HABITAT EQUIVALENCY ANALAYSIS

Presentation for USCRTF October 24, 2006 Workshop

Overview of Determining Compensation for Coral Reef Injuries: A Habitat Equivalency Analysis Approach

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HEA ⇨ A Method for Determining Compensation for Lost Natural Resources

- **Illustration: A coral reef is injured by a grounding (or a permitted activity); Injury area large**
- **The injured reef, *after Primary Restoration*, will take time (years) for recovery to return to its previous level of services. Hence services lost.**
- **<u>How much</u> of a <u>Compensatory Action</u> should there be to replace those lost services (in order to adequately compensate the Resource Trustee)?**

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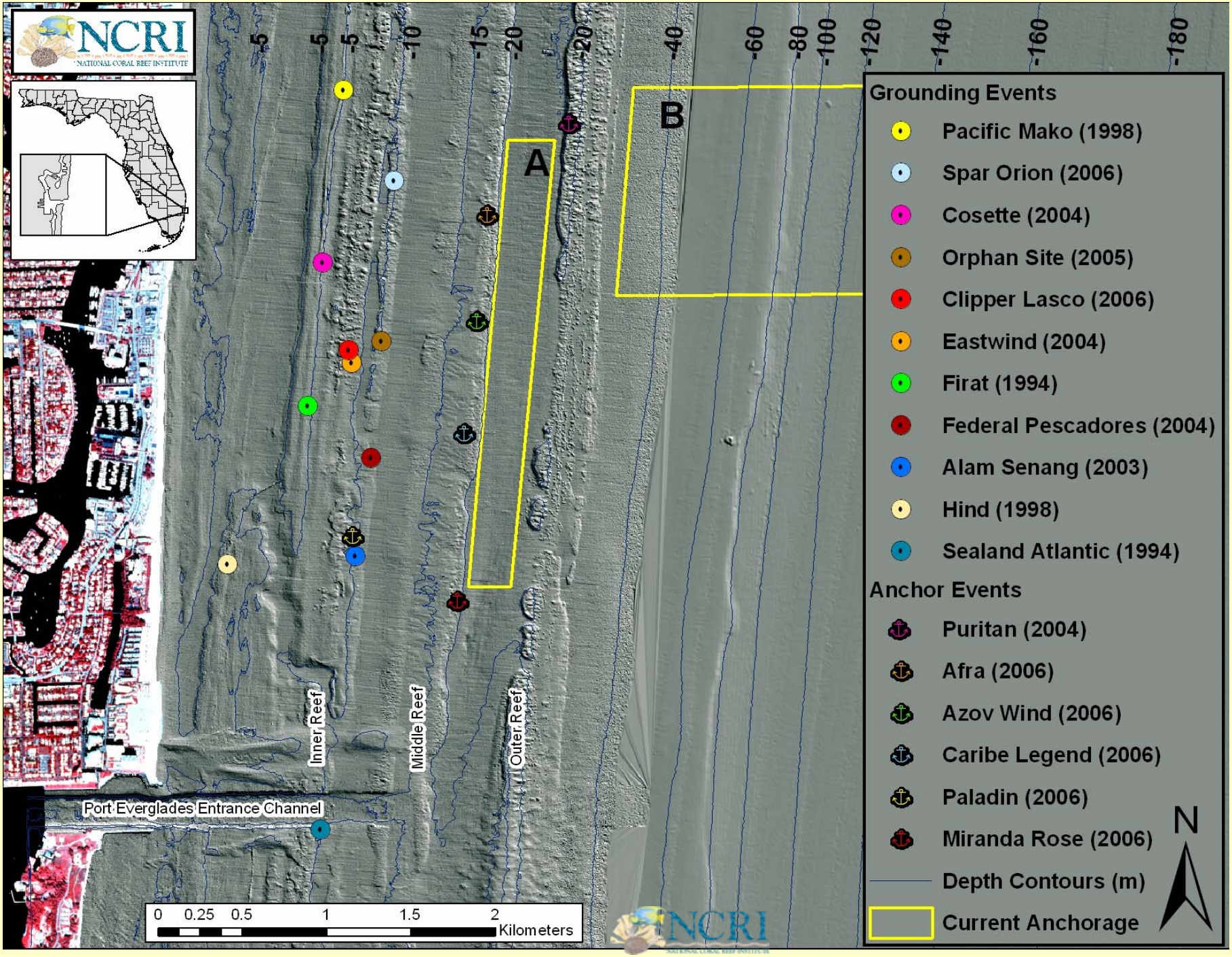
Illustration: Reef Injuries from Unplanned or Planned Events

Drawing Experience from:

- **Broward County, Florida** (and elsewhere)
- **Grounding Capital of the US** (you think you have it bad?)
- **(Planned Reef Injury Capital possibly soon)**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A
B
Inner Reef
Middle Reef
Outer Reef
Port Everglades Entrance Channel
0 0.25 0.5 1 1.5 2
Kilometers
Grounding Events
Pacific Mako (1998)
Spar Orion (2006)
Cosette (2004)
Orphan Site (2005)
Clipper Lasco (2006)
Eastwind (2004)
Firat (1994)
Federal Pescadores (2004)
Alam Senang (2003)
Hind (1998)
Sealand Atlantic (1994)
Anchor Events
Puritan (2004)
Afra (2006)
Azov Wind (2006)
Caribe Legend (2006)
Paladin (2006)
Miranda Rose (2006)
Depth Contours (m)
Current Anchorage
N
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Reef Injuries from Groundings (or other)

