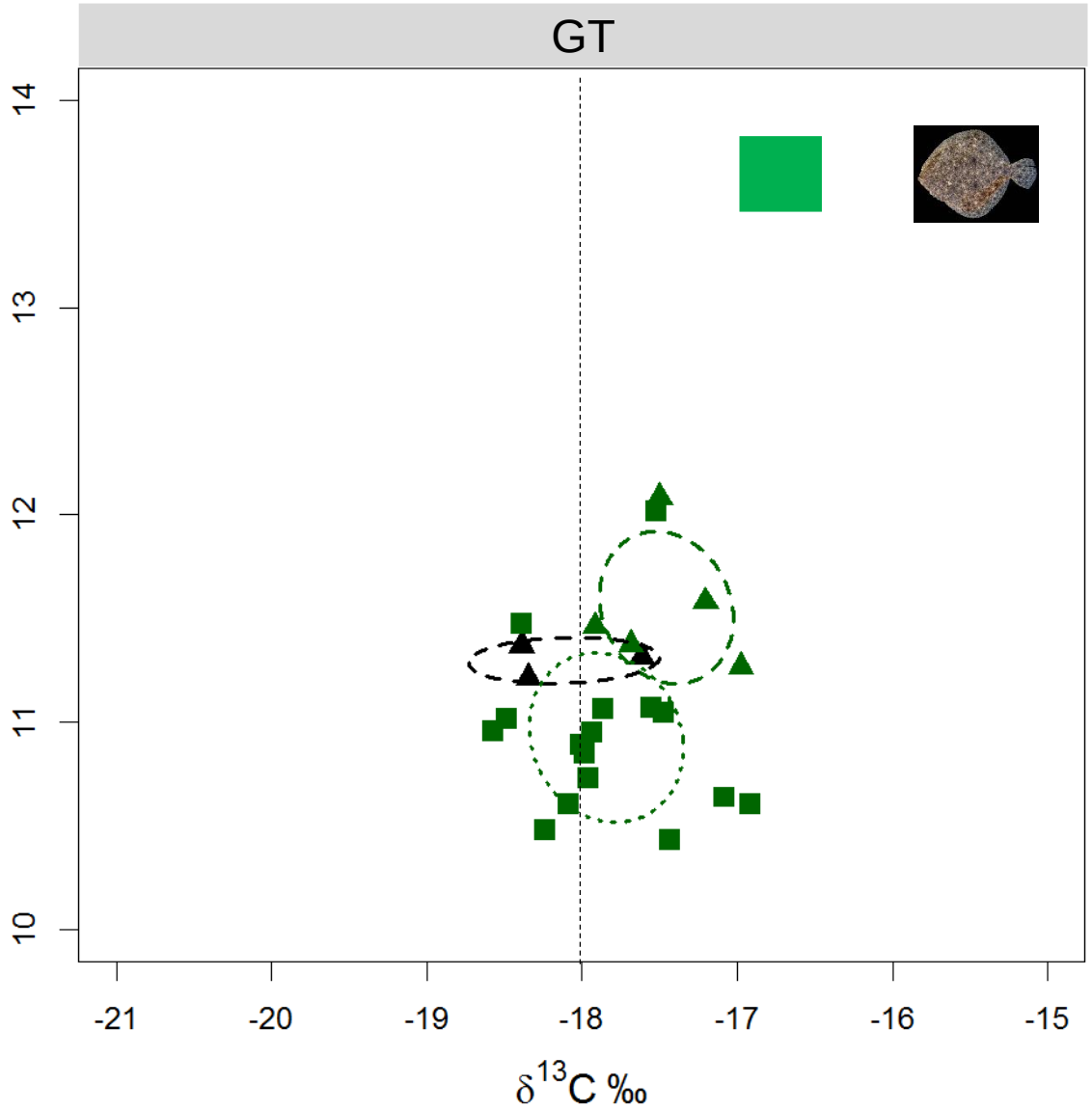
Significant effect of site (p = 0.007) on $\delta^{13}C$ (GT site > No GT site)

GT effect on turbot

GT peak

Weakest integration of the GT isotopic signal

Consumption of subtidal preys ?



GT effect on turbot

less specialized feeding strategy and selective feeding behavior

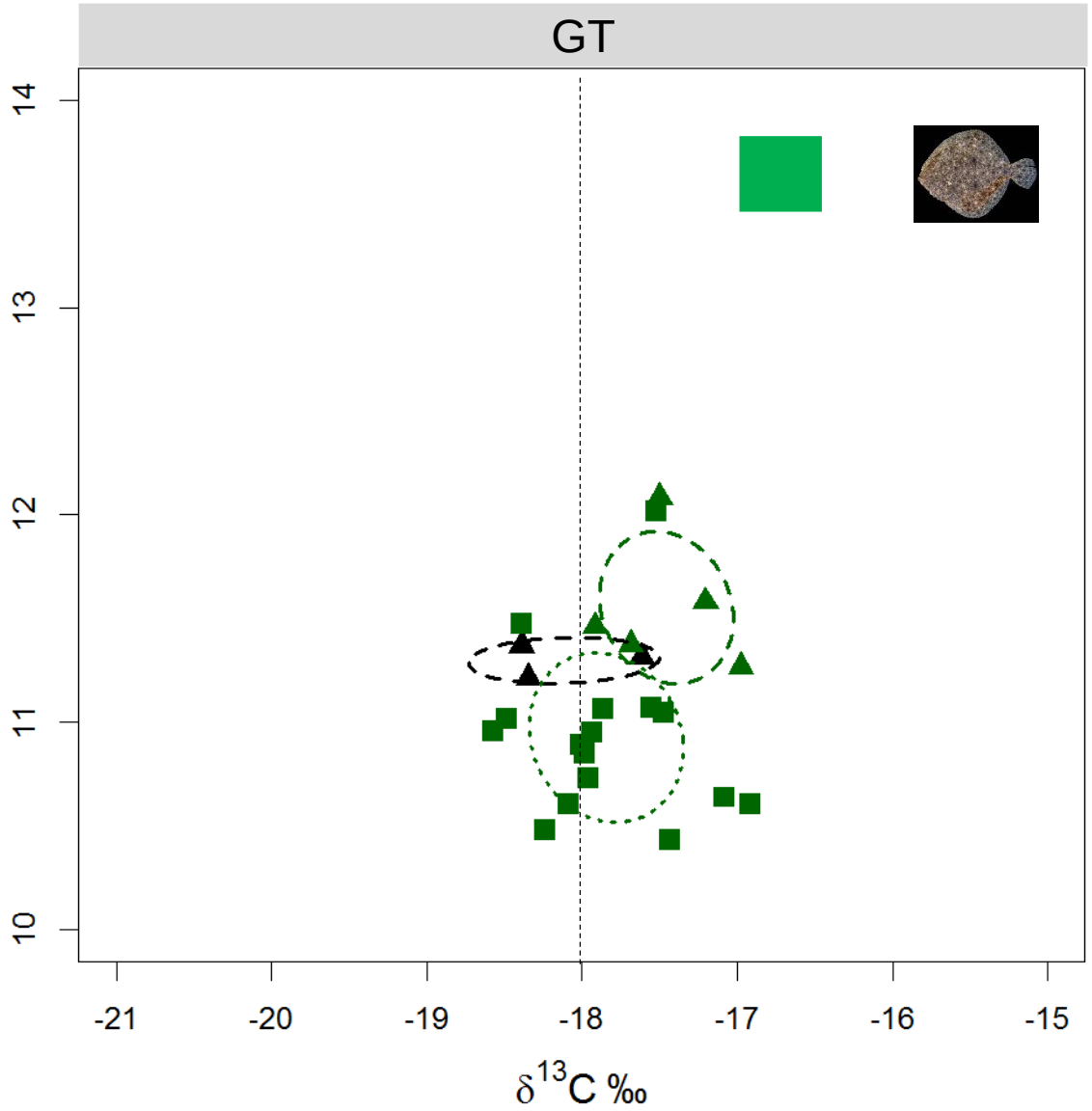
Weakest integration of the GT isotopic signal

Consumption of subtidal preys ?

Trophic plasticity

Less dietary resilience than sand sole

Just after the GT peak (July)



Conclusion

Pre GT

Residual 2011 GT signal via prey (autumn post GT signal, Quillien et al., 2016)

Conclusion

Pre GT → GT peak

More opportunistic feeding behavior
(Andersen et al., 2005; Pihl et al., 1992)

Conclusion

Pre GT → GT peak

More opportunistic feeding behavior (Andersen et al., 2005; Pihl et al., 1992)

Why ?

✓ Hypoxic conditions (Quillien, pers. obs.)

Conclusion

Pre GT → GT peak

More opportunistic feeding behavior (Andersen et al., 2005; Pihl et al., 1992)

Why ?

✓ Hypoxic conditions (Quillien, pers. obs.) ⟹ Reduction in locomotory activity (Dalla Via et al., 1998)

Tolerance to moderate hypoxia

O_2 30-100%

Conclusion

Pre GT → GT peak

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(Andersen et al., 2005; Pihl et al., 1992)

Why ?

✓ Hypoxic conditions (Quillien, pers. obs.) ⟹ **Tolerance to moderate hypoxia**

Reduction in locomotory activity
(Dalla Via et al., 1998)

O_2 30-100%

Reduction of activity and resting levels
(Dalla Via et al., 1998; van den Thilliart et al., 1994)

O_2 40 - 20%

Conclusion

Pre GT | GT peak

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Reduction in foraging time

Conclusion

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- Reduction of activity and resting levels (Dalla Via et al., 1998; van den Thilliart et al., 1994) — O_2 40 - 20%

✓ Chemical compound release (Harder et al., 2004)

⇓

Lower foraging success
(De Groot, 1971)

Reduction in foraging time

Conclusion

Pre GT → GT peak

More opportunistic feeding behavior (Andersen et al., 2005; Pihl et al., 1992)

+

Resistance to moderate *Ulva* bloom (site fidelity) and trophic plasticity

Why ?

