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The utility of an expert-elicitation-informed Bayes Decision Net for Tasman Bay and Golden Bay scallop ecosystem-based management

National Science Challenges
SUSTAINABLE SEAS
Ko ngā moana whakauka

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Climate, Freshwater & Ocean Science

In this talk I will describe a BDN decision support tool for Tasman Bay and Golden Bay (TBGB) scallop management strategy evaluation (MSE).

Our scallop MSE uses a **Structured Decision Making** framework approach to EBM.

Presentation structure:

I will provide contextual background to the TBGB scallop management issues investigated

I will briefly outline the **Structured Decision Making** (SDM) framework approach as applied in our case study

I will describe the BDN used in our study and the role **Expert Elicitation** played in its development and validation.

Finally, I will show how application of our BDN model with a **SDM framework** allows stakeholders and managers to make informed management decisions.

Disclaimer:

This work was undertaken as part of a larger EBM participatory tools development project under SS.

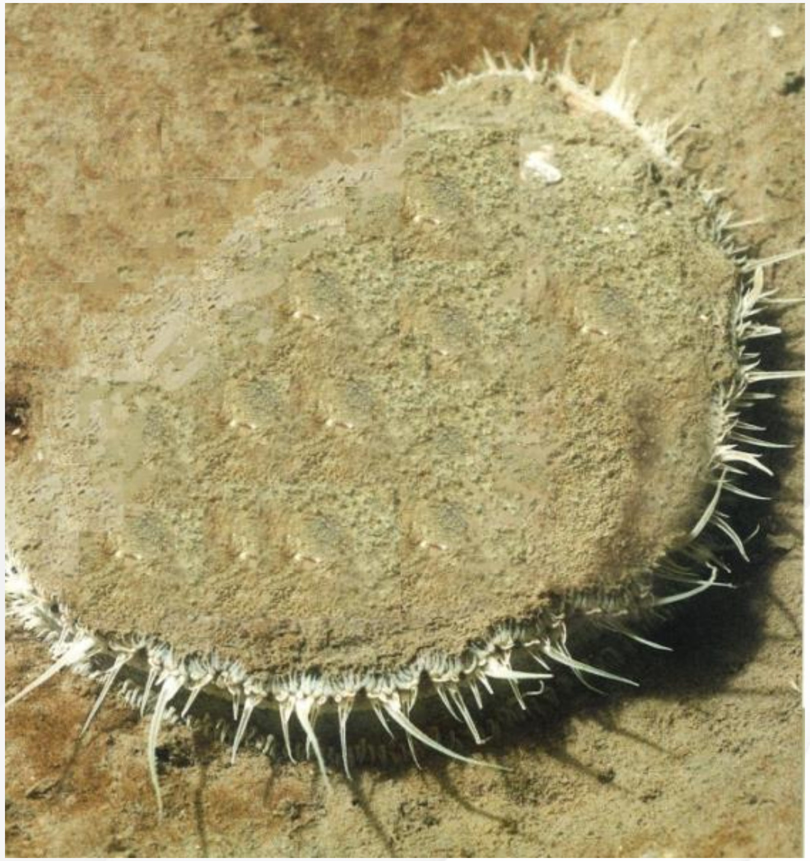
The BDN model presented today is currently **NOT** being used in TBGB scallop management decision making.

However the management objectives in our MSE framework were developed in consultation with TBGB scallop stakeholders and managers.