- **Rubble, Reef Framework, Scraping, Crushing, & Killing Organisms**

Crushed, Fractured, Overturned Hard Corals

A few examples…

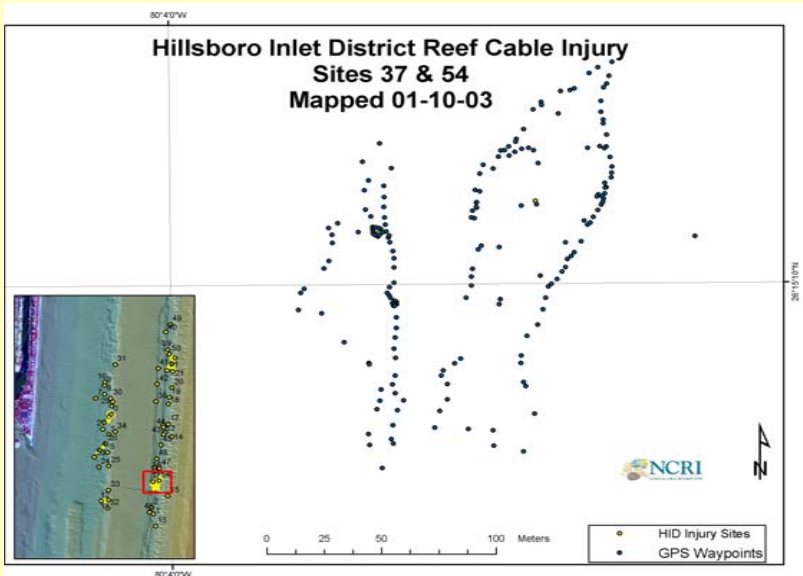
Ditto & Sheared Soft Corals & Sponges

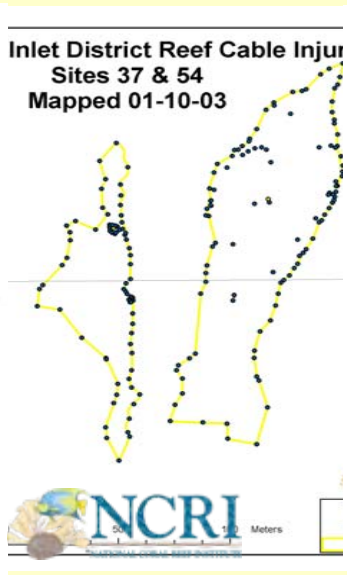
Dislodged Hard Corals

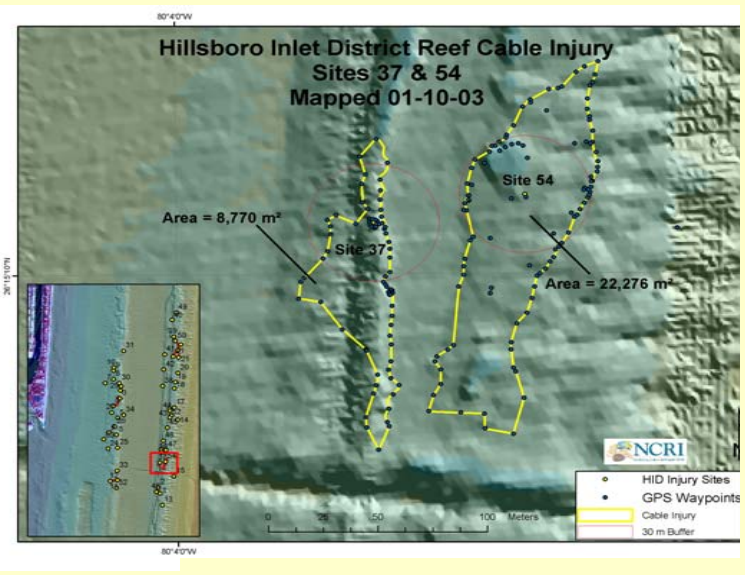
Managing the Challenge:

Injury Assessment

- Survey reef injury areas
- Assessed severity
- Mapped injury areas using GPS
- Planar areas estimated

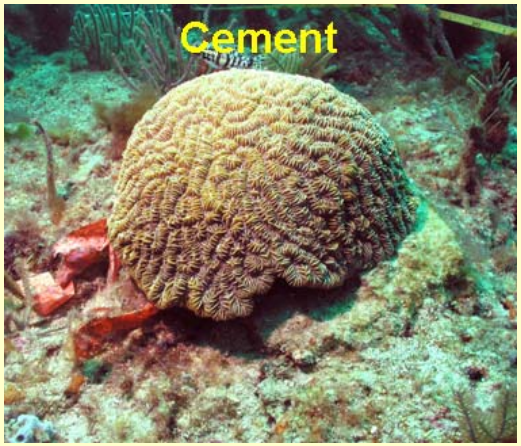


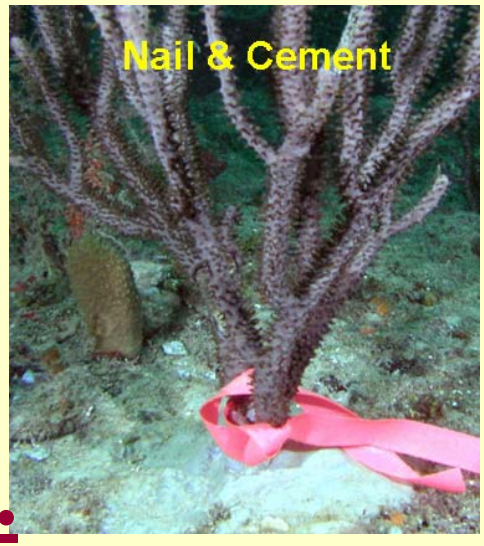




Triage & Primary Restoration: Rubble Stabilization, Framework Repair, Organism Reattachment

A few examples…





Nevertheless..

- **Reef frame & organisms injured**
- **Time needed to recover**
- **Resource Trustee desires (mandates)**

Compensation for its loss

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Addressing Amount of Compensation for Loss:

Habitat Equivalency Analysis (HEA) can be a Useful Solution:

- **Determines: How much of a Compensatory Action there should be to replace these lost services (in order to adequately compensate the Resource Trustee)**
- **HEA balances the services lost and gained over TIME.**

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HEA Principles

- **Natural resources are viewed as natural assets that provide services throughout lifetime.**
- **Total value of such a natural asset = present value of the future stream of all services (DISCOUNTED) over time.**
- **Discounting is simply the willingness to pay more for something now than in the future.**

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Discounting is Key HEA Concept

- What would you rather have: $1,000 today or $1,000 in 1 year from now? (Most want it now!...because…..)
- 3% discount rate, $1K 1year from now = only $970!
- 10% discount rate, $1K 1year from now = only $900! !

Translating this into the HEA:

- Total value of natural asset = (present) value of the future stream of all services (discounted) over time.

Σ  +  +  + …

NOW LATER

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Basic Procedure of HEA

- **Assess the amount & degree of injury to natural resources (after primary restoration).**
- **Determine services lost from injury until recovery or equilibrium state.**
- **Decide on restoration action (type or kind) and level of services to be gained (services provided over time).**
- **DISCOUNT RATE (time preference for value)**
- **From this, HEA determines amount of that compensatory action to be created such that** Services ***GAINED (provided by) the compensation over its lifetime = services LOST from the injury.***
- **Time history of services & D.R.: critical.**

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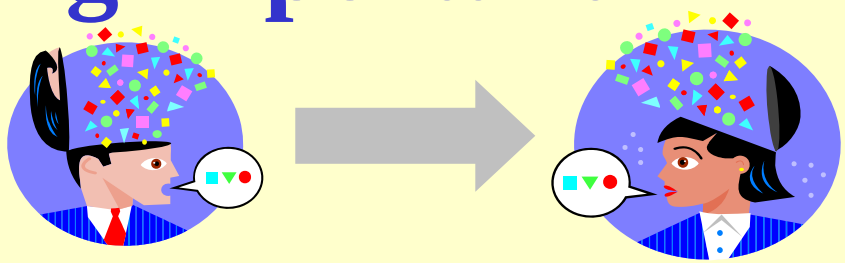
HEA: Structured framework for providing & considering important biological parameters



INPUT

- Amount of Injury (area)
- Nature of Natural Recovery (Amount, Duration, & Shape)
- Nature of Compensatory Action (trajectory towards equilibrium, persistence)
- Ratio of Services
- Discount Rate (%)

