Increased sea ice cover disrupts food web structure in Antarctic coastal benthic ecosystem

Loïc N. MICHEL, Bruno DANIS, Philippe DUBOIS, Marc ELEAUME, Jérôme FOURNIER, Cyril GALLUT, Philip JANE & Gilles LEPOINT

Contact: loicnmichel@gmail.com

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Sea ice is a **major environmental driver** of ecological processes in Antarctica

- Water column mixing
- Benthic-pelagic coupling
- Niche partitioning
- Benthic community structure
- ...

Image: NASA
Sea ice in Antarctica

Sea ice is a **major environmental driver** of ecological processes in Antarctica

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Sea ice is a **highly dynamic** system
Seasonal patterns of sea ice cover

Normal cycle:

**Austral winter**
Thick sea ice cover

**Austral summer**
Thinning and breakup of sea ice

Source: NOAA
Changes in Antarctic sea ice cover

Climate change causes contrasted changes in sea ice cover in Antarctica

**Spatial extent**

Changes in sea ice concentration

From King (2014), Nature 505: 491-492.
(Data 1979-2012)
Changes in Antarctic sea ice cover

Climate change causes contrasted changes in sea ice cover in Antarctica

**Spatial extent**
Changes in sea ice concentration

**Temporal extent**
Changes in sea ice season duration

From King (2014), Nature 505: 491-492.
(Data 1979-2012)

From Massom & Stammerjohn (2010), Pol. Sci. 4: 149-186
(Data 1979-2004)
Study site: Dumont d’Urville station

East Antarctica, Adélie Land
Petrels Island

Austral summer 2007-08
Study site: Dumont d’Urville station

East Antarctica, Adélie Land
Petrels Island

2013-2015: Event of high spatial and temporal sea ice coverage

No seasonal breakup during austral summers 2013-14 and 2014-15
Study site: Dumont d’Urville station

Time of sampling: Austral summer 2014-15

This is the sea
(Please trust me)
How will **benthic communities** respond to sudden **changes in sea ice cover**?

How could increased sea ice cover **impact** structure of **benthic food webs**?
Food web structure in marine ecosystems

Phytoplankton
Benthic biofilm + detritus
Sea ice algae
Food web structure in marine ecosystems

Resources supporting the consumers

- Phytoplankton
- Benthic biofilm + detritus
- Sea ice algae

Horizontal dimension
Food web structure in marine ecosystems

- Trophic position of the consumers:
  - Phytoplankton
  - Benthic biofilm + detritus
  - Sea ice algae

- Resources supporting the consumers:
  - Phytoplankton
  - Benthic biofilm + detritus
  - Sea ice algae

- Horizontal dimension
- Vertical dimension
Food web structure in marine ecosystems

Horizontal dimension

Vertical dimension

Here: models based on trophic markers (stable isotope ratios) were used to as proxies of both food webs dimensions

**Horizontal** dimension: use of a **mixing model** (SIAR) to identify main food items of consumers

**Vertical** dimension: use of a **trophic position model** (tRrophicPosition)

Phytoplankton

Benthic biofilm + detritus

Sea ice algae

Resources supporting the consumers
Sampling: under ice SCUBA diving
Sampling: food items

1. Sympagic algae

2. Suspended particulate organic matter (SPOM)
Sampling: food items

3. Benthic brown algae
*Himantothallus grandifolius*
4. Benthic biofilm
(heterogeneous mix of microalgae, bacteria, amorphous material and detrital items)
Some sampled consumers

Adamussium colbecki

Harmothoe sp.

Perkinsiana sp.

Flabelligera mundata

Adamussium colbecki

Marseniopsis sp.

Ammothea carolinensis

Heterocumis sp.

Stereichinus neumayeri

Odontaster validus

Hemigellius sp.
Some sampled consumers

In total: **28 taxa** (9 phyla, all present functional guilds)
Material & methods: analysis

University of Liège’s setup:
Vario MICRO cube EA coupled to an Isoprime 100 IRMS
High reliance of many **benthic invertebrates** on **sympagic material** exported to the seafloor

**Main food item** of 8 out of 14 primary consumers / omnivores (up to 80% of diet)

Why is it preferred by many consumers over more abundant food items such as biofilm?

Better **nutritional value**? Unlikely...

