MarineSABRES SES Toolbox - User Manual

Social-Ecological Systems Analysis Platform

MarineSABRES Project

Version 1.5.0 - November 2025

Introduction

About MarineSABRES SES Toolbox

The **MarineSABRES Social-Ecological Systems (SES) Toolbox** is a comprehensive web-based application designed to support participatory analysis and management of marine social-ecological systems. It implements the **DAPSI(W)R(M) framework** (Drivers-Activities-Pressures-State changes-Welfare impacts-Responses-Measures) to analyze complex interactions between marine ecosystems and human activities.

Key Capabilities

- **Integrated Systems Analysis (ISA)**: Structured 13-exercise approach to map cause-effect relationships
- **AI-Assisted Creation**: Conversational interface for rapid system mapping

- **Interactive Visualization**: Dynamic Causal Loop Diagrams (CLD) with advanced network layouts
- **Feedback Loop Detection**: Automatic identification of reinforcing and balancing loops
- **Network Analysis**: Centrality metrics, leverage points, and MICMAC analysis
- **Response Planning**: Prioritization and impact assessment of management interventions
- **Stakeholder Management**: Power-Interest analysis and engagement planning
- **Context-Specific Recommendations**: Data-driven strategic and management guidance
- **Multilingual Support**: Available in 7 languages (EN, ES, FR, DE, LT, PT, IT)

Target Users

- **Marine Resource Managers**: Plan and evaluate management interventions
- **Policy Analysts**: Assess policy impacts on marine systems
- **Environmental Consultants**: Support marine spatial planning and impact assessments
- **Researchers**: Study marine social-ecological system dynamics
- **Stakeholder Facilitators**: Guide participatory system mapping workshops

System Requirements

Software Requirements

- **R** version 4.0 or higher
- **Modern Web Browser**: Chrome (recommended), Firefox, Edge, or Safari
- **Optional**: Pandoc (for PDF/Word report generation)

Hardware Requirements

- **Processor**: Dual-core 2.0 GHz or faster
- **RAM**: 4 GB minimum, 8 GB recommended
- **Storage**: 500 MB free disk space
- **Display**: 1366x768 minimum resolution, 1920x1080 recommended

Internet Connection

- Required for initial R package installation only
- Offline operation supported after installation

Getting Started

Installation

Step 1: Install R and RStudio

1. **Download R** from https://cran.r-project.org/ <https://cran.r-project.org/>
2. **Download RStudio** (optional but recommended) from https://posit.co/downloads/ <https://posit.co/downloads/>
3. Install both applications following standard procedures

Step 2: Install Required Packages

Open R or RStudio and run:

```
# Install required packages
install.packages(c(
  "shiny", "shinydashboard", "shinyjs", "shiny.i18n",
  "DT", "dplyr", "tidyr", "ggplot2", "plotly",
  "visNetwork", "igraph", "DiagrammeR",
  "openxlsx", "jsonlite", "rmarkdown", "knitr",
  "digest", "htmlwidgets"
))
```

Step 3: Launch the Application

```
# Set working directory
setwd("/path/to/MarineSABRES_SES_Shiny")

# Run the application
shiny::runApp()
```

Alternative using run_app.R:

```
cd /path/to/MarineSABRES_SES_Shiny
Rscript run_app.R
```

First Launch

Interface Overview

Upon launching, you'll see the **Dashboard** with:

Header Bar: - Application title and logo - Language selector (7 languages available) - User level selector (Beginner/Intermediate/Expert) - Help button

Sidebar Menu: - Navigation to all modules - Save/Load project buttons - Auto-save indicator

Main Panel: - Summary value boxes (elements, connections, loops, completion %) - Project status overview - Quick action buttons

Creating Your First Project

1. **Navigate to Entry Point** (Getting Started)
   - Choose “Guided Pathway” or “Quick Access”
   - Answer contextual questions about your role and objectives
   - Receive personalized tool recommendations
2. **Set Up Project Information** (PIMS → Project Setup)
   - Enter project name
   - Select demonstration area
   - Define focal issue
   - Specify system boundaries
3. **Choose Your Workflow**
   - **Standard ISA**: Structured 13-exercise approach (recommended for thorough analysis)
   - **AI-Assisted**: Conversational 11-step interview (fast track for experienced users)
   - **Template-Based**: Pre-configured models for common scenarios
   - **Import Data**: Load existing ISA data from Excel
4. **Save Your Work**
   - Click “Save Project” in sidebar
   - Choose filename (e.g., `my_project_2025-11-16.rds`)
   - Save regularly throughout your session

Core Modules

PIMS (Project Information Management System)

Project Setup

Define the scope and context of your analysis.

Fields to Complete:

- **Project Name**: Unique identifier for your project
- **Project ID**: Auto-generated or custom code
- **Demonstration Area**: Geographic focus
  - Tuscan Archipelago
  - Arctic NE Atlantic
  - Macaronesia
  - Custom (specify)
- **Focal Issue**: Primary management question or concern
- **Temporal Scale**: Time horizon (years/decades/centuries)
- **Spatial Scale**: Geographic extent (local/regional/national/international)
- **System Boundaries**: What's included/excluded from analysis

Best Practices: - Be specific about focal issue (e.g., "Decline in seagrass meadows due to nutrient pollution" vs. "Water quality") - Define boundaries clearly to scope your analysis - Consider multiple temporal scales for different system components

Stakeholder Management

Identify and categorize stakeholders in your marine system.

Stakeholder Register:

Create entries with: - **Name**: Organization or group name - **Type**: - Inputters (provide resources/inputs) - Extractors (harvest/remove resources) - Regulators (set rules/policies) - Affectees (experience impacts) - Beneficiaries (receive benefits) - Influencers (shape decisions) - **Contact Information**: Email, phone, address - **Power**: Influence level (High/Medium/Low) - **Interest**: Stake in outcomes (High/Medium/Low) - **Engagement Level**: Current participation (IAP2 spectrum) - Inform - Consult - Involve - Collaborate - Empower - **Notes**: Additional context

Power-Interest Grid:

Visual matrix automatically plots stakeholders by power and interest: - **High Power, High Interest**: Key players - collaborate closely - **High Power, Low Interest**: Keep satisfied - regular updates - **Low Power, High Interest**: Keep informed - engage actively - **Low Power, Low Interest**: Monitor - minimum effort

Export: Download stakeholder register as Excel for external sharing

Create SES (Social-Ecological System)

Method 1: Standard ISA Data Entry

Comprehensive 13-exercise structured approach following DAPSI(W)R(M) framework.