OUTPUT

- Amount (area) of Compensatory Action (area) today to compensate for the loss of services of injury over time

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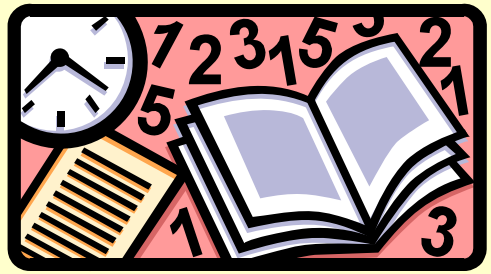
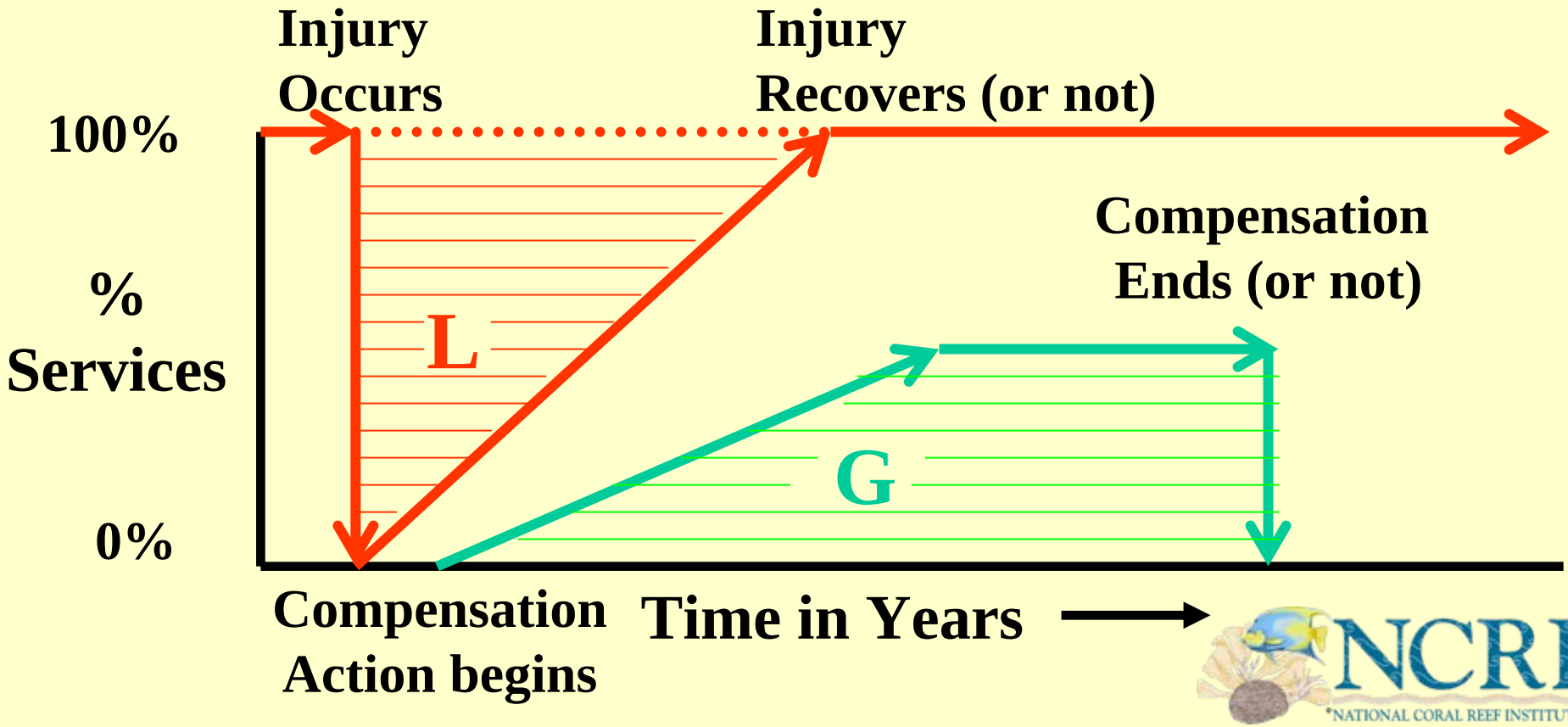
Calculating Compensatory Habitat – How does it work?



L(OSS)= Total Services (area-yr) of Injured Area Lost from injury
G(AIN)= Total Services (area-yr) Gained by compensatory action



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Types of HEA

- **Landscape:**
  - *Traditional method*
  - *Uniform landscapes; little difference in biological functions across the injured area.*
  - *Use keystone species, e.g., sea grass, A. palmata.*
- **Population approach (Milon and Dodge, 2001):**
  - *Injury area allocated into portions based on contribution of the organism / categories of interest.*
  - *Several, e.g., hard corals, gorgonians, sponges.*
  - *Individual HEA for each using its allocated area.*
  - *Results for each species (category) are summed.*

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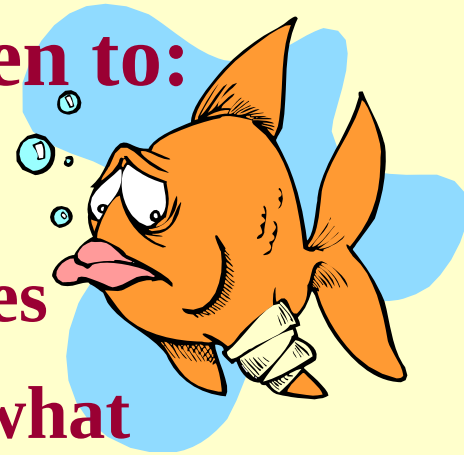
Injury and Compensatory Action Parameters are critical to HEA results



Careful consideration needs to be given to:

- **Amount (area) of injury**
- **Degree of injury to the biological services**
- **Over what time span and according to what trajectory will those services return to equilibrium**
- **Kind of compensatory action that is acceptable**
- **Service levels initially and over what duration**
- **Discount rate**

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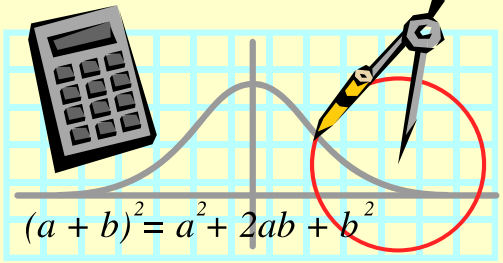

HEA Formulations

- **Formulas published by NOAA and others**

Other variables	
V_j	value per area-time of services provided by injured habitat
V_p	value per area-time of services provided by replacement habitat
x_t^j	level of services provided by injured habitat at end of time t
b^j	the pre-injury baseline level of services per area of injured habitat
x_t^p	level of services provided by replacement habitat at end of time t
b^p	initial level of services per area of replacement habitat
ρ_t	discount factor, where $\rho_t = 1/(1+r)^{(t-C)}$, r=discount rate per time unit
J	number of injured area units
P	size of compensatory replacement project

