Invasion dynamics and management of the tree *Casuarina equisetifolia* in the atoll of Moruroa (French Polynesia), a former nuclear test site in the South Pacific

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Biological invasions in islands

- One if not the main cause of biodiversity loss
- Island biota are more vulnerable to invasion
  - small population size & restricted distribution ranges
  - less competitive taxa
  - vacant ecological niches/missing functional group
- Higher risk of invasions in islands
  - alien species introduced without their natural enemies
  - dramatic increase of people and goods transportation ⇒ more alien species introductions
  - greater intensity of human impacts: land clearing, urbanization, fires, grazing or trampling by ungulates
Disturbance and plant invasion

- A major factor affecting invasibility of native ecosystems
  - increases resource availability (e.g. light, soil nutrient...)
  - reduces species competition

- Post-disturbance plant succession
  - pioneer/light-demanding/early successional species
  - shade-tolerant/late successional species
Disturbance gradient

- Importance of disturbance type, size, distribution and regime
- from micro-disturbances (local scale), macro-disturbance (landscape scale, e.g. fire, landslide, cyclone)...
- …to Mega-disturbances (ecosystem scale)
Moruroa, a National Defense Protected Zone
« l’atoll du grand secret »
Questions

- How to manage the *Casuarina equisetifolia* massive invasion in a coral atoll ecosystem?
- Are the nuclear tests the triggering factor of its “demographic explosion” on Moruroa?
Moruroa Atoll
(Tuamotu-Gambier Is., French Polynesia)

- tropical oceanic island (10-12 M yrs)
- 28 km x 10 km
- 3 km² of land area
- located at > 1,000 km from Tahiti
Human presence on Moruroa

- 1792: « discovered » by the first Europeans
- 1881: a governmental land, coconut plantations
- 1904-1906: uninhabited after cyclones
- 1962: officially declared a nuclear test site
- 1966-1974: 41 atmospheric nuclear tests
- 1976-1989: 137 underground nuclear tests
- 1995: last nuclear test
- 1996: signature by France of the international treaty banning nuclear tests
- 1996-1998: demolition of all infrastructures
  (except the airstrip, the road, a small port, blockhouses, towers, radiological & geomechanical monitoring installations, a small military base)

- From 1600-2500 people in 1994… to 25 soldiers in 2005
Casuarina equisetifolia L. (Casuarinaceae)

- « Pacific ironwood, beach she-oak, horsetail tree, Australian pine, filao, bois de fer, ʻaito, toa »
- Tree 5-20 m (up to 40 m)
- Native to Australia & Oceania (PNG, Solomon, Fidji, New Caledonia, Vanuatu, Tonga, Samoa…)
- Native in Eastern Polynesia? Introduced to Hawaii in 1882
- 0-400 m (up to 800 m) elevation; rainfall 200-5,000 mm/yr
- Volcanic and calcareous substrate

Maiao (Society Is.)
Rurutu (Austral Is.)
Fatu Hiva (Marquesas)
« Ideal » weed or aggressive colonizer of open disturbed areas and poor soils?

- Fast-growing (3 m in height/yr, 1-2 cm in diam./yr)
- Early reproduction (4-5 yrs)
- Prolific seed production
- Wind dispersed and sea-drifted
- Salt-resistant
- Drought-tolerant
- Nitrogen-fixing tree
- Forms monotypic stands with a dense leaf litter (allelopathy?)

- Coastal dunes and sandy sea-shore in South-Africa and Florida (USA)
- New lava flows in La Réunion (Mascarenes, Indian Ocean)
- Coastal and lowland dry/mesic forests and fernlands in Hawaii
- Phosphate-mined areas in the raised limestone island of Nauru (Pacific Is.)
Casuarina equisetifolia’s invasion dynamics on Moruroa

- Introduced in 1966 (as an ornamental, shade, hedge or wind-break tree)
- Recognized as invasive in 1994
- 150 ha invaded (50% of the land area) in 2005
Method

- 3 short field-trips in 2005 and 2007 (4-5 days each)
- Selection of 3 dense stands with different « physionomy »
- 7 permanent plots (100 m² quadrats)
- Tree number, Stem number, DBH (measured at 1.3 m)
- Density, Mean basal area
# Main results

<table>
<thead>
<tr>
<th>Stand/Population</th>
<th>Area (m²)</th>
<th>Stems/m²</th>
<th>Mean basal area (cm²/m²)</th>
<th>DBH max (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>« Very Old »</td>
<td>100</td>
<td>0.5</td>
<td>36.16</td>
<td>24.5</td>
</tr>
<tr>
<td>« Old »</td>
<td>300</td>
<td>0.9</td>
<td>32.3 ± 1.63</td>
<td>19.7</td>
</tr>
<tr>
<td>« Young »</td>
<td>300</td>
<td>2.9</td>
<td>27.1 ± 1.89</td>
<td>10</td>
</tr>
</tbody>
</table>
« Young » population structure (ca. 10 yrs old)
« Old » population structure (>20 yrs old)

DBH class (cm)

Stem number
« Very Old » population structure (>40 yrs old)
Discussion: invasion patterns and process

- Destruction of the vegetation and soil vitrification by the aerial nuclear tests (1966-1974)
- Construction and settlement period (1975-1995)
Invasion management: testing adapted control methods

- Cut-stump treatment (+ Glyphosate “Asteroide®”)
- Ring-barking/frilling (+ Glyphosate)
- Fire (low intensity)
# Preliminary results

% resprouting (2 months after treatment)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>« Young »</th>
<th>« Old »</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut-stump</td>
<td>38%</td>
<td>28%</td>
</tr>
<tr>
<td>Ring-barking/frilling</td>
<td>77%</td>
<td>56%</td>
</tr>
<tr>
<td>(% defoliation)</td>
<td>(83%)</td>
<td>(62%)</td>
</tr>
</tbody>
</table>

- Preliminary results

- Ring—barking/frilling

- Cut—stump

- Old & Young Treatment

- % resprouting (2 months after treatment)
Fire treatment
(2 months after burning)

- 77% defoliation

- Seedling carpet

- Bar chart showing stem number and DBH (cm) with categories for DBH >0-1, >1-2, >2-3, etc., and two bars for 'avec reprises' and 'sans reprises.'
Future prospects: a rehabilitation project

- Inventory of native (31 spp.) and alien (110 spp.) plant species
- Early eradication of potential invaders/sleeping weeds (8 spp.)
- Plantation of native plant seedlings in treated/defoliated areas
Acknowledgements

- French Minister of Defense (DSND, DGA/DSCEN), CEA, French Army based in Tahiti (COMSUP), High-Commissioner of French Polynesia, the officers & soldiers of Moruroa
Thanks a lot for your attention, merci beaucoup, mauruuru roa

Moruroa, a natural reserve for the future?