Tolerance to moderate hypoxia

✓ Hypoxic conditions (Quillien, pers. obs.) ⇒ Reduction in locomotory activity (Dalla Via et al., 1998) — O_2 30-100%

✓ Chemical compound release (Harder et al., 2004) ⇒ Reduction of activity and resting levels (Dalla Via et al., 1998; van den Thilliart et al., 1994) — O_2 40 - 20%

⇓

Lower foraging success (De Groot, 1971)

Reduction in foraging time

Conclusion

Pre GT → GT peak → Post GT1 → Post GT2

High site fidelity during
and after the *Ulva* bloom

+

Dietary resilience

Conclusion

- ✓ Some resistance to moderate GT (site fidelity, Le Luherne et al., 2017) but also forages in subtidal zone = hypoxia avoidance ?
- ✓ Trophic plasticity with a more opportunistic feeding behavior (Andersen et al., 2005; Pihl et al., 1992) and more generalist feeding strategy
- ✓ More affected by GT in their foraging success because mainly visual feeder (De Groot, 1971)
- ✓ Displays less dietary resilience than the sand sole

Conclusion

- ✓ Some resistance to moderate GT (site fidelity, Le Luherne et al., 2017) but also forages in subtidal zone = hypoxia avoidance ?
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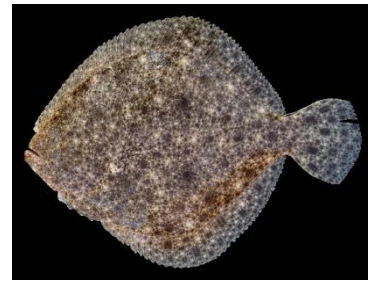
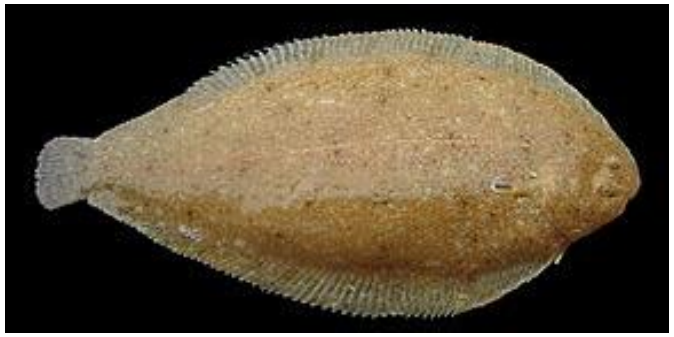
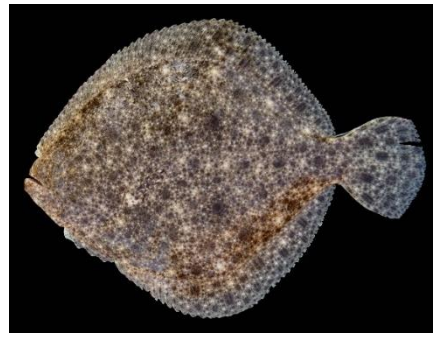


- ✓ Low site fidelity: forages in subtidal zone = hypoxia avoidance ?
- ✓ Trophic plasticity with a more opportunistic feeding behavior (Andersen et al., 2005; Pihl et al., 1992) and more generalist feeding strategy
- ✓ Most affected by GT in their foraging success (Nordström and Booth, 2007) because visual feeder (De Groot, 1971)
- ✓ Two-phase response to *Ulva* blooms linked to oxygen concentrations: 70-100% air saturation dietary switch than reduction feeding time and/or move to deeper waters (Pichavant et al., 2000)

Conclusion





Tolerance to moderate *Ulva* blooms

Species-specific behavioral response modulated by foraging behavior, sensory abilities and physiological tolerance to hypoxia

(1) Perspectives

Moderate Ulva blooms are linked to behavioral changes leading to

- ✓ Higher energy expenses (foraging, non-tidal swimming)
- ✓ Lower energy intake during Ulva bloom (Brey et al., 2012)
- ✓ Higher predation risks (avoidance and mortality)

⇨

?

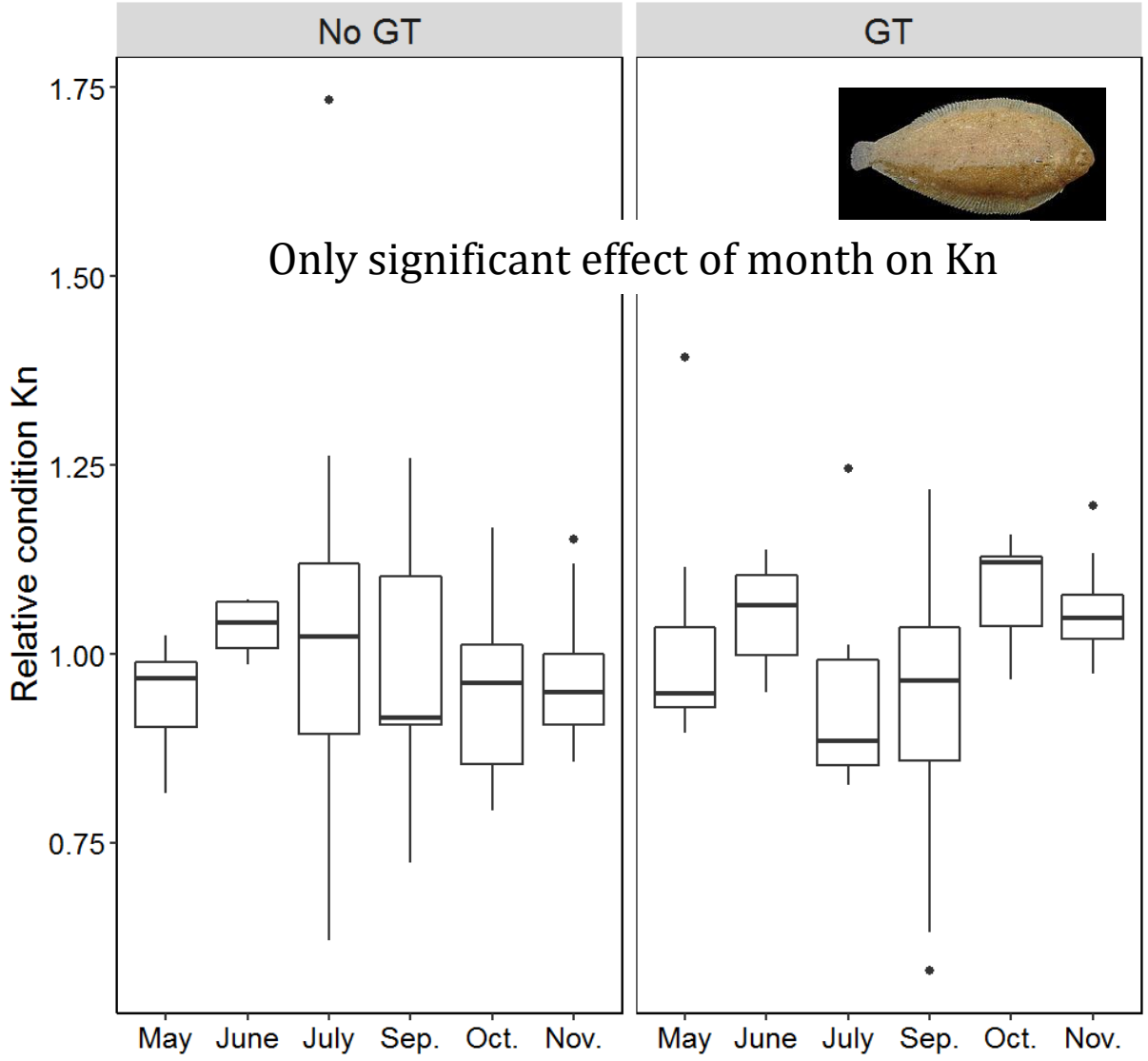
Detrimental consequences on juvenile growth rates (Le Luherne et al., 2017) and **body condition (which index ?)**