Time variables	
$t = 0$	Time when injury occurs
$t = B$	Time when injured area recovers to baseline levels
$t = C$	Time when the claim is presented
$t = I$	Time when the habitat project begins to provide services
$t = M$	Time when the habitat replacement project reaches full maturity
$t = L$	Time when the habitat replacement stops yielding services

Calculated quantities	
$(b^j - x_t^j)$	Extent of injury at time t
$(x_t^p - b^p)$	Increment in services provided by replacement project
$(b^j - x_t^j)/b^j$	percent reduction in services per area for injured area, relative to the injury site baseline level of services
$(x_t^p - b^p)/b^j$	percent increase in services per area for replacement site, relative to the injury site baseline level of services

- **Somewhat formidable**

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HEA Software to Assist: Visual_HEA

- **Kohler, K.E. and R.E. Dodge 2006. Visual_HEA: Habitat Equivalency Analysis software to calculate compensatory restoration following natural resource injury. Proceedings of the 10th International Coral Reef symposium. Okinawa, Japan. pp. 1611-1616.**
- **Facilitates the complex HEA calculations**
- **Free for non-commercial use**

  (Spanish version available)
- **GUI (Graphical User Interface)**
- **Full time histories of input/output services**
- **Allows quick examination of alternate scenarios**

- **Used in our Illustration:** ⇨ ⇨ ⇨ ⇨ ⇨ ⇨

For more information on Visual_HEA, visit www.nova.edu/ocean/visual_hea/

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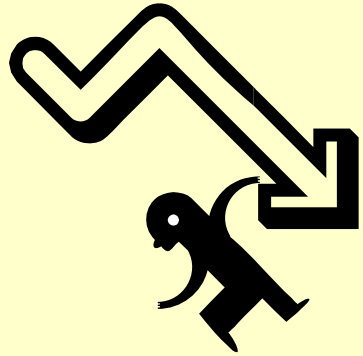
Illustration (Scenario A)



Injury Parameters:

Lost Services (after Primary Restoration)

(Landscape e.g., Hard Corals)

- **1,000 m^2 (.25 acres) total reef impact (some framework)**
- **all organisms destroyed**
- **200 year recovery, linear, 3% discount rate**

Compensatory Restoration Parameters:

Gained Services (depends on choice)

- **100% of the biological services of original**
- **200 years to reach equilibrium biological services**
- **Linear recovery, 3% discount rate**

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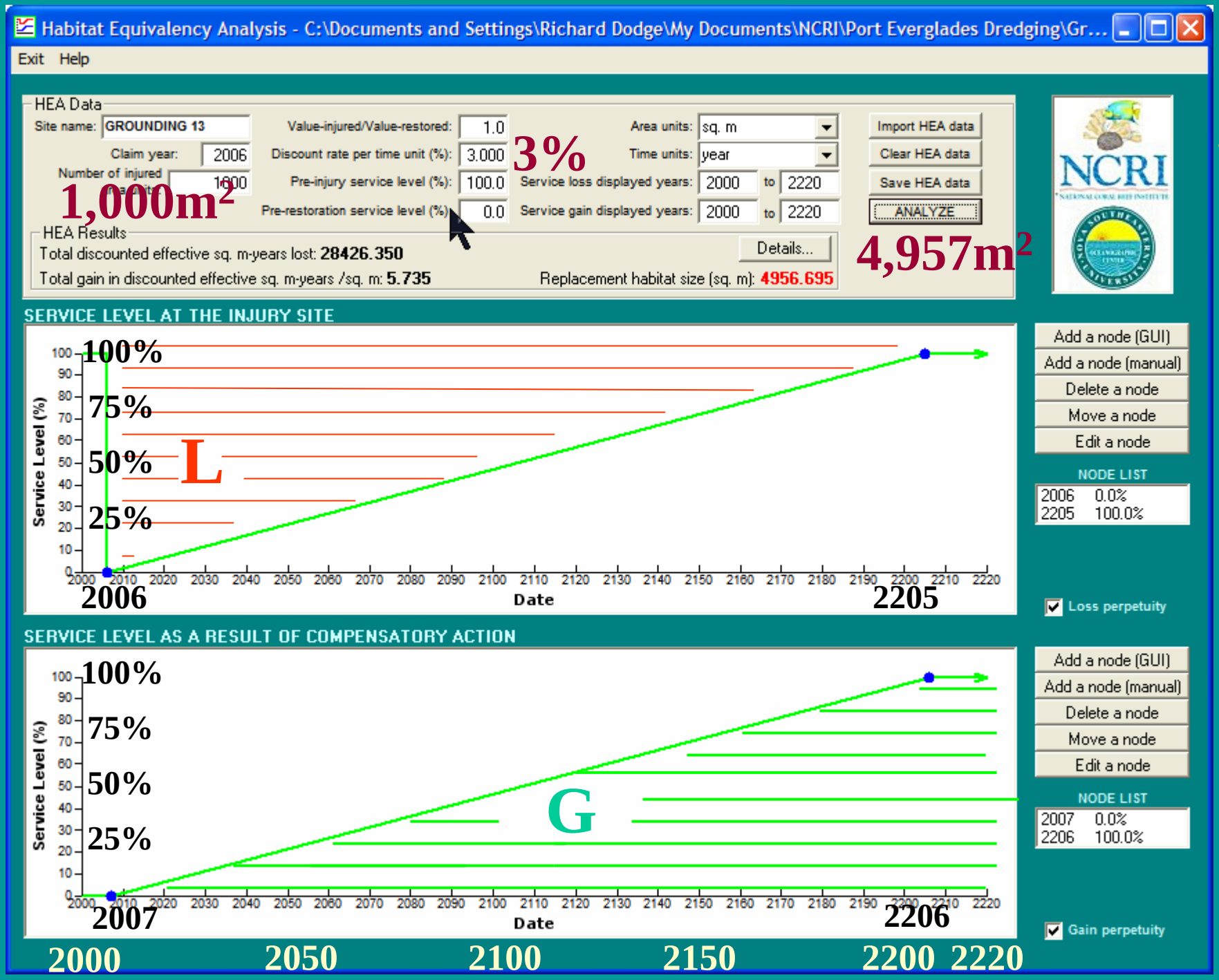
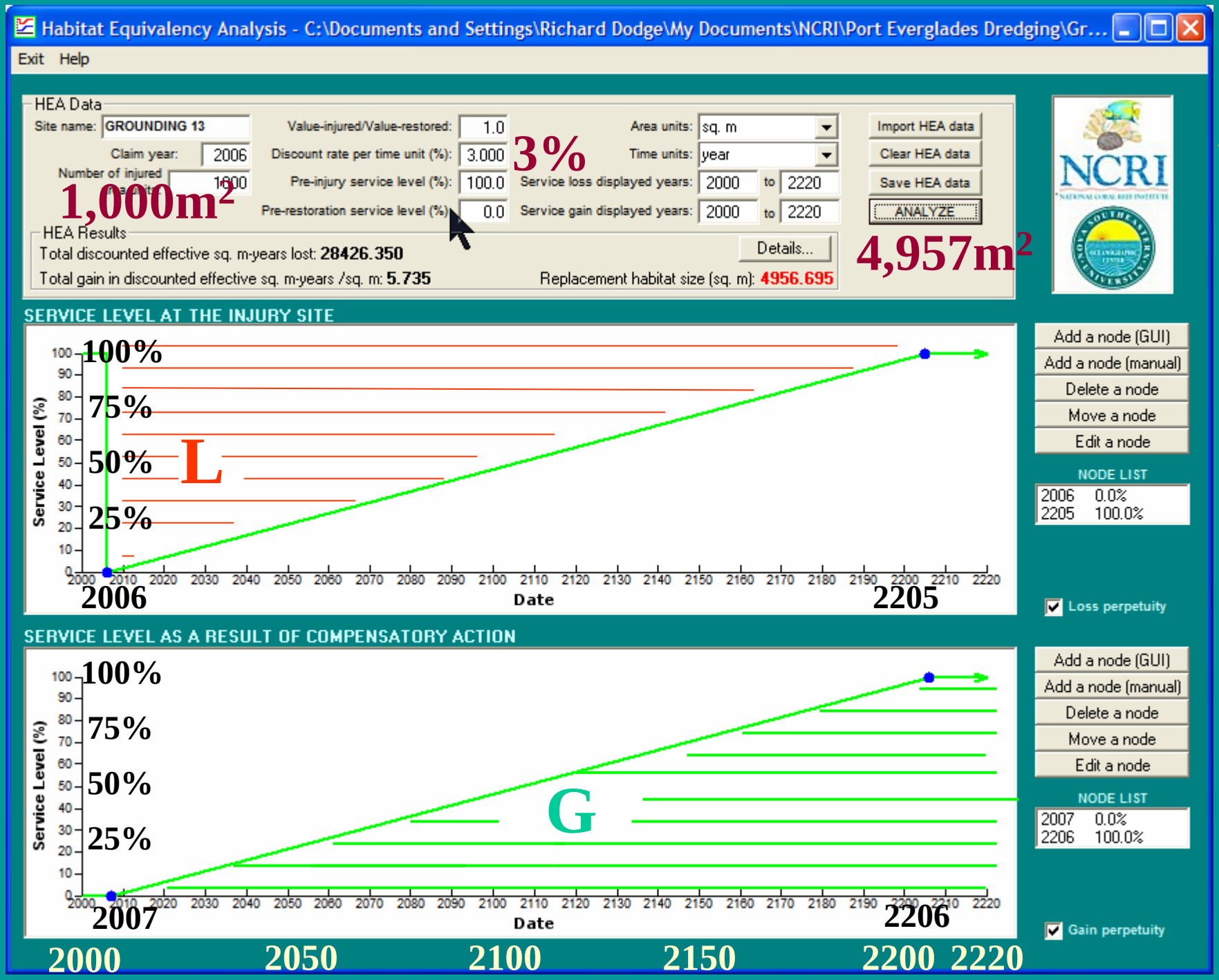