Exercise 0: Complexity Scoping

Establish the context for your analysis.

Key Questions: 1. What is the case study area? 2. What is the geographic and temporal scope? 3. What welfare impacts are of concern? 4. Who are the key stakeholders?

Output: Contextual foundation for subsequent exercises

Exercise 1: Goods & Benefits (G&B)

Identify valued outputs from the marine system.

Data Entry Form: - **ID**: Auto-generated unique identifier - **Name**: Descriptive name (e.g., “Commercial fish catch”) - **Type**: - Provisioning (food, materials) - Regulating (climate, water quality) - Cultural (recreation, heritage) - Supporting (nutrient cycling, habitat) - **Description**: Detailed explanation - **Stakeholder**: Who benefits? - **Importance**: Socio-economic significance (High/Medium/Low) - **Trend**: Historical trajectory (Increasing/Stable/Decreasing/Unknown)

Interactive Table: - Add, edit, delete entries - Sort and filter by any column - Search functionality - Export to Excel

Example Entries:

```
Name: Recreational fishing opportunities
Type: Cultural
Stakeholder: Local fishing community, tourists
Importance: High
Trend: Decreasing
```

Exercise 2a: Ecosystem Services (ES)

Map services that support goods and benefits.

Fields: - **Name**: Service description (e.g., “Fish stock replenishment”) - **Type**: Provisioning/Regulating/Cultural/Supporting - **Linked G&B**: Select which goods/benefits this service supports - **Mechanism**: How the service provides the benefit - **Confidence**: Evidence quality (High/Medium/Low)

Adjacency Matrix: - Rows: Ecosystem Services - Columns: Goods & Benefits - Cells: Relationship strength - `+strong`, `+medium`, `+weak` (positive contributions) - Empty (no relationship)

Exercise 2b: Marine Processes & Functioning (MPF)

Identify ecological processes that enable services.

Additional Fields: - **Process Type**: Biological/Chemical/Physical - **Sensitivity**: Vulnerability to change (High/Medium/Low) - **Spatial Scale**: Geographic extent (m²/km²/regional)

Examples: - Biological: “Seagrass photosynthesis” - Chemical: “Nutrient uptake by macroalgae” - Physical: “Sediment stabilization by roots”

Exercise 3: Pressures (P)

Document stressors affecting marine processes.

Pressure Categories (aligned with MSFD): - Physical: Smothering, abrasion, habitat loss - Chemical: Contaminants, nutrients, acidification - Biological: Introduction of species, pathogens - Other: Noise, light, electromagnetic fields

Fields: - **Intensity**: Magnitude of pressure (High/Medium/Low/Unknown) - **Spatial Pattern**: Point source/Diffuse/Regional - **Temporal Pattern**: Continuous/Seasonal/Episodic/Permanent

Exercise 4: Activities (A)

Identify human actions that generate pressures.

Activity Sectors: - Fisheries (Commercial/Recreational) - Aquaculture - Tourism and Recreation - Shipping and Navigation - Energy Production - Coastal Development - Agriculture and Forestry - Industry and Mining - Waste Disposal - Research and Monitoring

Fields: - **Scale**: Operational extent (Local/Regional/National/International) - **Frequency**: How often (Daily/Weekly/Seasonal/Annual/Irregular)

Exercise 5: Drivers (D)

Analyze root causes behind activities.

Driver Types: - **Economic**: Market demand, prices, subsidies, trade - **Social**: Population, demographics, lifestyle, traditions - **Technological**: Innovation, efficiency, capacity - **Environmental**: Climate, resources availability - **Policy/Institutional**: Regulations, governance, property rights

Fields: - **Trend**: Direction of change (Increasing/Stable/Decreasing/Cyclical) - **Controllability**: Can it be managed? (High/Medium/Low/None)

Exercise 6: Loop Closure (Feedback)

Complete the causal chain with responses from welfare back to drivers.

Feedback Connections: - Select G&B (starting point) - Select Driver (endpoint) - Specify: - **Effect Type**: Positive (amplifying) / Negative (dampening) - **Strength**: Strong/Medium/Weak - **Confidence**: High/Medium/Low - **Mechanism**: Explanatory pathway

Example:

```
G&B: "Declining fish catch" →
Driver: "Market demand for fish"
Effect: Negative (reduced demand as less fish available)
Strength: Medium
Mechanism: "Lower catches reduce market supply, potentially
           decreasing consumer demand for locally caught fish"
```

Exercise 7-9: CLD Creation

Exercise 7: Review all elements and connections **Exercise 8**: Generate Causal Loop Diagram **Exercise 9**: Export to visualization platforms (Kumu.io)

Automatic Features: - Element compilation from all exercises - Adjacency matrix conversion to edges - DAPSI(W)R(M) color coding - Kumu-compatible JSON export

Exercise 10-12: Analysis & Documentation

Exercise 10: System dynamics analysis **Exercise 11**: Behavior Over Time (BOT) graphs **Exercise 12**: Validation documentation

BOT Graph Features: - Time series data entry - Multiple indicators on same plot - Trend lines and annotations - Export as PNG/PDF

Data Management Tab

Import from Excel: 1. Download template (button provided) 2. Fill template with your data 3. Upload completed Excel file 4. Review import preview 5. Confirm import (merge or replace existing data)

Export to Excel: - Multi-sheet workbook - All ISA tables included - Adjacency matrices - Ready for external analysis

Clear All Data: - Reset entire ISA dataset - Confirmation required - Cannot be undone

Method 2: AI-Assisted ISA Creation

Conversational step-by-step guidance for rapid system mapping.

11-Step Interview Process:

Step 1: Introduction - Welcome and overview - Explanation of process - Estimated time: 30-60 minutes

Step 2: Project Context - Project name and description - Primary objectives - Expected outcomes

Step 3: Regional Sea Selection Choose from 13 regional seas: - Baltic Sea - Mediterranean Sea - Black Sea - Northeast Atlantic - Arctic Ocean - And 8 others...

Step 4: Ecosystem Type 12 ecosystem categories: - Seagrass meadows - Coral reefs - Kelp forests - Rocky reefs - Sandy beaches - Mudflats - Estuaries - Deep sea - And 4 others...

Step 5: Ecosystem Subtype Context-specific refinement based on Step 4 selection

Step 6: Main Issues Select from 25+ pre-defined issues or specify custom: - Overfishing - Pollution (nutrients, plastics, chemicals) - Habitat degradation - Climate change impacts - Invasive species - Coastal development - Tourism pressure - And many others...