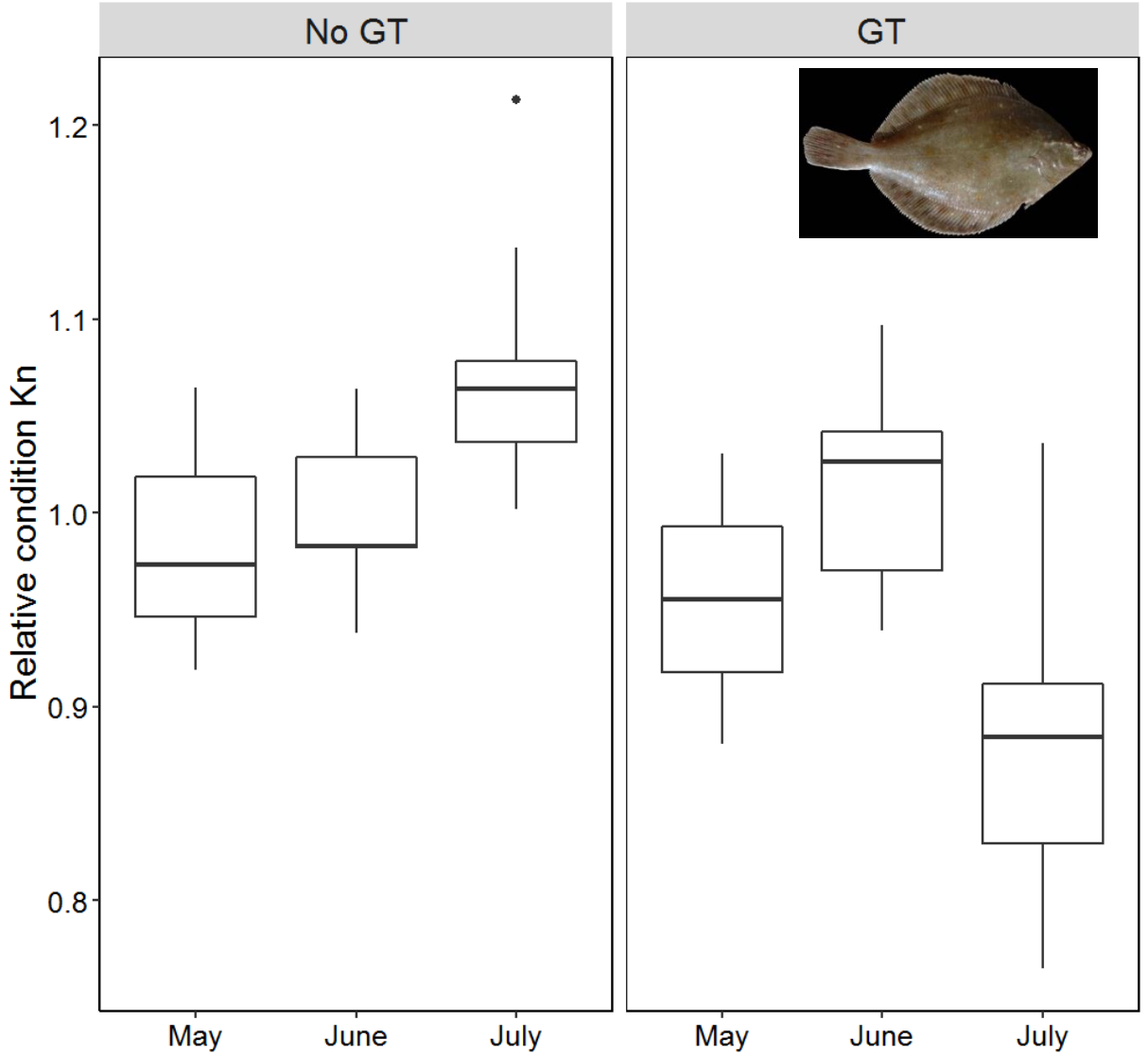
+

Lower abundances (displacement) (Le Luherne et al., 2016; Quillien et al., 2018)

(1) Perspectives: relative condition index Kn

Significant effect of site and month*site





(1) Perspectives: densities (intertidal zone 2012)

Significant effect of the site, sampling period and site * sampling period

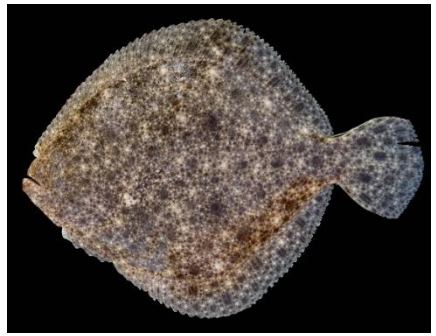
GT density < No GT density

Dominant species (relative abundance) both sites (78%)

Significant effect of the sampling period

GT density = No GT density

Very low relative abundance (2 to 7%)



Significant effect of the site, sampling period and site * sampling period

GT density < No GT density

Intermediate relative abundance (15-20%)

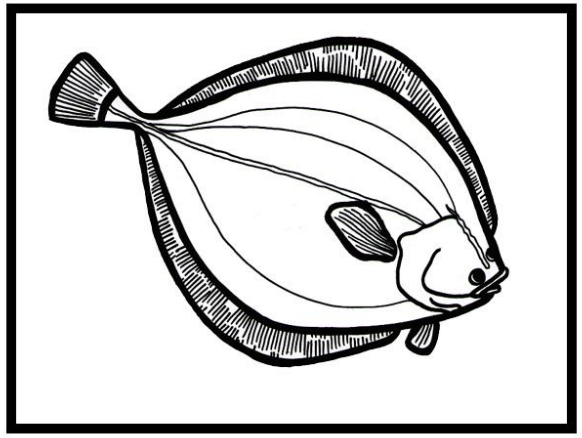
(2) Perspectives

Green tides

Hypoxic conditions (Cloern, 2001)
Chemical compound release
(Harder et al., 2004)

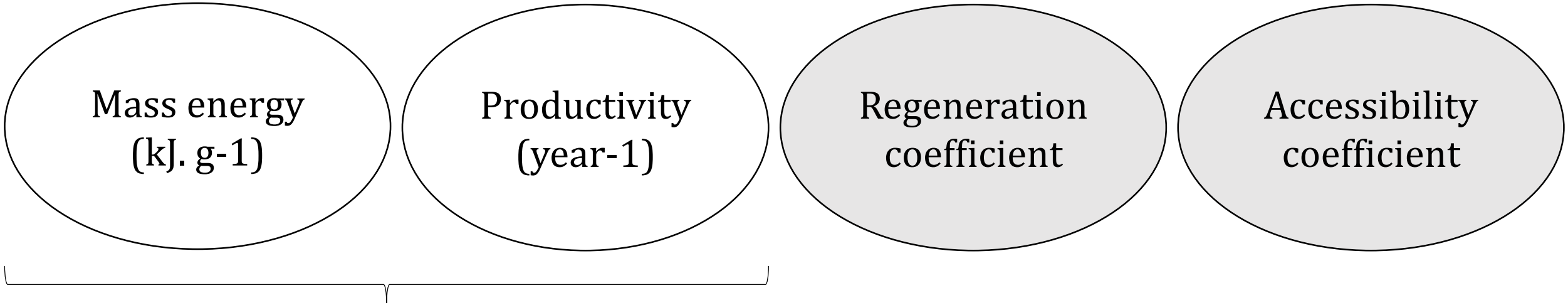
Changes in the « value » of the available prey community for predators = profitability ?

Available benthic energy coefficient (ABEC)
(Tableau et al., 2016)



? the value of impacted communities as foraging grounds for benthic predators are lower than reference communities ?

(2) Perspectives: ABEC

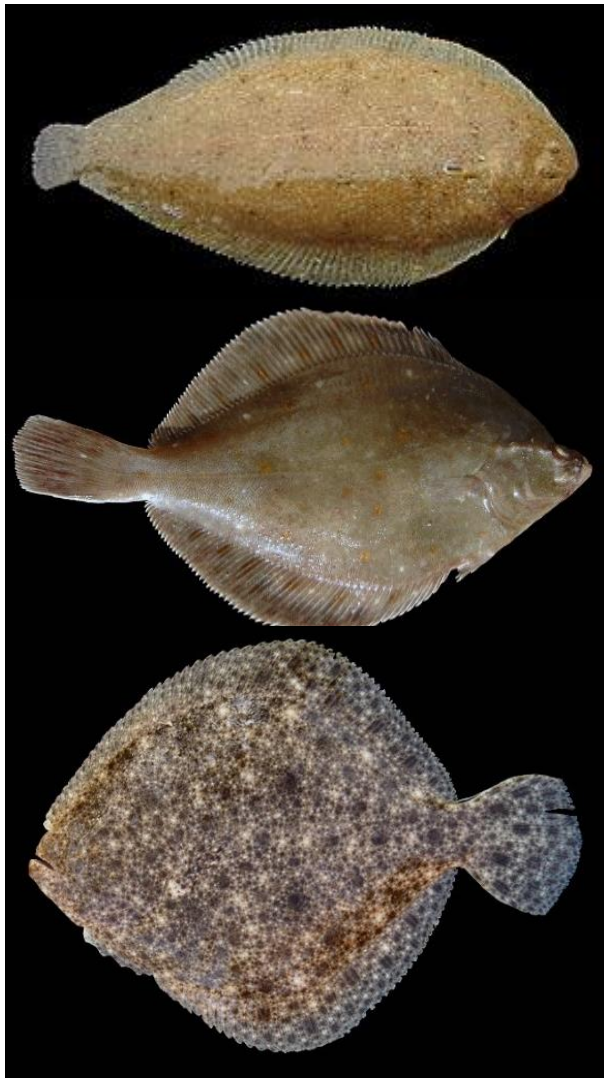


Mean annual biomass x energetic conversion factor (Brey et al., 2010) x estimated productivity (Brey et al., 2012)

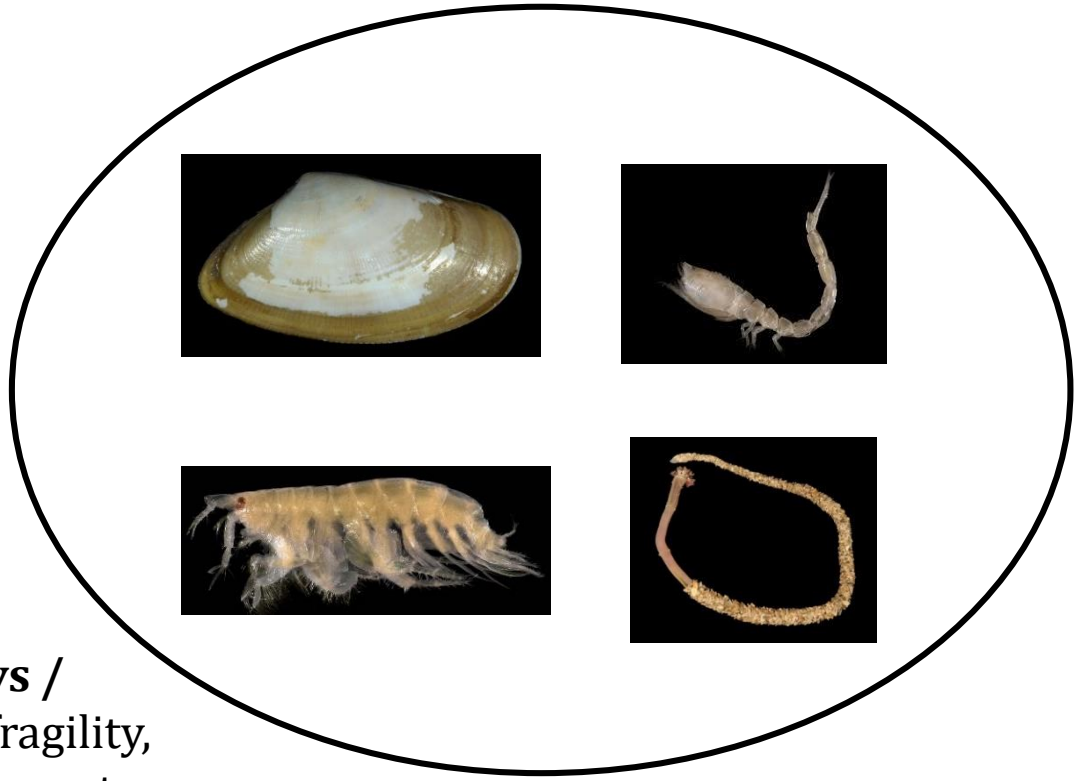
Very hard to estimated (very few studies) → not considered but it « just » underestimates the proditability