Better **palatability**? Pure aggregates of microalgae...
Preliminary microscopic examination:
Benthic biofilm = heterogeneous mix of microalgae, bacteria, amorphous material and detrital items
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*Benthic biofilm* = heterogeneous mix of *microalgae*, *bacteria*, *amorphous material* and *detrital items*

Yannick **LARA** – Poster nr. 28
Session 1.2 (Tuesday)
Preliminary microscopic examination:
*Benthic biofilm = heterogeneous mix of microalgae, bacteria, amorphous material and detrital items*

Here: *importance* of benthic biofilm in food web comparatively *limited* despite *high abundance*
Role of benthic biofilm in the food web

Preliminary microscopic examination: Benthic biofilm = heterogeneous mix of microalgae, bacteria, amorphous material and detrital items

Here: importance of benthic biofilm in food web comparatively limited despite high abundance

Ross Sea: Benthic invertebrates consume more detritic matter in sea-ice influenced locations

(Norkko et al. (2007), Ecology 88: 2810-2820)
Preliminary microscopic examination:
**Benthic biofilm = heterogeneous** mix of microalgae, bacteria, amorphous material and detrital items

Here: **importance** of benthic biofilm in food web comparatively **limited** despite **high abundance**

**Ross Sea**: Benthic invertebrates consume **more detritic matter** in sea-ice influenced locations

(Norkko et al. (2007), Ecology 88: 2810-2820)

**Important variation** in benthic ecosystem **response** to sea ice: sudden changes vs. stable conditions?

However: no data about **dynamics** of biofilm accumulation!

Here: long-lived benthic invertebrates with low metabolic rates ➔ **low isotopic turnover**? Is **isotopic equilibrium** reached?

Our model could **underestimate** actual **biofilm importance** for invertebrate feeding
Trophic position modelling

Overall: low trophic positions compared to literature
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Dominant omnivore taxa: very low trophic levels, mostly feeding directly on primary producers.
The food web we expected

Trophic position of the consumers

Resources supporting the consumers

Phytoplankton

Benthic biofilm + detritus

Sea ice algae
Shift in resources supporting consumers

High dependency of benthic invertebrates on sea ice-derived organic matter

Resources supporting the consumers:
- Phytoplankton
- Benthic biofilm + detritus
- Sea ice algae
Shift in resources supporting consumers

- High dependency of benthic invertebrates on sea ice-derived organic matter

Influence on interspecific ecological interactions (e.g. competition) and community structure?
Shift in trophic position of consumers

Trophic positions of many consumers lower than in other studies

Trophic position of the consumers

Resources supporting the consumers

Phytoplankton

Benthic biofilm + detritus

Sea ice algae
Shift in trophic position of consumers

Trophic positions of many consumers **lower** than in other studies

Influence on **energy flow** and **secondary production** by key omnivore taxa?

Resources supporting the consumers

- Phytoplankton
- Benthic biofilm + detritus
- Sea ice algae
Increase of sea ice cover strongly influences the benthic food web by modifying both its horizontal and its vertical structure.
Important sea ice cover is linked with high reliance of coastal benthic invertebrates on sympagic algae.
Take home message

- Important sea ice cover is linked with high reliance of coastal benthic invertebrates on sympagic algae.

- Resource use and trophic levels of Adélie Land consumers markedly differed from results obtained in other locations. High trophic plasticity of Antarctic invertebrates? Sudden changes vs. stable conditions?
Take home message

- Important sea ice cover is linked with **high reliance** of coastal benthic invertebrates on **sympagic algae**

- **Resource use** and **trophic levels** of Adélie Land consumers markedly **differed** from results obtained in **other locations**. High **trophic plasticity** of Antarctic invertebrates? Sudden **changes vs. stable** conditions?

- Interpretation of results is **complicated** by **lack** of **background data** ("normal" conditions) and by **physiological features** of studied organisms
**Take home message**

- Important sea ice cover is linked with **high reliance** of coastal benthic invertebrates on **sympagic algae**.

- **Resource use and trophic levels** of Adélie Land consumers markedly **differed** from results obtained in **other locations**. High **trophic plasticity** of Antarctic invertebrates? Sudden **changes vs. stable conditions**?

- Interpretation of results is **complicated** by **lack of background data** ("normal" conditions) and by **physiological features** of studied organisms.