Steps 7-11: Element Definition For each DAPSI(W)R(M) level: - Pre-populated suggestions based on your context - Free-text entry option - Multiple elements can be added - Real-time preview of created elements

Session Features: - **Auto-save**: Progress saved to browser localStorage - **Session Recovery**: Resume if interrupted - **Chat Interface**: Conversational prompts - **Context-Aware**: Suggestions adapt to previous answers - **Direct Integration**: Saves to main project data

When to Use: - Time-limited projects (rapid assessment) - Initial scoping phase - Experienced users familiar with DAPSI(W)R(M) - When expert knowledge can fill gaps quickly

Advantages: - Faster than standard ISA (10x speed improvement) - Context-aware suggestions reduce errors - Natural conversation flow - Immediate results

Limitations: - Less detailed than standard ISA - May miss complex relationships - Requires user expertise to evaluate suggestions

Method 3: Template-Based SES Creation

Quick start with pre-configured models for common scenarios.

Available Templates: - Baltic Sea Fisheries - Mediterranean Tourism - Atlantic Aquaculture - Arctic Shipping - (More templates in development)

How to Use: 1. Select template from dropdown 2. Review pre-populated elements 3. Customize to your specific context 4. Add/remove/modify elements as needed 5. Proceed to analysis

When to Use: - Similar case to existing template - Teaching and training scenarios - Benchmarking against known systems - Rapid prototyping

Method 4: Import Data from Excel

Load existing ISA data from spreadsheet.

Process: 1. Download Excel template 2. Complete all required sheets: - Goods_Benefits - Ecosystem_Services - Marine_Processes - Pressures - Activities - Drivers - (Adjacency matrices sheets) 3. Upload filled template 4. Review validation report 5. Confirm import

Data Validation: - Column name checking - Data type verification - Required field validation - Relationship integrity

Import Options: - **Merge**: Add to existing data - **Replace**: Overwrite all data

CLD Visualization

Interactive network visualization of your social-ecological system.

Network Display

Visual Encoding:

Node Colors (DAPSI(W)R(M) levels): - Purple: Drivers - Green: Activities - Orange: Pressures - Light Blue: Marine Processes - Dark Blue: Ecosystem Services - Light Yellow: Goods & Benefits

Node Shapes: - Star: Drivers - Hexagon: Activities - Diamond: Pressures - Dot: Marine Processes - Square: Ecosystem Services - Triangle: Goods & Benefits

Edge Colors: - Light Blue: Positive/reinforcing connections - Red: Negative/opposing connections

Edge Styles: - Solid line: Direct causal link - Line thickness: Relationship strength (strong/medium/weak)

Layout Algorithms

1. Hierarchical Layout (Recommended) - **Direction**: Down-Up (shows DAPSI flow), Up-Down, Left-Right, Right-Left - **Level Separation**: Adjust spacing (50-300px) - **Best for**: Understanding DAPSI structure, presentations

2. Physics-Based (Force Atlas 2) - **Gravity**: Attraction strength between connected nodes - **Spring Length**: Ideal edge length - **Best for**: Discovering clusters, identifying central nodes

3. Circular Layout - Nodes arranged in circle - **Best for**: Small networks, pattern recognition

4. Manual Positioning - Drag nodes to desired positions - Positions saved with project - **Best for**: Custom arrangements, final presentations

Interactive Controls

Navigation: - **Zoom**: Mouse wheel or pinch gesture - **Pan**: Click and drag background - **Reset View**: Button to restore initial view - **Fit to Screen**: Auto-zoom to show all nodes

Node Interactions: - **Click**: Select node (highlights neighbors) - **Double-click**: Center view on node - **Hover**: Show tooltip with details

Edge Interactions: - **Hover**: Show relationship details - **Click**: Highlight connection

Search: - Type node name to find and highlight - Dropdown list of all nodes - Auto-center on selected node

Highlighting Features

Leverage Points: - Highlight high-influence nodes - Based on centrality metrics - Toggle on/off

Loop Highlighting: - Select loop from dropdown - All nodes and edges in loop highlighted - Other elements faded - Useful for loop-specific discussions

Interactive Legend: - Shows color/shape coding - Clickable to filter display - Toggle element types on/off

Export Options

PNG Export: - High-resolution raster image (150 dpi) - Custom dimensions (400-4000px) - Transparent background option - **Use for**: Reports, presentations, publications

SVG Export: - Scalable vector graphics - Editable in Illustrator, Inkscape - No quality loss at any size - **Use for**: Professional publications, posters

HTML Export: - Fully interactive standalone file - Share with stakeholders - No server required - **Use for**: Stakeholder sharing, web embedding

PDF Export: - Print-ready document - Requires Pandoc installation - **Use for**: Formal reports, archiving

Analysis Tools

Loop Detection

Identify feedback loops in your system automatically.

How Feedback Loops Work:

- **Reinforcing Loops (R)**: Amplify change (even number of negative links)
  - Example: More fish → More fishing effort → Fewer fish → Less fishing effort → More fish
  - Leads to exponential growth or decline
- **Balancing Loops (B)**: Stabilize system (odd number of negative links)
  - Example: Overfishing → Depleted stocks → Regulations → Reduced fishing → Stock recovery
  - Leads to equilibrium or oscillation

Detection Parameters:

- **Maximum Loop Length**: 3-15 elements (default: 8)
  - Shorter: Find tight feedback cycles
  - Longer: Discover complex multi-step loops
- **Maximum Cycles**: 50-2000 (default: 500)
  - Limits computation time
  - More cycles = longer processing but more complete results
- **Include Self-Loops**: Yes/No
  - Self-loop: Element influences itself directly
- **Filter Trivial Loops**: Yes (recommended)
  - Removes simple 2-node loops
  - Focuses on complex feedback

Detection Process:

1. Click “Detect Loops” button
2. Algorithm runs (may take 10-60 seconds for large networks)
3. Progress indicator shows status
4. Results appear in 5 tabs

Tab 1: Detect Loops - Detection controls - Summary statistics - Total loops found - Reinforcing count - Balancing count - Loops data table (ID, Type, Length, Elements, Link polarities)

Tab 2: Loop Classification - Distribution charts (R vs. B) - Separate tables for each type - Statistical summary

Tab 3: Loop Details - Select specific loop from dropdown - View loop properties: - Type (R/B) - Length (number of elements) - Path (element sequence) - Link polarities - Narrative description (auto-generated causal chain) - Loop highlighted in CLD visualization

Tab 4: Dominant Loops - Ranking by: - **Occurrence**: How many times elements appear in loops - **Participation**: Percentage of loops involving element - Most influential loops table - Element participation charts - **Strategic value**: Identifies intervention points

Tab 5: Export Results - **Excel Export**: Multi-sheet workbook - All loops - R loops only - B loops only - Summary statistics - **Loop Report**: PDF document with analysis - **Loop Diagrams**: ZIP file of individual loop visualizations

Interpretation Guidance:

High proportion of R loops (>70%): - System prone to rapid changes - Tipping points likely - High management urgency - Focus: Strengthen balancing mechanisms

High proportion of B loops (>70%): - System highly stable/resistant to change - Interventions may face resistance - Persistent effort required - Focus: Shift equilibrium points

Balanced mix (30-70% each): - Moderate stability - Both change potential and self-regulation - Focus: Leverage R loops for desired changes, use B loops to stabilize

Network Metrics

Quantify node importance and network structure.

