Effects of exotic forest plantations on functional and structural indicators of stream health in south-central Chile

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Task 1

Estimate how the hydrological alteration caused by dams and land-use changes compromises the functioning of river systems.

Task 3

Based on the general project objective, the tasks are:

Task 2

Hydrol. Predictors Models

Task 4

Ecosystem Function & Structure

General project objective

Project HANSEL
Native forest conversion for forest exotic plantations is dramatic in south-central Chile.
Land-uses changes

Native forest landscape

Exotic plantation landscape

Changes in hydrology, nutrient concentration, physico-chemistry, energy subsides, sediment storage and routing to channels

Biodiversity

Ecosystem Functioning

Ecosystem services
How to study the influence the replacement of native forest in river ecosystems?
The main objective of this study is to assess the influence of replacement of native forest by exotic plantations on the structure and functioning of river ecosystems.
Study design: CONTROL-IMPACT design

Creating virtual watersheds

IMPACTS
Exotic plantations

CONTROLS
Native forest

FLUVIAL NETWORK
10,215 network segments
17 – 1,700 meters length
>20 catchment & local variables

Methods
Study design: CONTROL-IMPACT design

**IMPACTS**

Exotic plantations

**CONTROLS**

Native forest

**Land-use (%)**

- < 10
- 11% - 20%
- 21% - 30%
- 31% - 40%
- 41% - 50%
- 51% - 60%
- 61% - 70%
- 71% - 80%
- 81% - 90%
- > 90%

**Hydrological Classification**

- CI1
- CI2
- CI4
- CI9
- CI10
- CI11
- CI12
- CI13
- CI14

**Catchment area (km²)**

- < 0.15
- 0.15 - 100
- 101 - 200
- 201 - 400
- 401 - 800
- 801 - 1500
- 1501 - 3000
- 3001 - 6000
- 6001 - 12000
- > 12001
Hydrological indicators

Control Sites

HBV hydro. model

Flow Series (1980-2010)

85 Hydrological Indices

Magnitude
Frequency
Duration
Timing
Rate of change

Natural Flow Regime Paradigm

Standarize

Impacted Sites

HBV hydro. model

Flow Series (1980-2010)

85 Hydrological Indices

% of change in each impacted site respect the control sites

Mean Reference condition
Structural Indicators

Methods

Water characterization

- Water temperature
- pH
- Electrical Conductivity (EC)
- Total Dissolved Solids (TDS)
- Total Suspended solid (TDS)

Nutrients

- Nitrate
- Phosphate

Biofilm characterization

- Chlorophyll A (ChlA)
- Ephilitic biomass (EpB; biofilm organic matter)

Sediment characterization

- Sediment size

Biodiversity

- Richness
- Diversity
- Abundance
- EPT (intolerant)
- No-Insects (tolerant)
- Native vs non-native
**Methods**

**River Metabolism** \[ \Delta \text{DO} = \text{Primary Production} - \text{Respiration} \pm \text{Gas Exchange} \]

\[
\text{NDM}_i = \left[ \frac{\text{DO}_i - \text{DO}_{i-t}}{t} - K_2(C_s - \text{DO}_{i-t}) \right] \text{D}
\]

- **DO** dissolved oxygen (mg/L)
- **GPP**: Gross Primary Production
- **ER**: Ecosystem Respiration
- **NDM**: Net Daily Metabolism
- **K2** gas exchange coefficient
- **Cs**: DO saturation
- **D**

1. **Dissolved Oxygen (DO)** measure each 5 minutes
2. **72 Hours**
3. **Light** (sunrise/sunset)

**Gross Primary Production (GPP)**

**Ecosystem Respiration (ER)**

**Net Daily Metabolism (NDM)**
Hydrological indicators

Alteration of patterns of **low flows**

- **5% - 15%** alteration
- **50% - 90%** alteration

Major impacts in coastal sites

- Duration of low flow episode
- Number of high flows pulses
- Timing of highest flows