Initially estimated using 2 values (low = 0.1 and high = 1)

(2) Perspectives: ABEC and accessibility coefficient

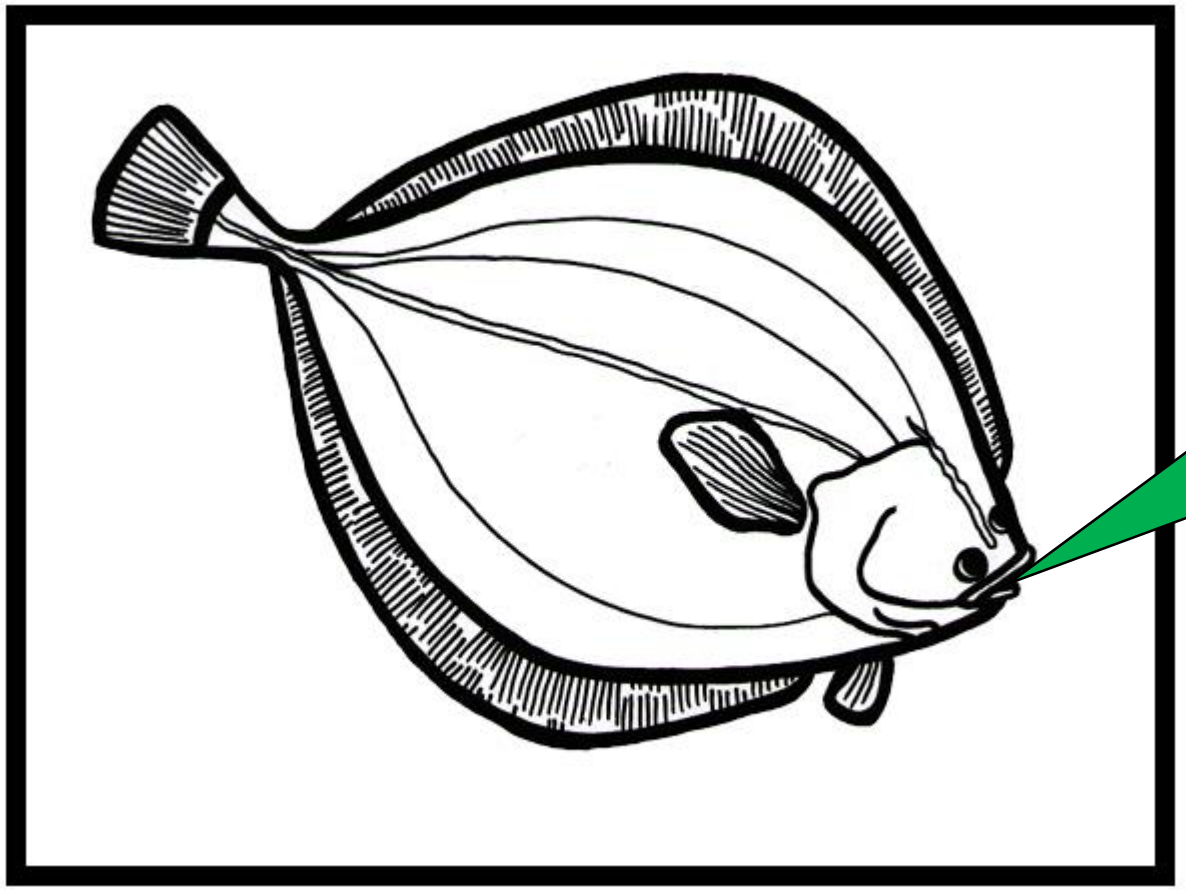


Predator-prey relations



Biological traits of preys / predators: size, protection, fragility, position / sediment, mouvement

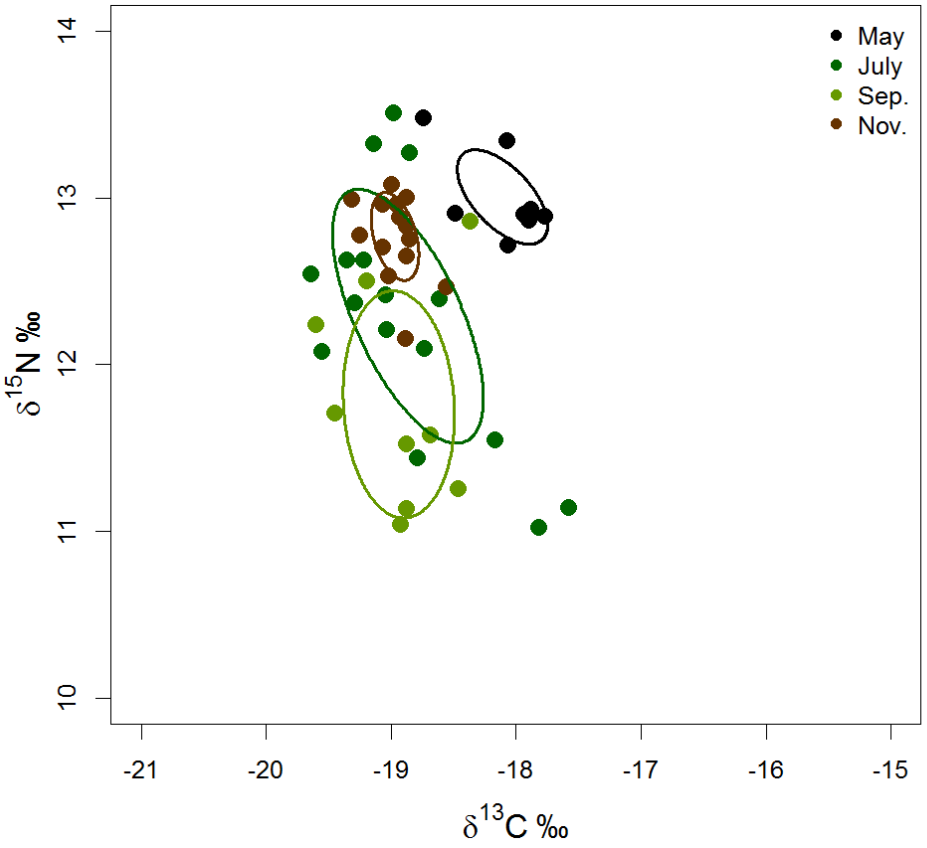
Biological traits of predators / preys:
Mouth size, sensory abilities…



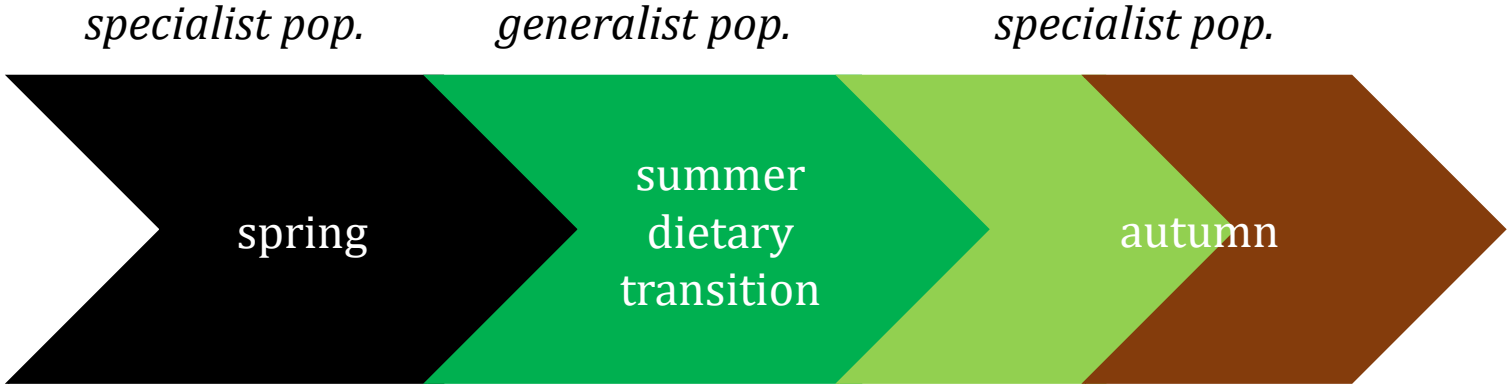
Thanks for your attention !

Questions ?