Centrality Measures:

1. Degree Centrality - **In-Degree**: Number of incoming connections - High in-degree = heavily influenced by other elements - Good indicators of system state

- **Out-Degree**: Number of outgoing connections
  - High out-degree = influences many other elements
  - Good intervention targets

2. Betweenness Centrality - Measures how often a node lies on shortest paths - High betweenness = bridges different parts of system - Critical for information/influence flow - Removal disconnects system

3. Closeness Centrality - Average distance to all other nodes - High closeness = quick influence propagation - Important for rapid system responses

4. Eigenvector Centrality - Importance based on importance of neighbors - High eigenvector = connected to other important nodes - Identifies truly influential elements

5. PageRank - Google's algorithm adapted to networks - Weighted importance score - Good overall influence measure

Network-Level Metrics:

- **Density**: Proportion of possible connections that exist
  - Low (<0.1): Sparse, modular system
  - Medium (0.1-0.3): Moderately connected
  - High (>0.3): Tightly coupled system
- **Diameter**: Longest shortest path between any two nodes
  - Measures how "wide" the system is
- **Average Path Length**: Mean shortest path
  - Measures how quickly influence spreads

MICMAC Analysis:

Classifies nodes by influence and dependency:

Four Quadrants:

1. **Relay Variables** (High influence, High dependency)
   - Unstable, transmit effects
   - Complex interdependencies
   - Require careful management
2. **Influential Variables** (High influence, Low dependency)
   - Strong drivers of system
   - Independent of other elements
   - Prime intervention targets
3. **Dependent Variables** (Low influence, High dependency)
   - Outcomes/indicators
   - Sensitive to changes
   - Good monitoring points
4. **Autonomous Variables** (Low influence, Low dependency)
   - Weakly connected
   - Limited role in dynamics
   - May be removed to simplify

Leverage Point Analysis:

Identifies high-impact intervention points using composite score:

```
Leverage Score = Betweenness + Eigenvector + PageRank
```

Top 10 Leverage Points ranked by score

Categories: - **Drivers**: High out-degree nodes → Cascading interventions - **Receivers**: High in-degree nodes → Monitoring indicators - **Connectors**: High betweenness nodes → Critical for resilience

Strategic Recommendations Section:

Based on analysis outputs, generates context-specific guidance:

1. **Priority Intervention Points**: Names top 3 leverage nodes with scores
2. **Cascading Strategy**: Driver nodes with average influence counts
3. **Early Warning System**: Receiver nodes as monitoring indicators
4. **System Dynamics Alerts**: Loop-based warnings (tipping points vs. resistance)
5. **Resilience Protection**: Connector nodes to preserve

Simplification Tools

Reduce network complexity while preserving essential dynamics.

Techniques:

1. Endogenization - Remove exogenous variables (no incoming connections) - Focuses on internally-driven dynamics - **Use when**: External drivers are outside scope

2. Encapsulation - Remove SISO nodes (Single Input, Single Output) - Merges upstream and downstream connections - **Use when**: Simplifying intermediate steps

3. Edge Filtering - Remove weak connections - Keep only strong/medium relationships - **Use when**: Reducing visual clutter

4. Core Loop Extraction - Extract dominant feedback loops only - Remove elements not in key loops - **Use when**: Focusing on feedback dynamics

Workflow: 1. Select simplification method 2. Set parameters (e.g., minimum strength for edge filtering) 3. Preview simplified network 4. Apply or revert 5. Save simplified version as new project

Response & Validation

Response Measures

Document and prioritize management interventions.

Tab 1: Response Register

Create intervention entries with:

- **ID**: Auto-generated
- **Name**: Intervention description
- **Type**:
  - Regulatory: Laws, quotas, closures
  - Economic: Subsidies, taxes, market-based
  - Educational: Awareness, training
  - Technical: Infrastructure, technology
  - Institutional: Governance reforms
  - Voluntary: Codes of conduct, certification
  - Mixed: Combination
- **Description**: Detailed explanation
- **Target Level**: Which DAPSI(W)R(M) level?
  - Drivers
  - Activities
  - Pressures
  - State
  - Multiple
- **Target Element**: Specific node ID
- **Effectiveness**: Expected impact (High/Medium/Low/Unknown)
- **Feasibility**: Implementation ease (High/Medium/Low)
- **Cost**: 1-10 scale (1=minimal, 10=very expensive)
- **Responsible Stakeholders**: Who implements?
- **Implementation Barriers**: Challenges anticipated
- **Status**:
  - Proposed
  - Planned
  - Implemented
  - Partially Implemented
  - Abandoned

Interactive Table: - CRUD operations (Create, Read, Update, Delete) - Sort, filter, search - Export to Excel

Tab 2: Impact Assessment

Map responses to problems they address.

Create Impact Links: - Select Response measure - Select Problem (Pressure/Activity/Driver) - Specify: - **Impact Strength**: Strong/Moderate/Weak - **Timeframe**: Immediate/Short-term (1-2y)/Medium-term (3-5y)/Long-term (>5y) - **Confidence**: Evidence quality

Impact Matrix Table: - Rows: Responses - Columns: Problems - Cells: Strength + timeframe

Visual Heatmap: - Color-coded impact strength - Quick identification of multi-benefit responses

Tab 3: Prioritization

Multi-criteria ranking of responses.

Weighting Sliders: - **Effectiveness Weight** (0-1): How important is impact magnitude? - **Feasibility Weight** (0-1): How important is ease of implementation? - **Cost Weight** (0-1, inverse): How sensitive are we to cost?