Habitat Equivalency Analysis - C:\Documents and Settings\Richard Dodge\My Documents\NCRI\Port Everglades Dredging\Gr...
Exit Help
HEA Data
Site name: GROUNDING 13
Claim year: 2006
Number of injured units: 1000
1,000m2
Value-injured/Value-restored: 1.0
Discount rate per time unit (%): 3.000
3%
Pre-injury service level (%): 100.0
Pre-restoration service level (%): 0.0
Area units: sq. m
Time units: year
Service loss displayed years: 2000 to 2220
Service gain displayed years: 2000 to 2220
Import HEA data
Clear HEA data
Save HEA data
ANALYZE
HEA Results
Total discounted effective sq. m-years lost: 28426.350
Total gain in discounted effective sq. m-years /sq. m: 5.735
Details...
Replacement habitat size (sq. m): 4956.695
4,957m2
NCRI
A
SERVICE LEVEL AT THE INJURY SITE
100%
75%
50%
25%
L
Service Level (%)
Date
2006
2205
Add a node (GUI)
Add a node (manual)
Delete a node
Move a node
Edit a node
NODE LIST
2006 0.0%
2205 100.0%
Loss perpetuity
SERVICE LEVEL AS A RESULT OF COMPENSATORY ACTION
100%
75%
50%
25%
G
Service Level (%)
Date
2007
2206
Add a node (GUI)
Add a node (manual)
Delete a node
Move a node
Edit a node
NODE LIST
2007 0.0%
2206 100.0%
Gain perpetuity
2000
2050
2100
2150
2200
2220