Seasonal changes in the trophic ecology of juvenile *P. lascaris*

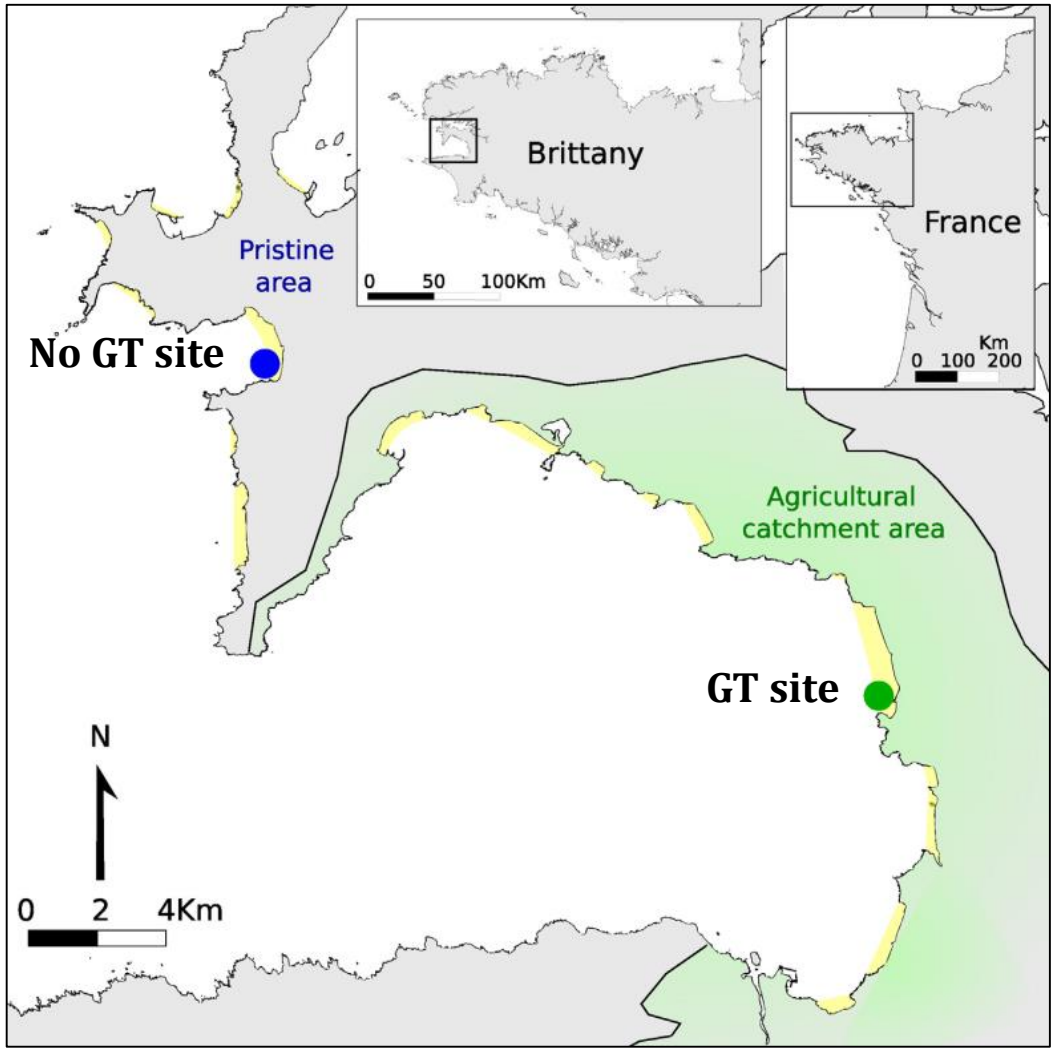


- ✓ Specialized feeding strategy and selective feeding behavior
- ✓ Diet similar to the litterature (Cabral et al., 2002; Quiniou, 1986; Rodriguez, 1986) = bivalves, small crustaceans and polychaetes



Quillien et al., 2015; Yeakel et al., 2016

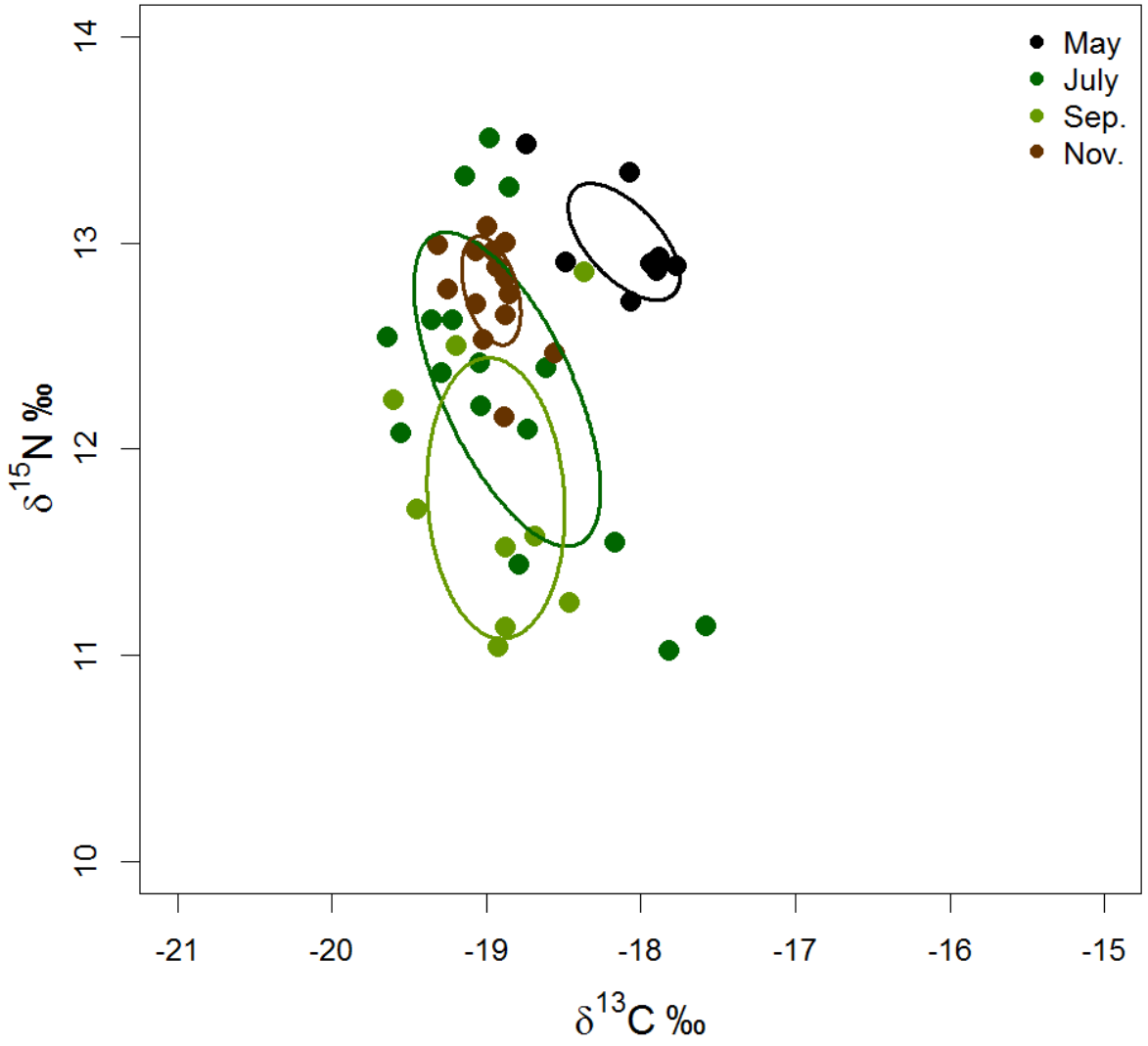
(1) Sampling (2012)



- **Macroinvertebrates** (>1mm) sampled between April and December = **potential prey of *P. lascaris***
- ***P. lascaris*** sampled during the day at rising tide (beach trawl)
- **Sources of organic matter**: POM = particulate organic matter, SOM = sedimented organic matter + *Ulva*

Quillien et al., 2016; Quillien et al., 2015; Quillien et al., 2018

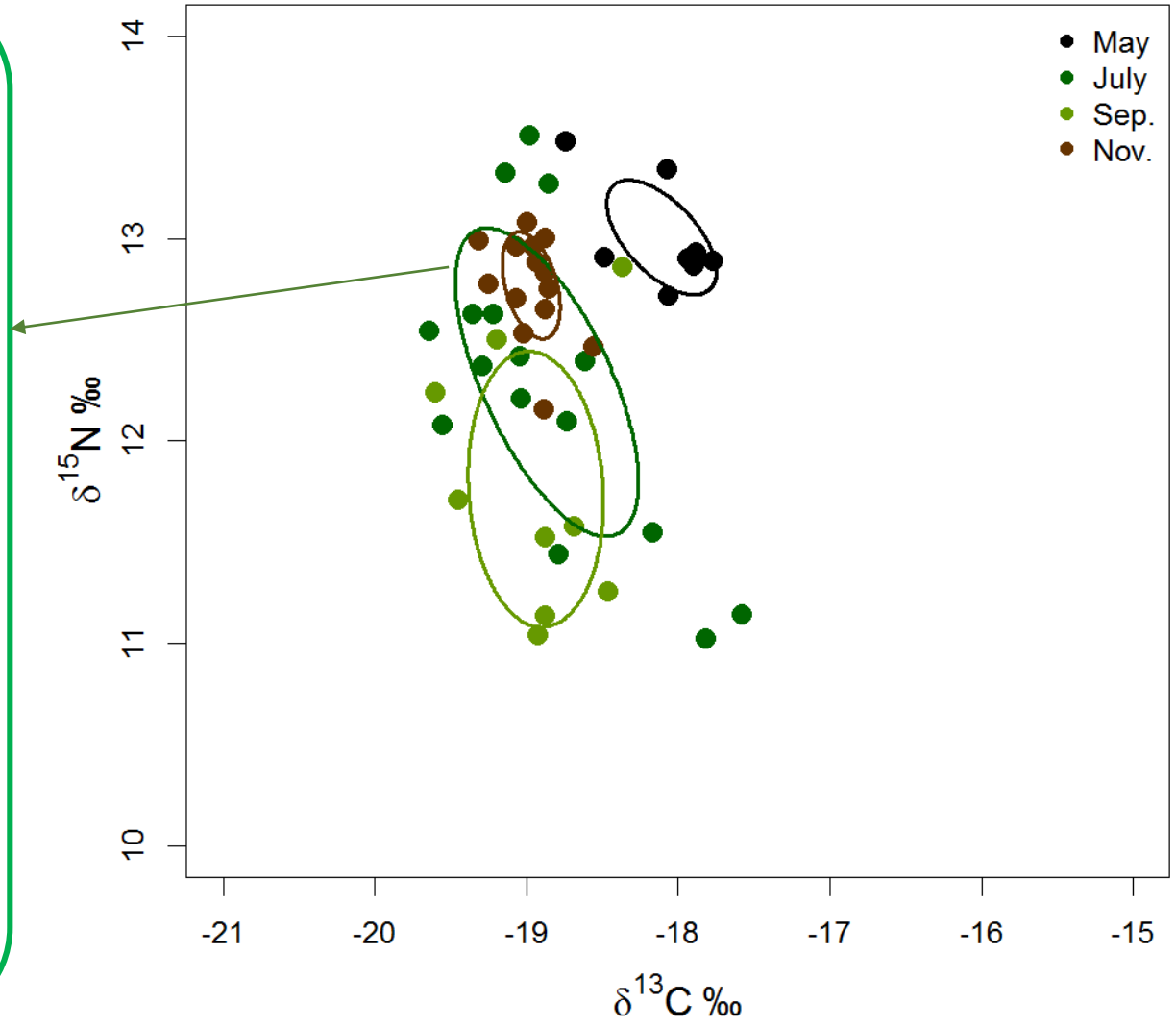
Seasonal variations of the isotopic niche