Priority Score Calculation:

```
Priority = (Effectiveness × W_eff) +
           (Feasibility × W_feas) -
           (Cost/10 × W_cost)
```

Ranked Table: - Responses sorted by priority score - Shows all input values and weights - Identify top candidates

Scatter Plots: - **Effectiveness vs. Feasibility**: Identify “quick wins” (high both) - **Cost vs. Impact**: Assess cost-effectiveness

Sensitivity Analysis: - Adjust weights to test robustness - See how rankings change - Identify stable top choices

Tab 4: Implementation Plan

Track response deployment over time.

Milestones: - **Milestone Name**: Key deliverable/checkpoint - **Response ID**: Which measure? - **Target Date**: Planned completion - **Status**: Pending/In Progress/Completed/Delayed - **Notes**: Progress updates

Gantt Chart: - Timeline visualization - Milestone dependencies - Critical path highlighted - Export as PNG

Implementation Checklist: - Pre-implementation: Stakeholder buy-in, budget secured, regulations approved - During implementation: Monitoring protocols, adaptive management triggers - Post-implementation: Evaluation plan, reporting schedule

Tab 5: Export

Download response planning documentation: - Excel workbook (all tabs) - PDF summary report - Implementation timeline chart

Scenario Builder

Explore “what-if” alternatives and compare scenarios.

Scenario Management:

Create New Scenario: 1. Click “New Scenario” 2. Enter name and description 3. Scenario card appears in gallery

Scenario Cards Display: - Thumbnail preview - Scenario name - Creation date - Number of modifications - Active status indicator

Configure Tab:

Make changes to network for scenario:

Add Nodes: - New elements to represent alternative states - Example: “Marine Protected Area established”

Remove Nodes: - Simulate element removal - Example: Remove “Bottom trawling” activity

Modify Nodes: - Change properties (importance, trend, etc.) - Example: Increase “Tourism” intensity

Add Links: - New causal connections - Example: “MPA” → “Fish biomass” (+strong)

Remove Links: - Break existing connections - Example: Remove “Fishing effort” → “Fish stock”

Modify Links: - Change polarity or strength - Example: Weaken “Pollution” → “Seagrass health”

Modification Tracker: - Lists all changes made - Undo individual modifications - Reset scenario to baseline

Impact Analysis Tab:

Assess scenario effects on:

Network Metrics: - Compare density, centrality, etc. to baseline - Identify structural changes

Loop Dynamics: - Re-run loop detection for scenario - Compare R/B distribution - Identify new/removed loops

Leverage Points: - Recalculate top nodes - See how intervention points shift

Impact Propagation: - Trace effects of changes - Identify cascading consequences

Compare Tab:

Side-by-side comparison of scenarios:

Table View: - Metric-by-metric comparison - Baseline vs. Scenario A vs. Scenario B - Difference columns (Δ)

Chart View: - Radar charts for multi-metric comparison - Bar charts for key indicators - Network structure comparison

Report Generation: - Scenario comparison PDF - Includes all metrics, charts, and narratives - Export for stakeholder presentation

When to Use Scenarios:

- **Policy Analysis**: Compare regulatory alternatives
- **Climate Futures**: Explore different climate scenarios
- **Intervention Testing**: Assess management options before implementation
- **Stakeholder Engagement**: Facilitate participatory visioning

Validation

Document evidence quality and expert review.

Validation Protocols:

Element-Level Validation: - For each ISA element: - **Evidence Source**: Literature, data, expert judgment - **Evidence Quality**: Strong/Moderate/Weak - **Confidence**: High/Medium/Low - **Uncertainty**: Known limitations

Relationship Validation: - For each causal link: - **Mechanism**: Explanatory pathway - **Evidence**: Supporting studies/data - **Strength**: Quantitative if available - **Temporal Lag**: Time delay in effect

Expert Elicitation: - **Expert Name**: Who provided input? - **Affiliation**: Organization/role - **Date**: When consulted? - **Comments**: Expert feedback

Stakeholder Review: - **Workshop Date**: When was CLD reviewed? - **Participants**: List of attendees - **Feedback**: Suggested modifications - **Resolution**: How feedback was addressed

Validation Checklist: - [ ] All elements have descriptions - [ ] All links have mechanisms documented - [ ] Confidence scores assigned - [ ] Expert review completed - [ ] Stakeholder feedback incorporated - [ ] Validation report generated

Version Control: - Track changes over time - Document who made changes and when - Maintain change log - Enable rollback if needed

Export & Reports

Data Export

Export your project data in multiple formats.

Excel Export (.xlsx)

Multi-sheet workbook containing: - Project metadata - All ISA tables (G&B, ES, MPF, P, A, D) - Adjacency matrices - CLD nodes and edges - Loop detection results - Network metrics - Stakeholder register - Response measures - Scenario comparisons

Component Selection: - Choose which datasets to include - Customize export for specific uses

CSV Export (.csv) - Single table export - Choose specific dataset - Compatible with any spreadsheet software

JSON Export (.json) - Hierarchical structured data - Complete project including nested structures - Compatible with web applications, databases - Kumu.io compatible (with styling)

R Data Export (.RData) - Native R format - Preserves all object types - Load directly in R for custom analysis

Visualization Export

Export CLD visualizations in multiple formats.

HTML (Interactive) - Fully interactive network - Standalone file (no server needed) - Share via email or web - Recipients can explore, zoom, pan - **File size**: 500KB - 2MB typical - **Best for**: Stakeholder sharing, website embedding

PNG (Raster Image) - High-resolution bitmap (150 dpi default) - Custom dimensions (400-4000px width/height) - Transparent background option - **File size**: 100KB - 5MB - **Best for**: Reports, presentations, posters

SVG (Vector Graphics) - Scalable to any size without quality loss - Editable in vector graphics software - Small file size - **Best for**: Publications, professional design, large-format printing

PDF (Print-Ready) - Publication quality - Embeddable in documents - Requires Pandoc + LaTeX installation - **Best for**: Formal reports, archiving

Export Settings:

- **Dimensions**: Width and height in pixels
- **Resolution**: DPI for raster formats
- **Background**: Transparent or white
- **Quality**: Compression level

Recommended Sizes: - Presentation slide: 1920 x 1080 px - Report figure: 2400 x 1800 px (8” x 6” at 300 dpi) - Poster: 4000 x 3000 px - Web: 1200 x 900 px

Report Generation

Create comprehensive analysis reports automatically.