HEA Parameters:
Landscape Results

Scenario	A	B	C	D	E
INJURY Parameters					
Start Year	2006	2006	2006	2006	2006
Amount of Injury (m2)	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**
Recovery (Years)	200	200	200	never	never
Recovers to ?% full services	100%	100%	100%	0%	0%
COMPENSATION Parameters					
Start Year	2007	2007	2007	2007	2007
Reaches ?% full services	100%	100%	50%	100%	50%
Time to Equilibrium (years)	200	200	200	200	200
DISCOUNT RATE	3%	6%	3%	3%	6%
Compensation Amount (m2)	**4,957**	**??**	**??**	**??**	**??**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HEA Data
Site name: GROUNDING 13
Claim year: 2006
Number of injured units: 1000
1,000m2
Value-injured/Value-restored: 1.0
Discount rate per time unit (%): 3.000
3%
Pre-injury service level (%): 100.0
Pre-restoration service level (%): 0.0
Area units: sq. m
Time units: year
Service loss displayed years: 2000 to 2220
Service gain displayed years: 2000 to 2220
Import HEA data
Clear HEA data
Save HEA data
ANALYZE
HEA Results
Total discounted effective sq. m-years lost: 28426.350
Total gain in discounted effective sq. m-years /sq. m: 5.735
Details...
Replacement habitat size (sq. m): 4956.695
4,957m2
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SERVICE LEVEL AT THE INJURY SITE
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Service Level (%)
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Delete a node
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NODE LIST
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SERVICE LEVEL AS A RESULT OF COMPENSATORY ACTION
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2206 100.0%
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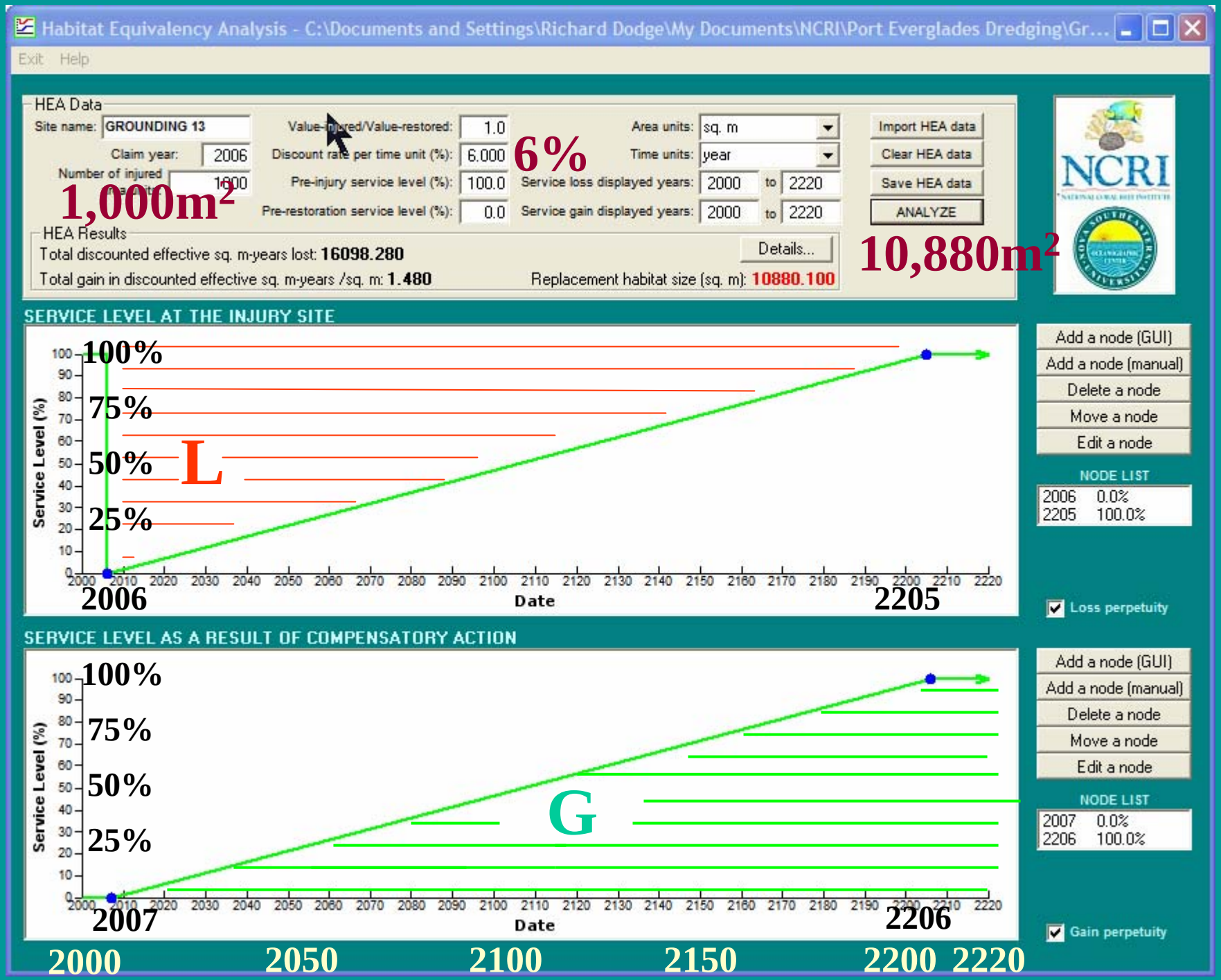
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Help
HEA Data
Site name: GROUNDING 13
Claim year: 2006
Number of injured units: 1000
Value-injured/Value-restored: 1.0
Discount rate per time unit (%): 6.000
Pre-injury service level (%): 100.0
Pre-restoration service level (%): 0.0
Area units: sq. m
Time units: year
Service loss displayed years: 2000 to 2220
Service gain displayed years: 2000 to 2220
Import HEA data
Clear HEA data
Save HEA data
ANALYZE
1,000m2
6%
HEA Results
Total discounted effective sq. m-years lost: 16098.280
Total gain in discounted effective sq. m-years /sq. m: 1.480
Details...
Replacement habitat size (sq. m): 10880.100
10,880m2
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Add a node (GUI)
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NODE LIST
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2205 100.0%
Loss perpetuity
SERVICE LEVEL AS A RESULT OF COMPENSATORY ACTION
Service Level (%)
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NODE LIST
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Gain perpetuity
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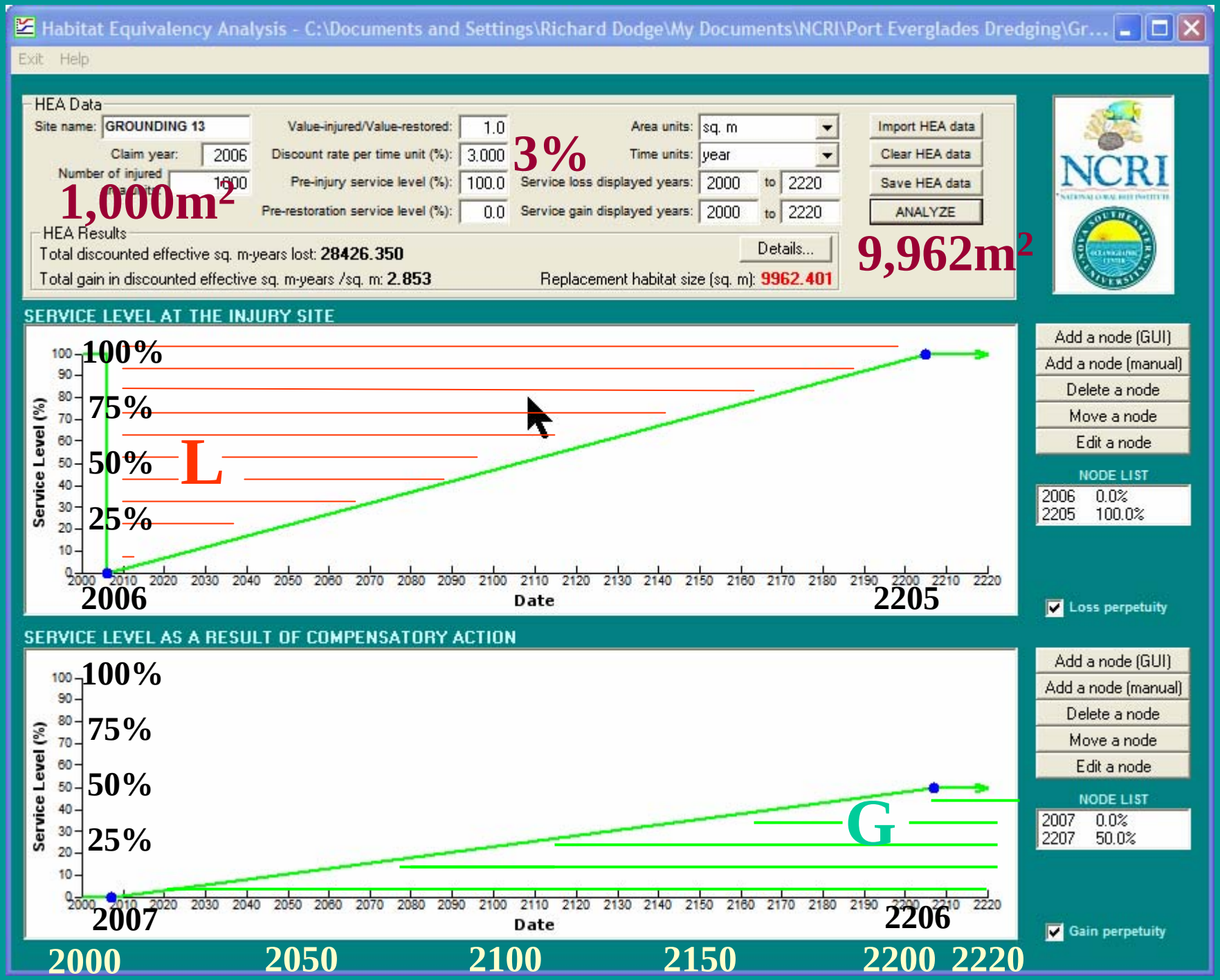
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Exit
Help
HEA Data
Site name: GROUNDING 13
Claim year: 2006
Number of injured
1,000m2
Value-injured/Value-restored: 1.0
Discount rate per time unit (%): 3.000
3%
Pre-injury service level (%): 100.0
Pre-restoration service level (%): 0.0
Area units: sq. m
Time units: year
Service loss displayed years: 2000 to 2220
Service gain displayed years: 2000 to 2220
Import HEA data
Clear HEA data
Save HEA data
ANALYZE
HEA Results
Total discounted effective sq. m-years lost: 28426.350