Jackson et al., 2011

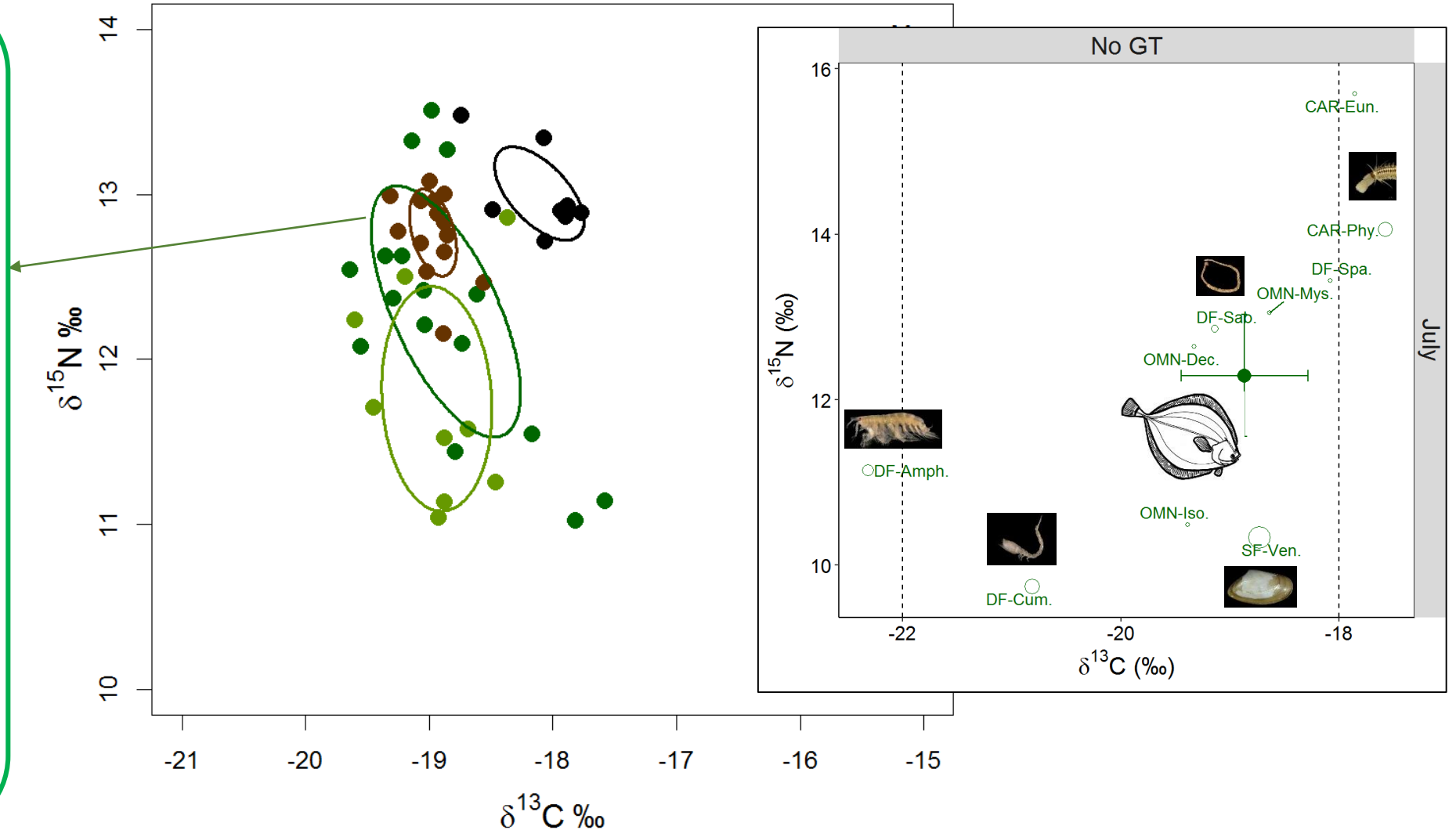
Summer trophic ecology

specialized feeding strategy and selective feeding behavior



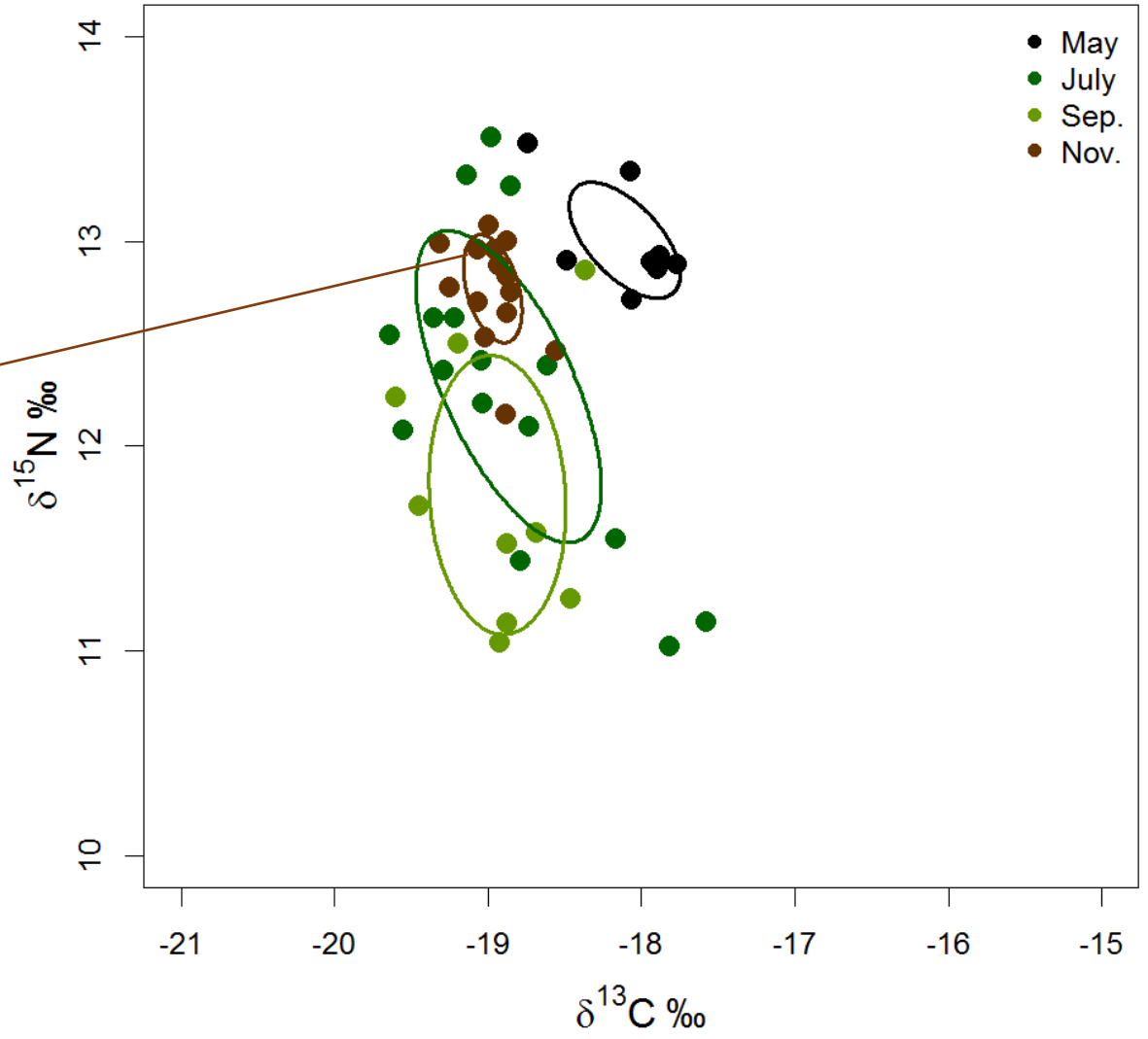
Summer trophic ecology

specialized feeding strategy and selective feeding behavior



Autumn trophic ecology

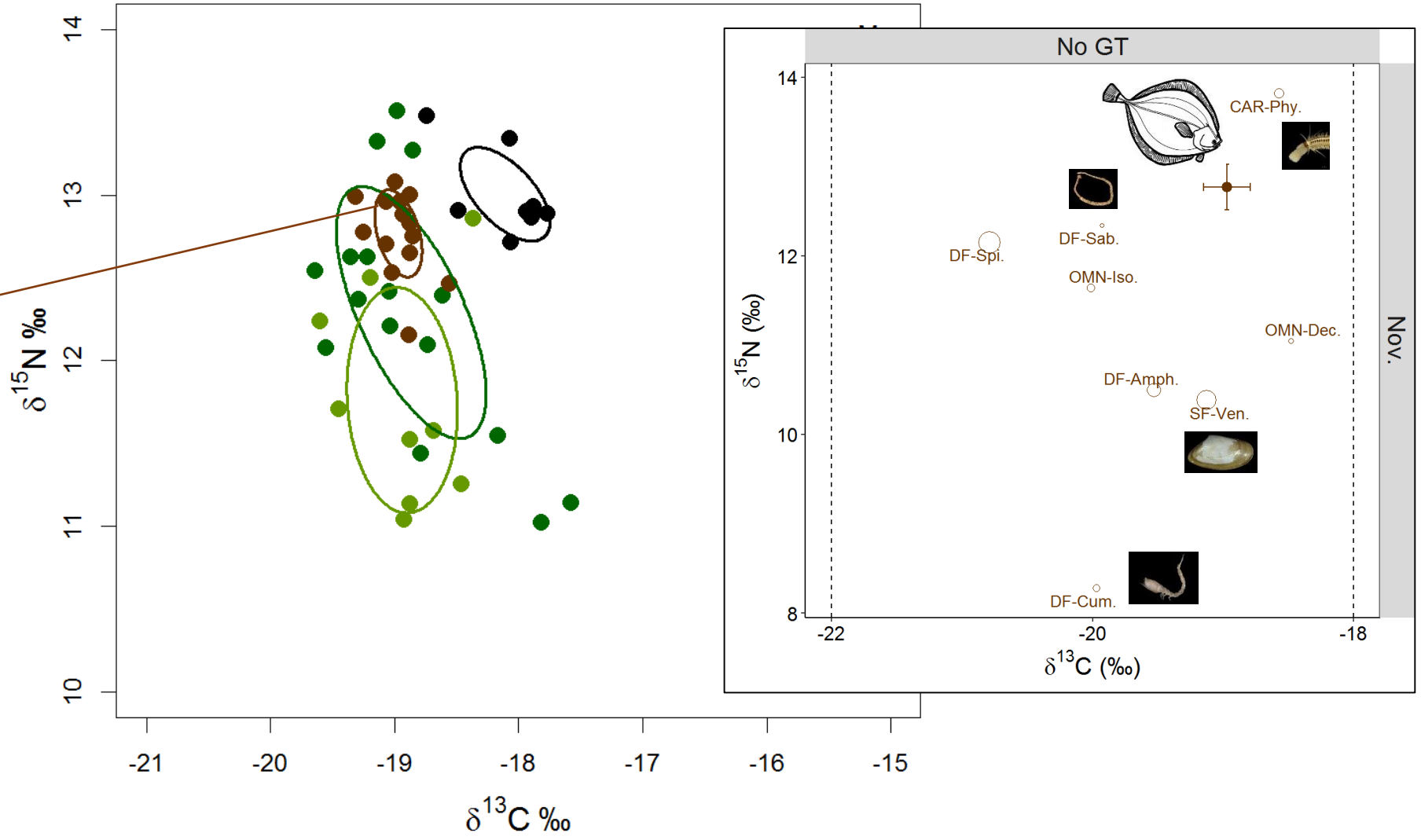