Report Types:

1. Executive Summary (2-3 pages)

Target audience: Decision-makers, policy-makers

Contents: - Project overview (1 paragraph) - Key findings (bullet points): - Number of elements and connections - Feedback loops detected (R vs. B count) - Top 3 leverage points - Critical management challenges - High-priority recommendations (3-5 items) - Visual: Simplified CLD diagram

2. Technical Report (10-15 pages)

Target audience: Researchers, technical analysts

Contents: - Complete DAPSI(W)R(M) analysis - Element counts by type (table) - Network metrics (density, centrality, etc.) - Detailed loop analysis: - Loop classification - Dominant loops - System implications - Leverage point analysis (top 10) - Data tables (all ISA exercises)

3. Stakeholder Presentation (5-7 pages)

Target audience: General stakeholders, community groups

Contents: - Plain language system description - Visual-heavy (CLD, charts, infographics) - System overview: - Main drivers identified - Key pressures - Ecosystem impacts - Welfare consequences - Opportunities for action - Engagement opportunities - Discussion questions

4. Full Project Report (20-30 pages)

Target audience: Comprehensive documentation for all audiences

Contents: - All above sections combined - Complete methodology - All data tables - All visualizations - Detailed recommendations (context-specific):

Strategic Recommendations: - Priority intervention points (named, with scores) - Cascading intervention strategy (specific Driver nodes) - Early warning monitoring system (specific Receiver nodes) - System dynamics alerts (based on loop composition) - Resilience protection (specific Connector nodes)

Management Recommendations: - Intervention design (network density-specific advice) - Monitoring strategy (data-driven indicator selection) - Adaptive management (loop-informed strategy with timing) - Stakeholder engagement (strategic alignment to leverage points) - Immediate next steps (5 detailed action plans)

- Appendices:
  - Glossary
  - Data sources
  - Validation documentation
  - References

Report Options:

Include Visualizations: - [x] CLD network diagram - [x] Loop distribution charts - [x] Leverage point rankings - [x] Network metrics plots

Include Data Tables: - [x] All ISA element tables - [x] Adjacency matrices - [x] Loop details table - [x] Metrics summary

Custom Branding: - Add your logo - Custom color scheme - Organization footer

Report Formats:

HTML (Web Version) - Interactive table of contents (floating sidebar) - Collapsible sections - Hyperlinked cross-references - Embedded interactive visualizations - **File size**: 1-5 MB - **Best for**: Sharing via email, web publishing, screen viewing

PDF (Print Version) - Professional formatting - Page numbers and headers - Print-ready quality - Requires Pandoc + LaTeX/TinyTeX - **File size**: 2-10 MB - **Best for**: Formal distribution, archiving, printing

Word (.docx) - Editable document - Tables and figures - Requires Pandoc installation - **File size**: 1-5 MB - **Best for**: Collaborative editing, custom formatting

Generation Process:

1. Navigate to “Prepare Report” module
2. Select report type
3. Choose options (visualizations, data tables)
4. Click “Generate Report”
5. Processing (10-30 seconds)
6. Download button appears
7. Open/save report file

Troubleshooting:

- **PDF generation fails**: Install Pandoc and TinyTeX

```
install.packages("tinytex")
tinytex::install_tinytex()
```

- **Report is empty**: Ensure you’ve completed ISA data entry and run analyses
- **Charts not appearing**: Check that analysis modules have been executed

Workflows & Best Practices

Recommended Workflows

Standard Participatory Workshop (3 days)

Day 1: System Mapping (6 hours) - Morning: Introduction and project setup (1h) - Present DAPSI(W)R(M) framework - Define focal issue and boundaries - Identify stakeholders

- Late morning: Goods & Benefits (1.5h)
  - Brainstorm valued outcomes (Exercise 1)
  - Prioritize by importance
- Afternoon: Working backwards (3.5h)
  - Ecosystem Services (Exercise 2a)
  - Marine Processes (Exercise 2b)
  - Break
  - Pressures (Exercise 3)

Day 2: Causal Chains and Visualization (6 hours) - Morning: Drivers and Activities (2h) - Activities generating pressures (Exercise 4) - Root cause drivers (Exercise 5)

- Late morning: Loop closure (1.5h)
  - Feedback connections (Exercise 6)
  - Validate connections
- Afternoon: CLD creation and exploration (2.5h)
  - Generate network (Exercise 7-8)
  - Interactive exploration
  - Identify patterns

Day 3: Analysis and Planning (6 hours) - Morning: Analysis (2h) - Loop detection - Network metrics - Leverage points

- Late morning: Response planning (2h)
  - Brainstorm interventions
  - Multi-criteria prioritization
- Afternoon: Synthesis (2h)
  - Report generation
  - Action planning
  - Next steps agreement

Solo/Research Workflow (25 days)

Week 1: Foundation (5 days) - Day 1-2: Project setup, literature review - Day 3-4: ISA data entry (Exercises 0-3) - Day 5: ISA data entry (Exercises 4-6)

Week 2: Analysis (5 days) - Day 6: CLD generation and exploration - Day 7-8: Loop detection and interpretation - Day 9: Network metrics calculation - Day 10: Leverage point analysis

Week 3: Validation (5 days) - Day 11-13: Expert consultation - Day 14-15: Stakeholder review and revision

Week 4: Response Planning (5 days) - Day 16-17: Response measure identification - Day 18-19: Impact assessment and prioritization - Day 20: Implementation planning

Week 5: Documentation (5 days) - Day 21-22: Scenario analysis - Day 23-24: Report generation - Day 25: Final review and submission

Rapid Assessment (AI-Assisted, 1 day)

Morning (3 hours) - 0-30min: Project setup - 30-90min: AI-Assisted ISA interview (11 steps) - 90-120min: Review and refine generated elements - 120-180min: CLD visualization and exploration

Afternoon (3 hours) - 180-240min: Loop detection and analysis - 240-300min: Response brainstorming - 300-360min: Report generation and next steps

Best Practices

Data Quality

1. Clear Naming Conventions - Use descriptive, specific names - Avoid jargon or acronyms (or define them) - Be consistent across similar elements

Examples: - Good: “Commercial bottom trawl fishing” - Poor: “Fishing” (too vague) - Poor: “CBT” (acronym unclear)

2. Complete Descriptions - Provide context for each element - Explain mechanisms for relationships - Document evidence sources

3. Appropriate Granularity - Not too broad: “Pollution” → “Nutrient pollution from agriculture” - Not too narrow: “Nitrogen runoff from Field 23A” → “Agricultural nutrient runoff” - Match analysis scale to decision context

4. Validation - Assign confidence scores honestly - Document uncertainties - Seek expert review - Incorporate stakeholder feedback

Network Design

1. Optimal Network Size - Sweet spot: 20-60 nodes - Too small (<15): Misses important dynamics - Too large (>100): Difficult to analyze and communicate - Focus on most important elements