Total gain in discounted effective sq. m-years /sq. m: 2.853
Details...
Replacement habitat size (sq. m): 9962.401
9,962m2
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SERVICE LEVEL AT THE INJURY SITE
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Add a node (manual)
Delete a node
Move a node
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2205 100.0%
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SERVICE LEVEL AS A RESULT OF COMPENSATORY ACTION
Service Level (%)
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Add a node (manual)
Delete a node
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NODE LIST
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Gain perpetuity
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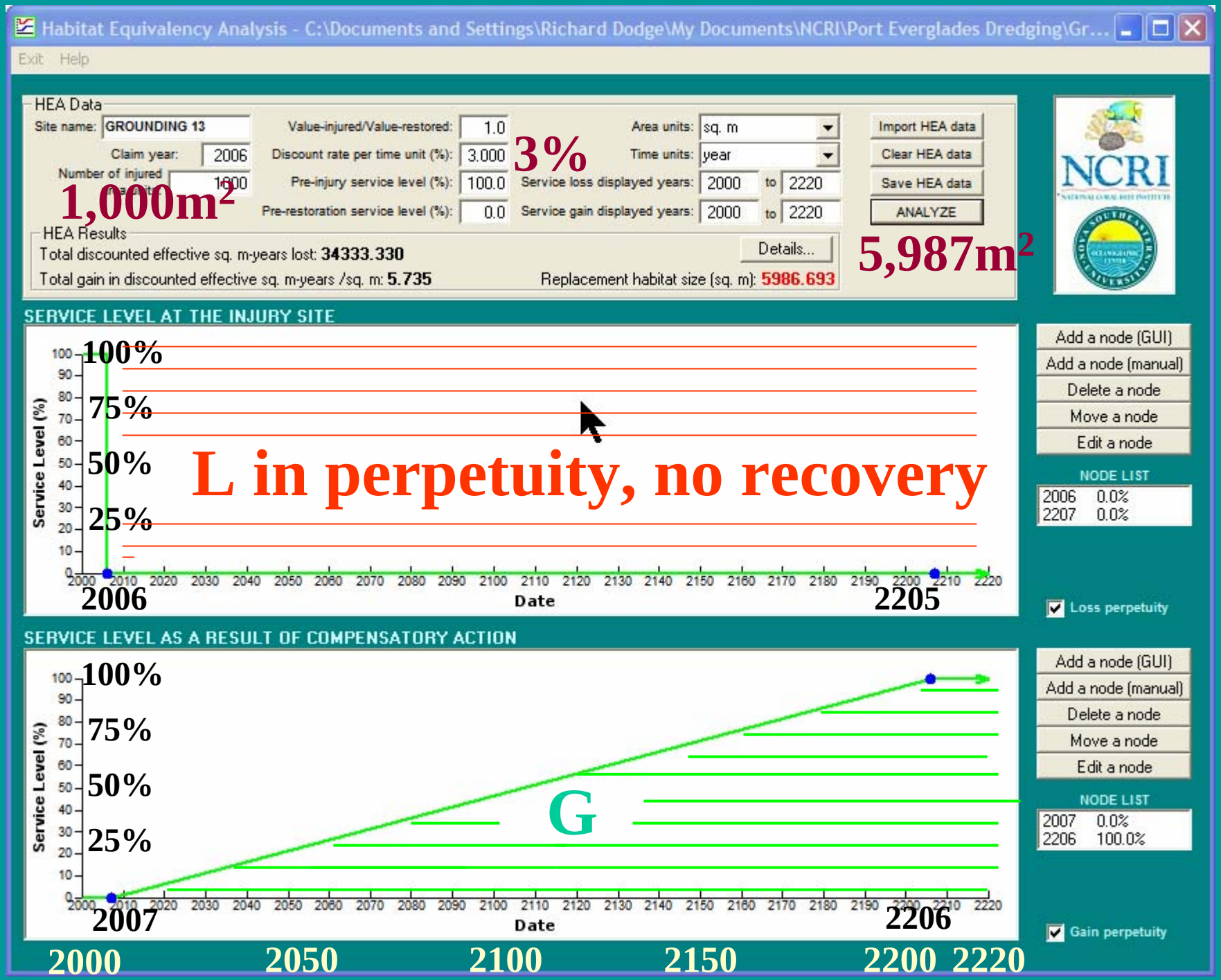
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Exit Help
HEA Data
Site name: GROUNDING 13
Claim year: 2006
Number of injured
1,000m2
Value-injured/Value-restored: 1.0
Discount rate per time unit (%): 3.000
3%
Pre-injury service level (%): 100.0
Pre-restoration service level (%): 0.0
Area units: sq. m
Time units: year
Service loss displayed years: 2000 to 2220
Service gain displayed years: 2000 to 2220
Import HEA data
Clear HEA data
Save HEA data
ANALYZE
HEA Results
Total discounted effective sq. m-years lost: 34333.330
Total gain in discounted effective sq. m-years /sq. m: 5.735
Details...
Replacement habitat size (sq. m): 5986.693
5,987m2
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D
SERVICE LEVEL AT THE INJURY SITE
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Service Level (%)
L in perpetuity, no recovery
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Add a node (manual)
Delete a node
Move a node
Edit a node
NODE LIST
2006 0.0%
2207 0.0%
Loss perpetuity
SERVICE LEVEL AS A RESULT OF COMPENSATORY ACTION
100%
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50%
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Service Level (%)
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Add a node (GUI)
Add a node (manual)
Delete a node
Move a node
Edit a node
NODE LIST
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Gain perpetuity
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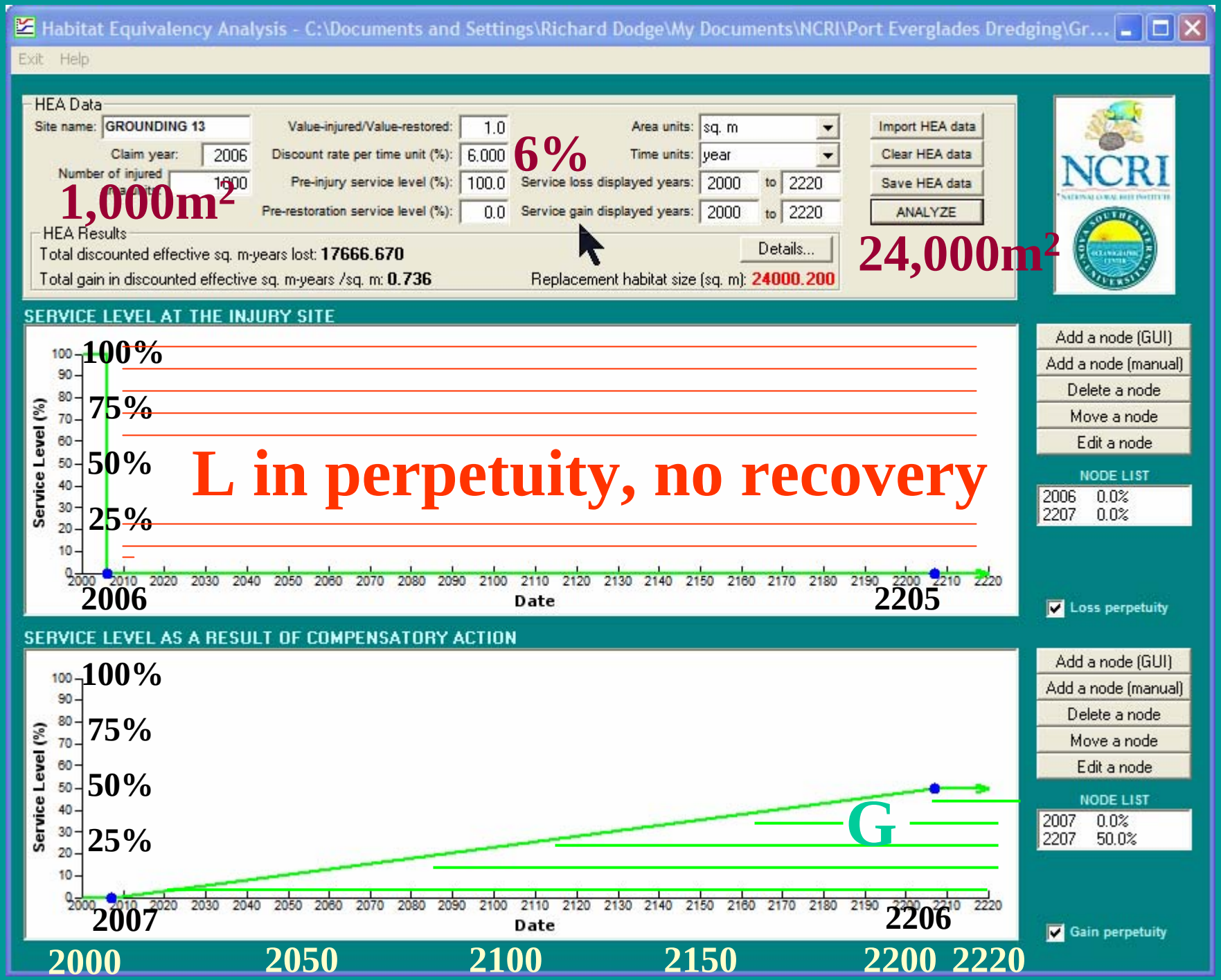
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HEA Data
Site name: GROUNDING 13
Claim year: 2006
Number of injured units: 1000
1,000m2
Value-injured/Value-restored: 1.0
Discount rate per time unit (%): 6.000
6%
Pre-injury service level (%): 100.0
Pre-restoration service level (%): 0.0
Area units: sq. m
Time units: year
Service loss displayed years: 2000 to 2220
Service gain displayed years: 2000 to 2220
Import HEA data
Clear HEA data
Save HEA data
ANALYZE
HEA Results
Total discounted effective sq. m-years lost: 17666.670
Total gain in discounted effective sq. m-years /sq. m: 0.736
Details...
Replacement habitat size (sq. m): 24000.200
24,000m2
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E
SERVICE LEVEL AT THE INJURY SITE
Service Level (%)
100%
75%
50%
25%
L in perpetuity, no recovery
2006
2205
Date
Add a node (GUI)
Add a node (manual)
Delete a node
Move a node
Edit a node
NODE LIST
2006 0.0%
2207 0.0%
Loss perpetuity
SERVICE LEVEL AS A RESULT OF COMPENSATORY ACTION
Service Level (%)
100%
75%
50%
25%
G
2007
2206
Date
Add a node (GUI)
Add a node (manual)
Delete a node
Move a node
Edit a node
NODE LIST
2007 0.0%
2207 50.0%
Gain perpetuity
2000
2050
2100
2150
2200
2220

