Eelgrass (Zostera marina, L.) distribution variability in the St. Lawrence Estuary as detected by Landsat historical images (1985-2017)

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Credit: M. Cusson
Coastal zones, nearshore environments

- Dynamic interaction of processes;
- Hosts diverse (vegetated) habitats:
  - Primary production;
  - Nursery of diverse species (including some with economical importance);
  - Nutrient cycling;
  - Coastline protection;
  - Global carbon storage (“blue carbon”).
- High economic value of ecosystem services (Costanza et al. 2014);
- Threatened by human pressure;
- Climate change;
Seagrass

- Wide biogeographical distribution;

- Median rate of decline of 7% per year since 1990 (Waycott et al., 2009);

- Need of effective monitoring tools;
Seagrass

- Wide biogeographical distribution;
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- Need of effective monitoring tools;

Objective

Establish a baseline for regional monitoring of areal distribution of the eelgrass (*Zostera marina*, L.) on selected regions of the Saint Lawrence Estuary.
Study area
Study area

- Presence of salt marshes, macroalgae and microphytobenthos;
- Eelgrass habitats are prominent;
- Previous studies: mainly based on aerial photographs surveys (either using photogrammetry techniques and oblique photos);
- Often limited to a specific region and a “snapshot” on time.
Study area

- High spatial coverage:
  - Upper estuary;
  - Saguenay River;
  - Lower Estuary;
  - Gaspé Peninsula and Baie des Chaleurs.

- Aerial photographs, *in situ* verification (divers);

- 4 classes of classification:
  - 1) Continuous meadows;
  - 2) Discontinuous meadows;
  - 3) Sparse meadows;
  - 4) Presence.
  
  - 1, 2 → high density;
  - 3, 4 → medium and low density.

- 6,433 ha of eelgrass meadows in the study area.
The Landsat missions

Source: USGS
The Landsat missions

SPATIAL RESOLUTION: 30 m

Source: USGS

* MSS bands 1–4 were known as bands 4–7, respectively, on Landsats 1–3
**Workflow**

**Dataset**
- Scene metadata (USGS Earth Explorer)
- Tidal data (http://isdm-gdsi.gc.ca)

**Scene selection**
Cloud-free and low tide conditions

**Classification**
- Segmentation
- Attribute table
- Local knowledge

**Image pre-processing**

**Verification**
- Acoustic data
- WorldView 3 im. classification
Dataset

- Earth explorer (image preview, order, selection criteria);
- Tidal data: DFO – Marine environmental data (http://isdm-gdsi.gc.ca);
- Comparison between tide and scene acquisition time;
- Low tide scene preview;
- Acquisition restricted to Jun-Jul-Aug-Sep-Oct;
- Visual inspection for cloud-free scenes;
- Download of scenes (Level 2 products – L4, L5, L7 and L8);
- Atmospherically corrected products: reflectance values.
Baie de Sept-Îles: 15 images; Péninsule Manicouagan: 16 images; Rimouski: 16 images; L’Isle Verte: 22 images
Scene cropping

- ESRI ArcGIS 10.5;

- MNDWI (Xu 2006):

\[
\frac{\text{Green} - \text{SWIR}}{\text{Green} + \text{SWIR}} \rightarrow \text{threshold};
\]

- Isobath delimitation:

20 m minimum.
Image segmentation and attribute extraction

- PCI Geomatica 2017
  - Segmentation and attribute extraction
Rule-based classification

- ESRI ArcGIS 10.5;
- Rule-set is not applied on all time-series;
Verification

- Single-beam acoustics
  (CIDCO, Baie de Sept-Îles 2017)
Verification

- Single-beam acoustics (CIDCO, Baie de Sept-Îles 2017)
- Classified WorldView 3 (1.24 m spatial resolution) image acquired in 2017 (F. Danhiez, pers. comm.);
- Qualitative assessment.
Baie des Sept-Îles

![Image 1985](1985.png)

![Image 2009](2009.png)

![Image 2001](2001.png)

![Image 2017](2017.png)
Péninsule Manicouagan
Rimouski

1989

1998

2011

2016
L’Isle verte

1985

1993

2007

2016
Area retrieval

- Sept-Îles
- Manicouagan
- Rimouski
- L'Isle Verte

Area (ha)

Year

Increase in area

- Sept-Îles: 7-fold
- Manicouagan: 8-fold
- Rimouski: 2-fold
- L'Isle Verte: 3-fold
Map of changes

- Boolean queries (AND, NOT and OR)
Map of changes

- Boolean queries (AND, NOT and OR)
Summary

- Landsat heritage missions provides a powerful source of data to investigate seagrass distribution over the time-lapse of the missions coverage;

- Contrary to the world average tendency, the Saint Lawrence estuary (or at least the studied areas) presents a clear pattern of increasing the area of seagrass meadows;

- The increase pattern seem to move towards the coastline;

- The cause(s) of this increasing remains an open question.
Next steps

- **Know issues:**
  - Atmospheric correction;
  - Dynamic action of tides: submerged / emerged meadows → impact on classification procedures;
  - Cloud-free scenes were visually selected (can contain cirrus clouds that can also affect classification).

- **All the procedure are being implemented in MATLAB environment:**
  - Automatic (batch) processing;
  - Higher (very much) volume of data (scenes) are being analyzed;
  - Landsat team (NASA/USGS) quality control of cloud are being used to flag images;
  - Implementation of a water correction procedure (Lyzenga 1981) → testing phase;
  - Quantitative verification (validation) with maps generated from higher spatial resolution technologies (e.g. aerial photographs).
References