Central sites

Costal sites
Structural indicators: Water, sediment & biofilm

Results

Nitrate: $F_{1,16} = 7.2 \ p<0.05$

Phosphate: $F_{1,16} = 3.5 \ p>0.1$

Impact sites

Control sites
Structural indicators: Water, sediment & biofilm

Results

Granulometry - D90

Impact Zone $F_{1,16} = 25.9$ p<0.01
Impact Zone $F_{1,16} = 27.96$ p<0.01

Granulometry - D50

Impact Zone $F_{1,16} = 15.9$ p<0.01
Impact Zone $F_{1,16} = 6.5$ p<0.05

Structural indicators: Water, sediment & biofilm

Impact sites  Control sites
**Structural indicators:** Water, sediment & biofilm

**Chlorophyll A**

- **Central** sites: Mean = 4.5 mg/m², SD = 0.8
- **Coastal** sites: Mean = 5.2 mg/m², SD = 1.1

*F*<sub>1,17</sub> = 3.7, p = 0.10

**Ephilitic Biomass**

- **Central** sites: Mean = 4200 mg/m², SD = 800
- **Coastal** sites: Mean = 1500 mg/m², SD = 300

*F*<sub>1,17</sub> = 22.34, p < 0.01

**Impact Interaction**

- **Central** sites: Mean = 4000 mg/m², SD = 800
- **Coastal** sites: Mean = 1500 mg/m², SD = 300

*F*<sub>1,6</sub> = 39.4, p < 0.01

*F*<sub>1,7</sub> = 1.05, p > 0.05

Impact sites: yellow

Control sites: green
**UCSC**

**Results**

**Structural indicators:** Biological (invertebrates)

- **ETP Richness**
  - **Central Coastal**
  - **Impact Zone** F\(_{1,16}\) = 6.57 p<0.05
  - **Impact Zone** F\(_{1,16}\) = 20.9 p<0.01

- **Non-insects-Richness**
  - **Central Coastal**
  - **Impact Zone** F\(_{1,16}\) = 7.4 p<0.01
  - **Impact Zone** F\(_{1,16}\) = 22.8 p<0.01

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**Graphs:**

- **ETP Richness**
  - **Central Coastal**
  - **Impact sites**
  - **Control sites**

- **Non-insects-Richness**
  - **Central Coastal**
  - **Impact sites**
  - **Control sites**
Results

Structural indicators: Biological (fishes)

- **Richness (native species)**
  - Central: 2 species
  - Coastal: 3 species

- **Abundance**
  - Central: 10 individuals
  - Coastal: 30 individuals

- **Biomass**
  - Central: 80 grams
  - Coastal: 160 grams

The graphs compare data from control sites (green bars) and impact sites (yellow bars) for the structural indicators of Biological (fishes) in Central and Coastal regions.
Results

Functional indicators: Ecosystem Metabolism

- **Gross Primary Production (GPP)**
  - *F*$_{1.16}$ = 0.48, *p* = 0.49
  - Central: ~600 mgO$_2$/m$^2$*day*
  - Coastal: ~400 mgO$_2$/m$^2$*day*

- **Ecosystem Respiration (ER)**
  - *F*$_{1.16}$ = 6.1, *p* < 0.05
  - Central: ~3000 mgO$_2$/m$^2$*day*
  - Coastal: ~2000 mgO$_2$/m$^2$*day*

- **Net Ecosystem Production (NEP)**
  - *F*$_{1.17}$ = 4.4, *p* < 0.05
  - Central: ~-6000 mgO$_2$/m$^2$*day*
  - Coastal: ~-5000 mgO$_2$/m$^2$*day*

Yellow bars represent impact sites, and green bars represent control sites.
- Patterns of low flows were highly altered in the catchments dominated by forest plantations, where reductions over 50% were observed for the summer flows.

- Substrate size, conductivity and invertebrate communities showed clear differences among control and impact sites while some other structural indicators, such as epilithic biomass or fish communities, differed their behaviour according to location.

- River ecosystem metabolism provided consistent results and can be considered a good indicator to measure the effect of forest replacement in rivers. Changes might be related with an accelerated functioning of basal trophic levels and higher rates of consumption of allochthonous material.

- Results of this study are promising to provide cause-effects relationships between structural and functional indicators to better understand how forest plantations affect river ecosystems. However, additional samples to be collected in coming months are expected to test significance of these results.