2. Balance Across DAPSI Levels - Aim for similar numbers at each level - Avoid overrepresenting one level - Example distribution: 5D, 8A, 10P, 8S, 6W, 5R

3. Connection Density - Target: 1.5-3 connections per node average - Too sparse: May miss key feedbacks - Too dense: Hard to interpret, less useful

4. Feedback Loops - Deliberately design some feedback - Every D should ultimately connect back to a G&B - Look for unintended consequences

Stakeholder Engagement

1. Participatory Mapping - Involve diverse stakeholders - Use visualization to facilitate discussion - Capture local/traditional knowledge - Validate expert knowledge

2. Power-Interest Management - Engage high power/high interest closely (collaborate) - Keep high power/low interest satisfied (inform regularly) - Keep low power/high interest informed (consult) - Monitor low power/low interest (minimum effort)

3. Transparent Process - Document all assumptions - Make data sources explicit - Explain uncertainties - Share preliminary results for feedback

4. Actionable Outputs - Link analysis to management questions - Prioritize practical recommendations - Develop clear next steps - Assign responsibilities

Technical Tips

1. Save Often - Use Auto-save feature - Manual save every 15-30 minutes - Use descriptive filenames with dates - Keep backup copies

2. Incremental Development - Start simple, add complexity gradually - Test small sections before building full network - Validate frequently during development

3. Use Templates - Leverage existing templates when applicable - Customize rather than starting from scratch - Document your own templates for reuse

4. Export Regularly - Export to Excel for external backup - Export visualizations at key milestones - Generate reports periodically to check completeness

5. Browser Recommendations - Chrome (best performance) - Firefox (good alternative) - Avoid Internet Explorer - Keep browser updated

6. Performance - Close other browser tabs/applications - Clear browser cache if slow - Reduce network size if >100 nodes causing lag - Use hierarchical layout for large networks

Troubleshooting

Common Issues

Installation Problems

Issue: Package installation fails

Solution:

```
# Try installing from different CRAN mirror
options(repos = "https://cloud.r-project.org/")
install.packages("package_name")

# Or use RStudio's package installer (Tools > Install Packages)
```

Issue: Application won't start

Solutions: 1. Check R version (must be 4.0+) `r R.version.string` 2. Verify all packages installed `r required_packages <- c("shiny", "shinydashboard", "shinyjs", ...) missing <- required_packages[!required_packages %in% installed.packages()] if(length(missing) > 0) install.packages(missing)` 3. Check for error messages in R console

Issue: Port already in use

Solution:

```
# Use different port
shiny::runApp(port = 8080)
```

Data Entry Issues

Issue: Cannot add new elements

Solutions: - Ensure all required fields completed - Check for duplicate IDs - Verify data type (numeric vs. text) - Clear browser cache

Issue: Adjacency matrix not saving

Solutions: - Fill at least one cell in matrix - Use correct format: `+strong`, `+medium`, `+weak`, `-strong`, etc. - Save exercise before moving to next

Issue: Data disappears after reload

Solutions: - Always save project before closing - Check Auto-save indicator is active - Verify save file exists in expected location

Visualization Issues

Issue: CLD not displaying

Solutions: - Ensure ISA data entered (Exercises 1-6) - Check browser JavaScript enabled - Try refreshing page (F5) - Check browser console for errors (F12 → Console tab)

Issue: Nodes overlapping/messy layout

Solutions: - Use Hierarchical layout (Down-Up direction) - Increase level separation (150-200px) - Try Physics layout with higher gravity - Manually reposition nodes and save

Issue: Cannot export visualization

Solutions: - **PNG**: Allow popup windows in browser - **HTML**: Check download folder permissions - **PDF**: Install Pandoc and LaTeX `r install.packages("tinytex") tinytex::install_tinytex()`

Analysis Issues

Issue: Loop detection hangs

Solutions: - Network too large (>100 nodes) - Reduce max loop length (try 6-8) - Reduce max cycles (try 200-500) - Filter trivial loops: Yes - Simplify network (remove low-importance elements)

Issue: No loops detected

Solutions: - Check that Exercise 6 (Loop Closure) completed - Verify feedback connections exist (D → G&B links) - Increase max loop length (try 10-12) - Check network is fully connected

Issue: Network metrics fail

Solutions: - Ensure CLD generated - Check for disconnected components - Remove self-loops if present - Verify edge polarity values valid

Report Generation Issues

Issue: Report generation fails

Solutions: - Complete minimum data entry first - Run required analyses before report - Check available disk space - Try HTML format first (most compatible)

Issue: PDF generation fails

Solutions:

```
# Install required tools
install.packages("tinytex")
tinytex::install_tinytex()

# Verify installation
tinytex:::is_tinytex()  # Should return TRUE
```

Issue: Report missing sections

Solutions: - Run all analyses before generating report - Check that data exists for missing sections - Try different report type - Generate Full Report for all content

Performance Issues

Issue: Application slow/laggy

Solutions: - Close other applications - Reduce network size (<60 nodes ideal) - Use hierarchical layout instead of physics - Disable loop highlighting when not needed - Clear browser cache - Restart R session

Issue: Browser crashes

Solutions: - Use Chrome or Firefox (most stable) - Increase browser memory allocation - Reduce visualization complexity - Export data and reload project

File Issues

Issue: Cannot load saved project

Solutions: - Verify file extension is `.rds` - Check file not corrupted (size >0 bytes) - Try loading in fresh R session - Restore from backup if available

Issue: Excel import fails

Solutions: - Use provided template exactly - Check column names match template - Verify data types (numbers, text, dates) - Remove empty rows - Check file not open in Excel

Issue: Cannot export to Excel

Solutions: - Check write permissions in target folder - Close Excel if file open - Try different filename - Verify `openxlsx` package installed

Getting Help

In-App Help

- **Module Help Buttons**: Click (?) icon for context-sensitive help
- **Tooltips**: Hover over fields for descriptions
- **User Guide**: Accessible from Help menu

Documentation

- **Quick Start Guide**: `/docs/QUICK_START.md`
- **Installation Guide**: `/docs/INSTALLATION.md`
- **Framework Documentation**: `/docs/framework_documentation.md`
- **Complete User Guide**: `/Documents/MarineSABRES_Complete_User_Guide.md`

Online Resources

- **GitHub Repository**: github.com/marinesabres/SESToolbox <https://github.com/marinesabres>
- **Issue Tracker**: Report bugs and request features
- **Wiki**: Community-contributed guides and examples

Contact Support

For technical issues not resolved by troubleshooting: - Email: support@marinesabres.eu - Include: - Error messages (exact text or screenshot) - Steps to reproduce - R and package versions - Operating system