Despite being interpreted as a positive signal by mainstream media, **local or large-scale trends of sea ice increase** in **Antarctica** could actually have strong **impacts on benthic ecosystems**.
Funding

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**French Polar Institute (IPEV)**
Thanks for your attention

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Horizontal dimension: mixing model

**Mixing law:** "You are what you eat"

An *animal*’s stable isotope composition is a **proportional mix** of its *food items*’ stable isotope compositions.
Horizontal dimension: mixing model

Mixing law: "You are what you eat"

An animal’s stable isotope composition is a proportional mix of its food items’ stable isotope compositions.

Analysis of stable isotope composition of consumers and potential food items

Use of SIAR (Stable Isotope Analysis in R) mixing model

Quantitative estimates of contributions of each food item to each consumer diet

Identifications of resources supporting each consumer’s populations
Stable isotopes: you are what you eat

Mixing law: an animal’s stable isotope composition is a proportional mix of its food items’ stable isotope compositions.
Stable isotopes: you are what you eat

Mixing law: an animal’s stable isotope composition is a proportional mix of its food items’ stable isotope compositions

Analysis of stable isotope composition of a consumer and those of its potential food items through mass spectrometry

Estimation of contributions of each item to consumer diet
Stable isotopes: you are what you eat

Real-life ecosystems: many potential food items + natural variability of isotopic compositions

Necessity of complex mathematical tools: mixing models (SIAR – Stable Isotope Analysis in R)
SIAR 4.2 in R 3.2.2

No concentration dependencies

TEFs: $\Delta^{13}C = 0.40 \pm 1.20 \%$; $\Delta^{15}N = 2.30 \pm 1.61 \%$ (mean ± SD; TEFs for aquatic consumers from McCutchan et al. 2003 Oikos 102: 378-390)

$10^6$ iterations

Burn-in size: $10^5$
Results - SIAR modelling

Contribution to consumer diet


Sympagic algae

Suspended Particulate Organic Matter (SPOM)

Benthic algae + Biofilm
Results - SIAR modelling

Contribution to consumer diet

- Sympagic algae
- Suspended Particulate Organic Matter (SPOM)
- Benthic algae + Biofilm

Results - SIAR modelling

Contribution to consumer diet

Sympagic algae

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Results - SIAR modelling

Contribution to consumer diet

Sympagic algae

Suspended Particulate Organic Matter (SPOM)

Benthic algae + Biofilm

The heavy nitrogen stable isotope \(^{15}\text{N}\) follows a predictable stepwise enrichment pattern with increasing trophic level.

- **Primary producers**: TL = 1
- **Primary consumers**: TL = 2
- **Secondary consumers**: TL = 3
The heavy nitrogen stable isotope ($^{15}$N) follows a predictable stepwise enrichment pattern with increasing trophic level.

Measurement of stable isotope composition of consumers and baseline items (primary producers) leads to the inference of trophic level of animals.

Use of tRophicPosition model to infer trophic level of animals.
Low trophic positions of consumers
Results: food sources and primary consumers

Food items:
- SPOM
- Biofilm
- Harmothoe sp.
- Flabelligera mundata
- Polycirrus sp.
- Perkinsiana sp.
- Tropidon longstaffii
- Marseniopsis sp.
- Laternula elliptica
- Adamussium colbecki
- Ophiura sp.
- Sterechinus neumayeri
- Diplasterias brucei
- Odontaster validus
- Heterocucumis sp.
- Staurocucumis sp.

Food items

Polychaetes

Molluscs

Echinoderms
Results: secondary consumers

- Saliasterias brachiata
- Acodontaster sp.
- Isotealia antarctica
- Decolopoda australis
- Ammotech a carolinensis
- Parborlasia corrugatus
Inter-annual change in isotopic compositions

<table>
<thead>
<tr>
<th>Producers</th>
<th>2013-14</th>
<th>2014-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>POM</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>$H.\ grandifolius$ blades</td>
<td>▼</td>
<td>▼</td>
</tr>
<tr>
<td>Biofilm</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Sympagic algae</td>
<td>▲</td>
<td>▲</td>
</tr>
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<table>
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<tr>
<th>Consumers</th>
<th>2013-14</th>
<th>2014-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ophiura sp.</td>
<td>▼</td>
<td>▼</td>
</tr>
<tr>
<td>$Odentaster validus$</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>$Sterechinus neumayeri$</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
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Image: NASA