specialized feeding strategy and selective feeding behavior



Autumn trophic ecology

specialized feeding strategy and selective feeding behavior

high prey diversity (9/14 tropho-orders) and high $\delta^{15}N$



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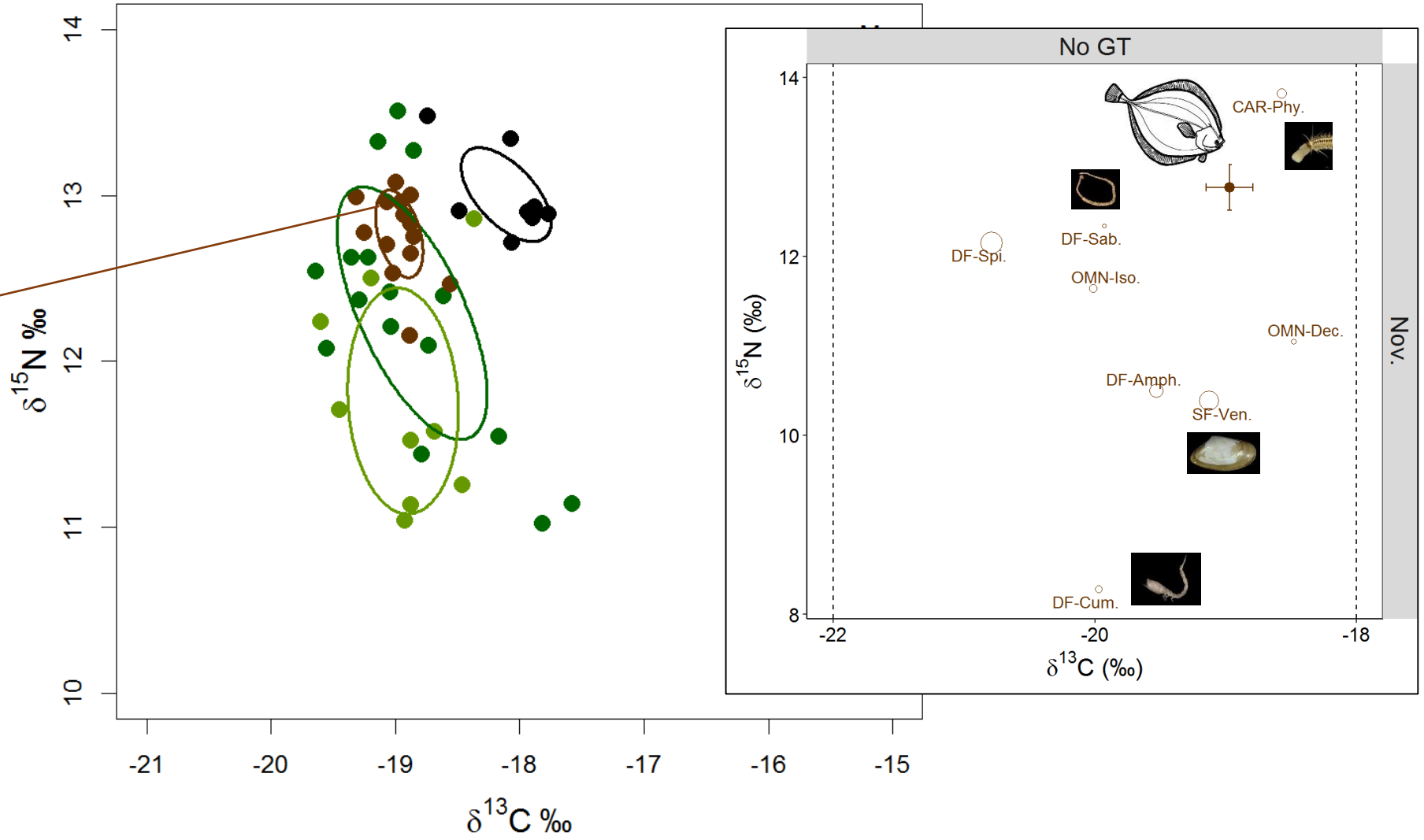
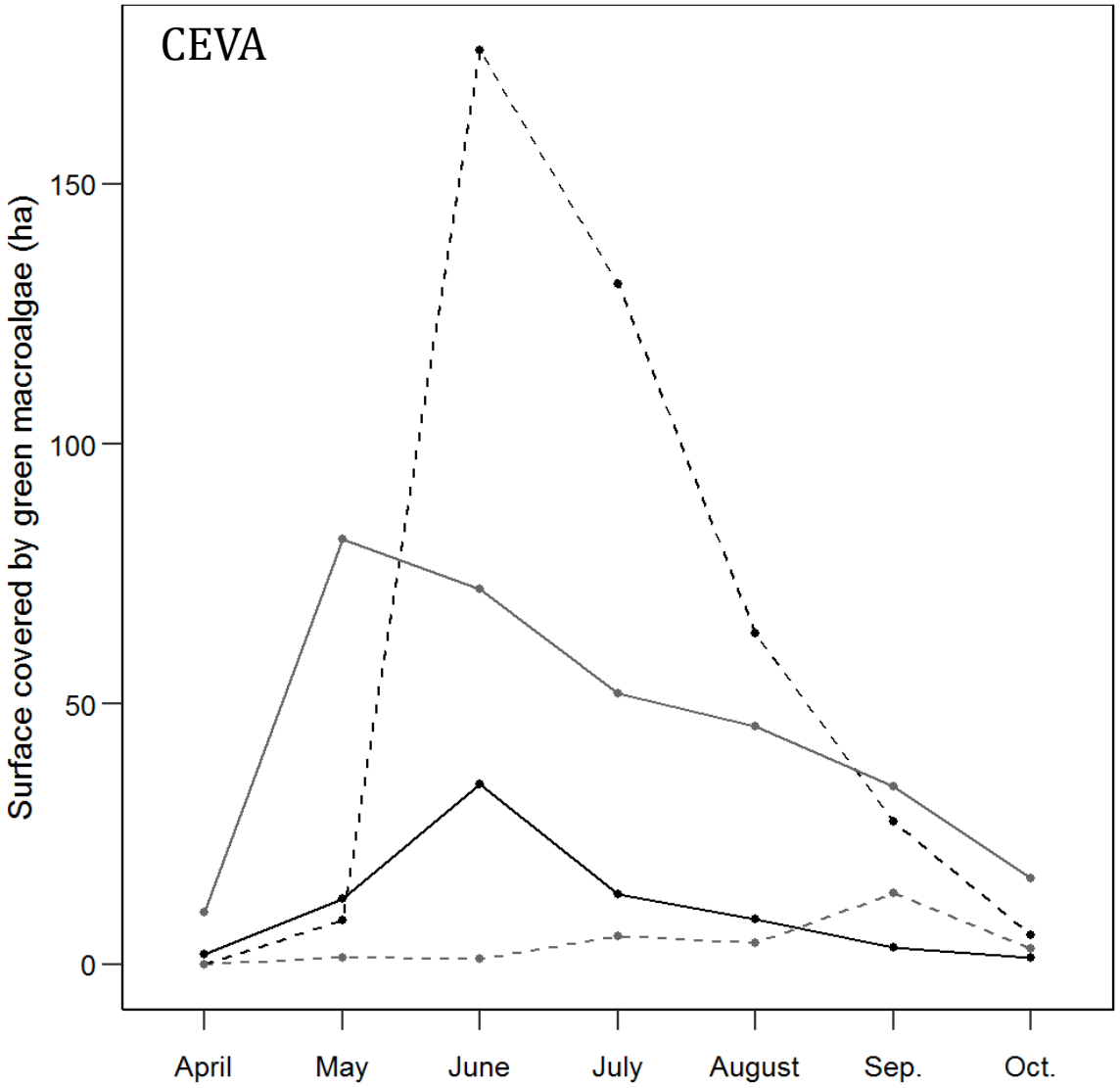