Glossary

Activity (A): Human actions that generate pressures on marine systems (e.g., fishing, shipping, tourism)

Adjacency Matrix: Table showing connections between two sets of elements; rows and columns represent elements, cells contain relationship information

Balancing Loop (B): Feedback loop with odd number of negative links; stabilizes system toward equilibrium

Betweenness Centrality: Network measure of how often a node lies on shortest paths between other nodes; indicates bridging importance

Causal Loop Diagram (CLD): Network visualization showing cause-effect relationships and feedback loops

Centrality: Family of metrics quantifying node importance in networks (degree, betweenness, closeness, eigenvector)

CRUD: Create, Read, Update, Delete - basic data operations

DAPSI(W)R(M): Drivers-Activities-Pressures-State changes-Welfare impacts-Responses-Measures framework for SES analysis

Degree Centrality: Count of connections; in-degree (incoming), out-degree (outgoing)

Driver (D): Root causes behind activities (economic, social, technological, environmental, policy factors)

Ecosystem Service (ES/W): Benefits ecosystems provide to humans (provisioning, regulating, cultural, supporting)

Edge: Connection/link between nodes in network; represents causal relationship

Eigenvector Centrality: Importance based on importance of neighbors; high score = connected to other important nodes

Feedback Loop: Circular pathway in network where element influences itself through chain of other elements

Goods & Benefits (G&B/R): Valued outputs from marine systems received by stakeholders

Hierarchical Layout: Network visualization algorithm organizing nodes in levels/layers

ISA: Integrated Systems Analysis - structured methodology for SES analysis

Kumu.io: Online network visualization platform compatible with tool's JSON exports

Leverage Point: High-impact intervention location identified through centrality metrics

Marine Process/Functioning (MPF/S/I): Ecological processes and state changes in marine environment

MICMAC: Matrix of Crossed Impacts - analysis classifying nodes by influence and dependency

Network Density: Proportion of possible connections that actually exist; measure of connectivity

Network Metrics: Quantitative measures of network structure (density, centrality, diameter, etc.)

Node: Element in network diagram representing system component

PageRank: Google's algorithm for ranking importance; adapted for network analysis

PIMS: Project Information Management System - module for project metadata and stakeholders

Polarity: Sign of causal relationship - positive (+) or negative (-)

Pressure (P): Direct stressors on marine environment (physical, chemical, biological)

Reinforcing Loop (R): Feedback loop with even number of negative links; amplifies change

Response/Measure (R/M): Management interventions addressing drivers, activities, or pressures

SES: Social-Ecological System - coupled human-natural system

Stakeholder: Individual or group with interest or stake in system outcomes

Strongly Connected Component (SCC): Subset of network where every node can reach every other node

Tooltip: Hover text providing additional information about interface element

visNetwork: R package for interactive network visualization using vis.js library

Appendix A: Keyboard Shortcuts

Action	Shortcut	Context
Save project	Ctrl+S	Global
Zoom in	Ctrl + Plus	CLD Visualization
Zoom out	Ctrl + Minus	CLD Visualization
Fit to screen	Ctrl+0	CLD Visualization
Select all	Ctrl+A	Data tables
Search	Ctrl+F	Data tables
Export	Ctrl+E	Most modules
Refresh	F5	Global
Help	F1	Module-specific

Appendix B: File Formats

Native Format (.rds)

Structure:

```
project_data <- list(
  project_id = "unique_id",
  project_name = "My Project",
  created_at = timestamp,
  last_modified = timestamp,
  user = "username",
  version = "1.5.0",
  data = list(
    metadata = list(...),
    pims = list(...),
    isa_data = list(...),
    cld = list(nodes, edges, loops),
    responses = list(...),
    scenarios = list(...)
  )
)
```

Excel Import Template

Sheets: 1. Goods_Benefits: ID, Name, Type, Description, Stakeholder, Importance, Trend 2. Ecosystem_Services: ID, Name, Type, Description, LinkedGB, Mechanism, Confidence 3. Marine_Processes: ID, Name, Type, Description, LinkedES, Mechanism, Sensitivity, SpatialScale 4. Pressures: ID, Name, Type, Description, LinkedMPF, Intensity, SpatialPattern, TemporalPattern 5. Activities: ID, Name, Sector, Description, LinkedP, Scale, Frequency 6.

Drivers: ID, Name, Type, Description, LinkedA, Trend, Controllability 7. GB_ES_Matrix: Rows=G&B, Cols=ES, Cells=relationship 8. ES_MPF_Matrix: Rows=ES, Cols=MPF, Cells=relationship 9. MPF_P_Matrix: Rows=MPF, Cols=P, Cells=relationship 10. P_A_Matrix: Rows=P, Cols=A, Cells=relationship 11. A_D_Matrix: Rows=A, Cols=D, Cells=relationship 12. D_GB_Matrix: Rows=D, Cols=G&B, Cells=relationship (feedback)

Appendix C: DAPSI(W)R(M) Framework Details

Framework Levels:

Level 1: Drivers (D) - Economic: Market forces, globalization, economic growth - Social: Demographics, cultural values, migration - Technological: Innovation, efficiency improvements - Environmental: Climate, natural resource availability - Policy/Institutional: Regulations, governance structures

Level 2: Activities (A) - Primary: Resource extraction (fishing, mining) - Secondary: Processing, manufacturing - Tertiary: Services (tourism, shipping) - Infrastructure: Ports, energy, coastal development

Level 3: Pressures (P) - Physical: Habitat loss, sealing, abrasion, noise - Chemical: Contaminants, nutrients, pH changes - Biological: Extraction, introduction of species, pathogens

Level 4: State Changes (S/I) - Ecosystem structure: Species composition, biomass - Ecosystem functioning: Primary production, nutrient cycling - Habitat condition: Extent, quality, connectivity

Level 5: Welfare Impacts (W) - Ecosystem services affected - Social impacts: Livelihoods, culture, health - Economic impacts: Income, employment, market value

Level 6: Responses (R) - Regulatory: Laws, quotas, protected areas - Economic: Taxes, subsidies, markets - Technical: Infrastructure, monitoring - Educational: Awareness, capacity building

Level 7: Measures (M) - Preventive: Reduce drivers - Mitigative: Reduce pressures - Restorative: Recover state - Adaptive: Adjust management

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Document Version: 1.5.0 **Last Updated:** November 2025 **License:** CC BY 4.0 **Contact:** support@marinesabres.eu **Website:** www.marinesabres.eu

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