HEA Parameters:
Landscape Results

Scenario	A	B	C	D	E
INJURY Parameters					
Start Year	2006	2006	2006	2006	2006
Amount of Injury (m2)	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**
Recovery (Years)	200	200	200	never	never
Recovers to ?% full services	100%	100%	100%	0%	0%
COMPENSATION Parameters					
Start Year	2007	2007	2007	2007	2007
Reaches ?% full services	100%	100%	50%	100%	50%
Time to Equilibrium (years)	200	200	200	200	200
DISCOUNT RATE	3%	6%	3%	3%	6%
Compensation Amount (m2)	**4,957**	**10,880**	**9,962**	**5,987**	**24,000**

What Works: HEA Utility

- HEA calculates amount of compensatory area due as a result of an injury.
- Allows comparison of restoration alternatives under multiple scenarios of injury recovery, service levels, and restoration type (speeded by software).
- Focuses on reef processes, services parameters, not $.
- While $ are important, reef biology, geology, and functionality dictate restoration considerations.
- HEA useful in direct and indirect use cases, e.g., lost services are biological uses: substrate, habitat, pollution sinks, wave breaks, habitat, etc.
- RT & RP agree on HEA & parameters

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Lessons to be Learned:

- **Early action primary restoration of injury resources avoids higher compensatory restoration requirements.**
- **HEA useful, calculates compensation scenarios, & focuses RT and RP on Reef Restoration as an necessary management tool.**
- **Discount Rate important. Not necessarily necessary to use "standard" 3%. Higher discount rate (pay me now) means higher compensation.**

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Recommendations

- HEA useful (but only as good as its input: GIGO)
- Compensatory Action tool
- Tool to focus RP and RT on correct input parameters, many of which are biological.
- Software allows easy calculation and scenario comparisons
- Goal: Achieve Optimal & Fair Compensation for Reef Injuries