Green tides in Brittany and over time at our impacted site (2012)



Beaches: a widespread and harsh ecosystem…

REFLECTIVE

narrow and steep

Defeo and McLachlan, 2005;
McLachlan and Brown, 2006

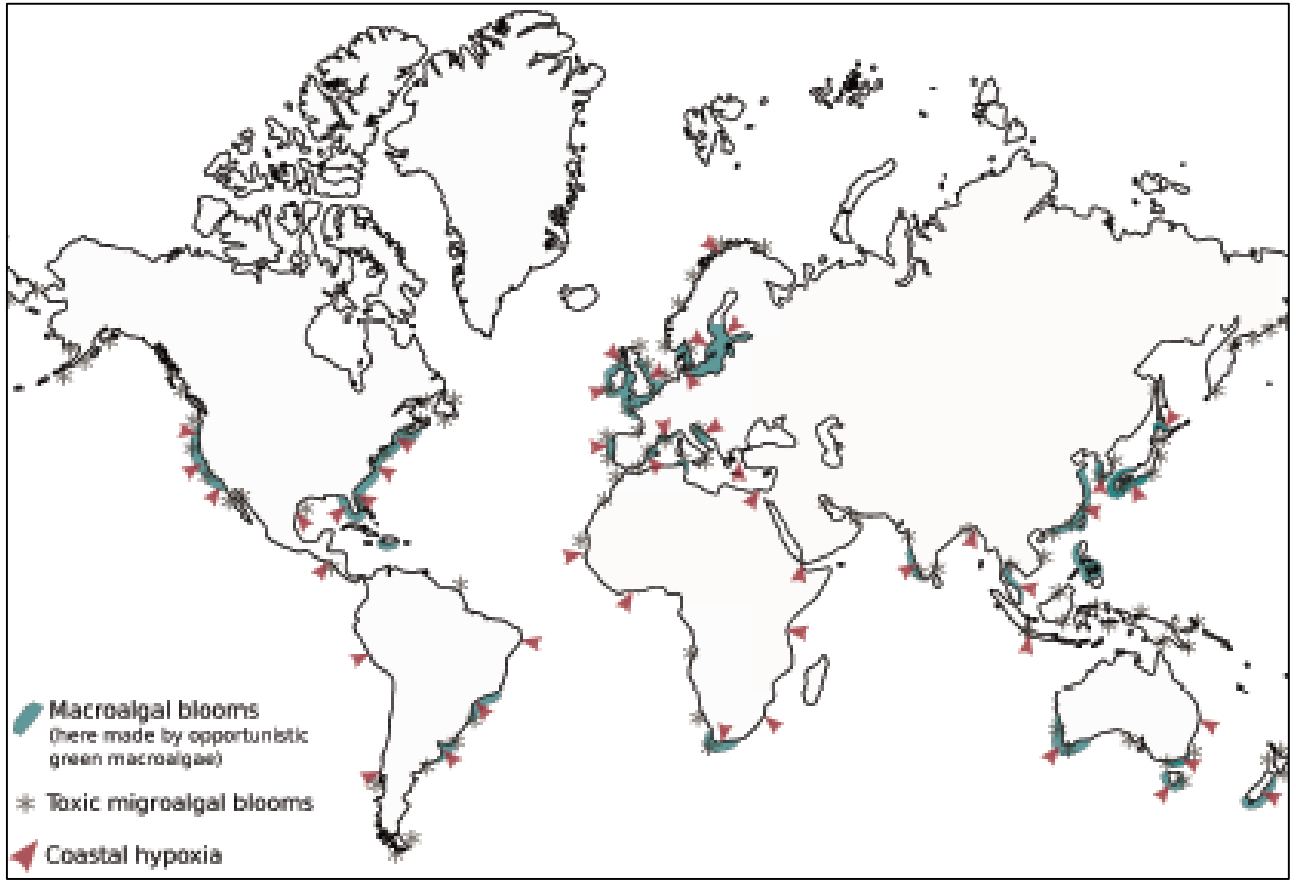
INTERMEDIATE

most dynamic and changeable with the seasons with a medium slope

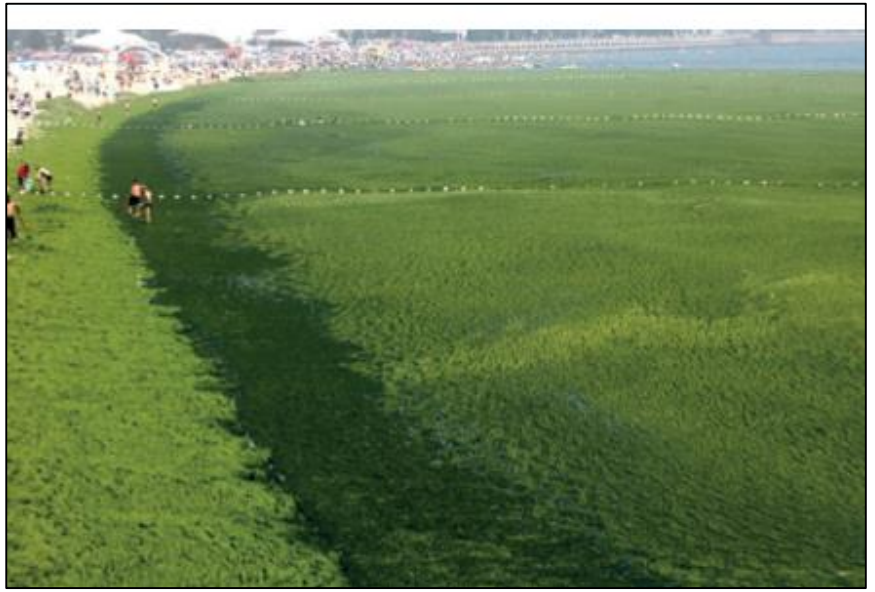
wide and flat

DISSIPATIVE

...such as eutrophication and green tides...



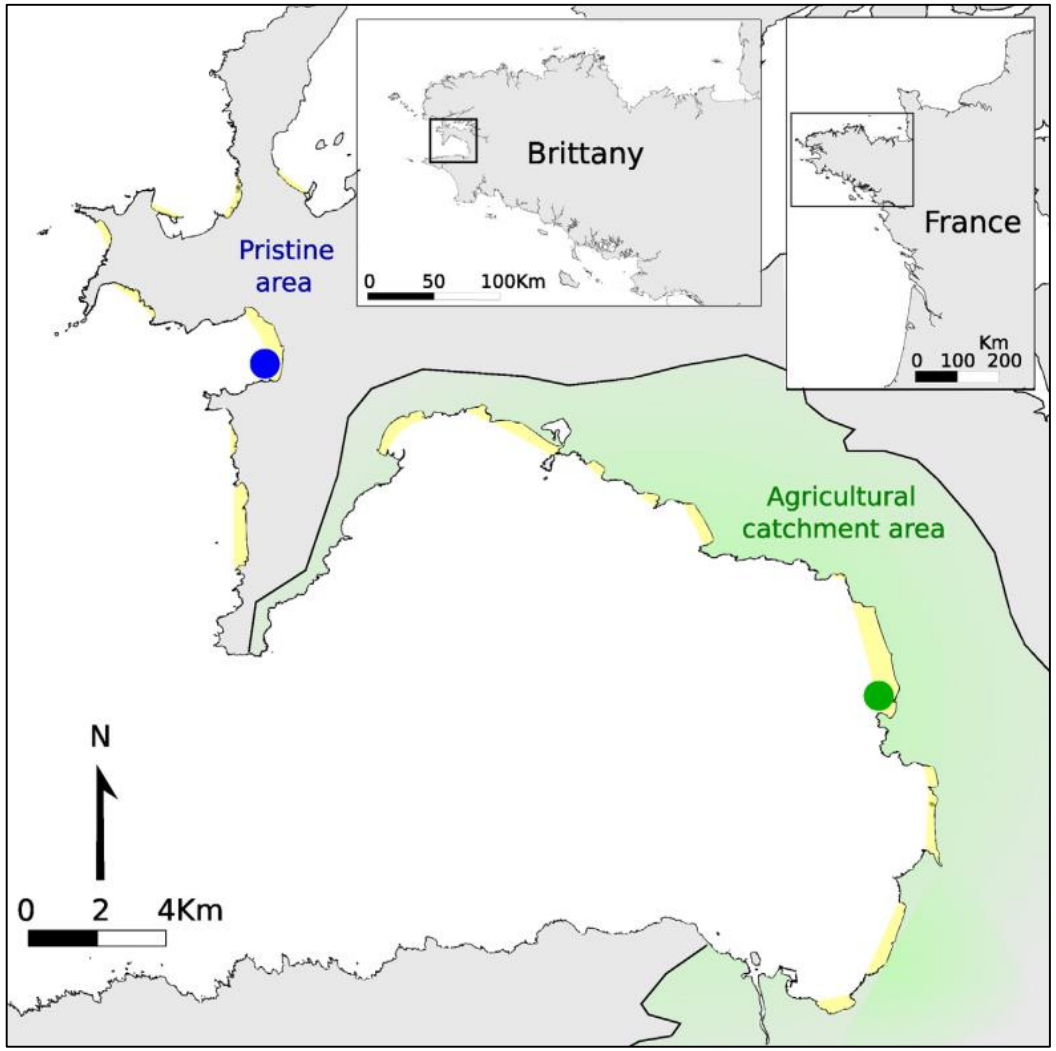
Quillien, 2016



Smetacek & Zigone, 2013, Nature

Charlier et al., 2008; Defeo et al., 2009; Ye et al., 2011

...in the case of juveniles at macrotidal and exposed sandy beaches ?



Quillien et al., 2016

1

What is the trophic ecology of the sand sole *Pegusa lascaris* in its juvenile stage at a reference macrotidal nursery site ?

2

Is the trophic ecology of juveniles *P. lascaris* modified at a macrotidal nursery site historically impacted by GT and if so, how ?