TBGB Scallop EBM issues

TBGB scallop stocks have high economic, social and cultural value to:

- Local iwi
- Commercial fishers
- Recreational fishers

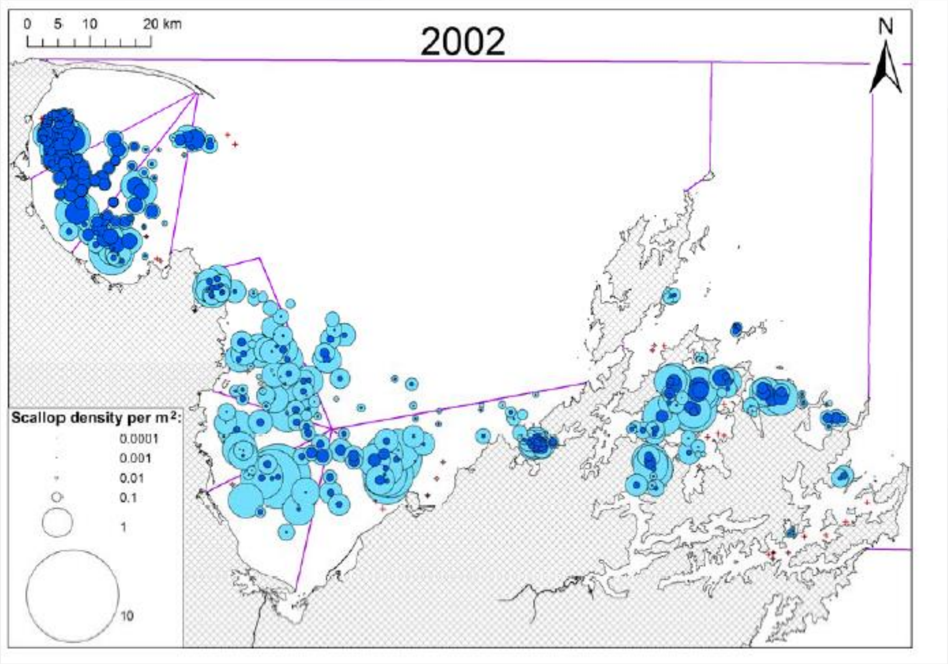


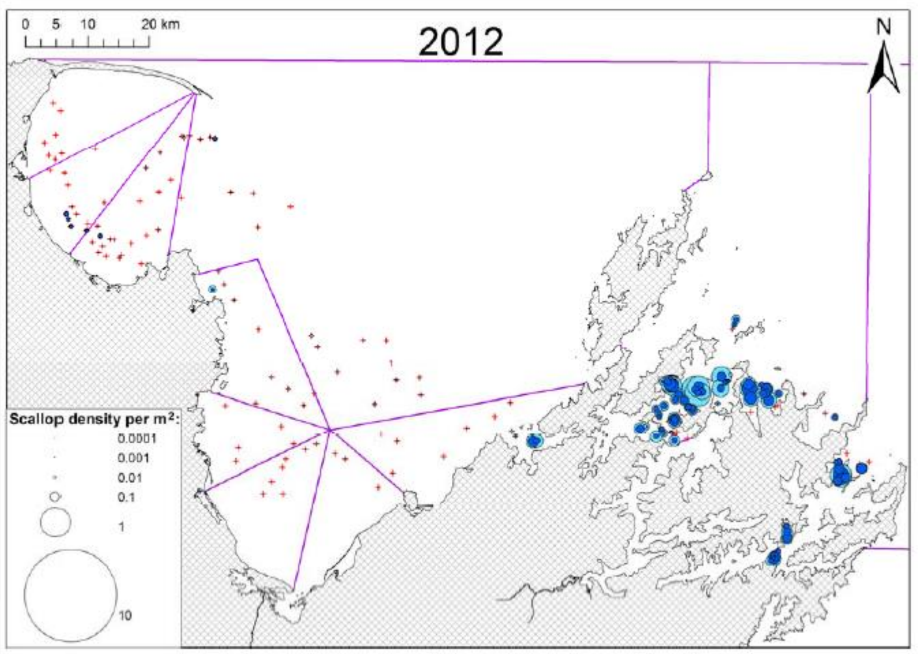
TBGB Scallop EBM issues

During the 1990’s scallops were abundant throughout TBGB and supported a 500 t pa commercial dredge fishery.

Scallop abundance fell markedly through the 2000s by 2012 most dense beds had disappeared

Since 2012 commercial scallop fishery in the wider TBGB area has been closed



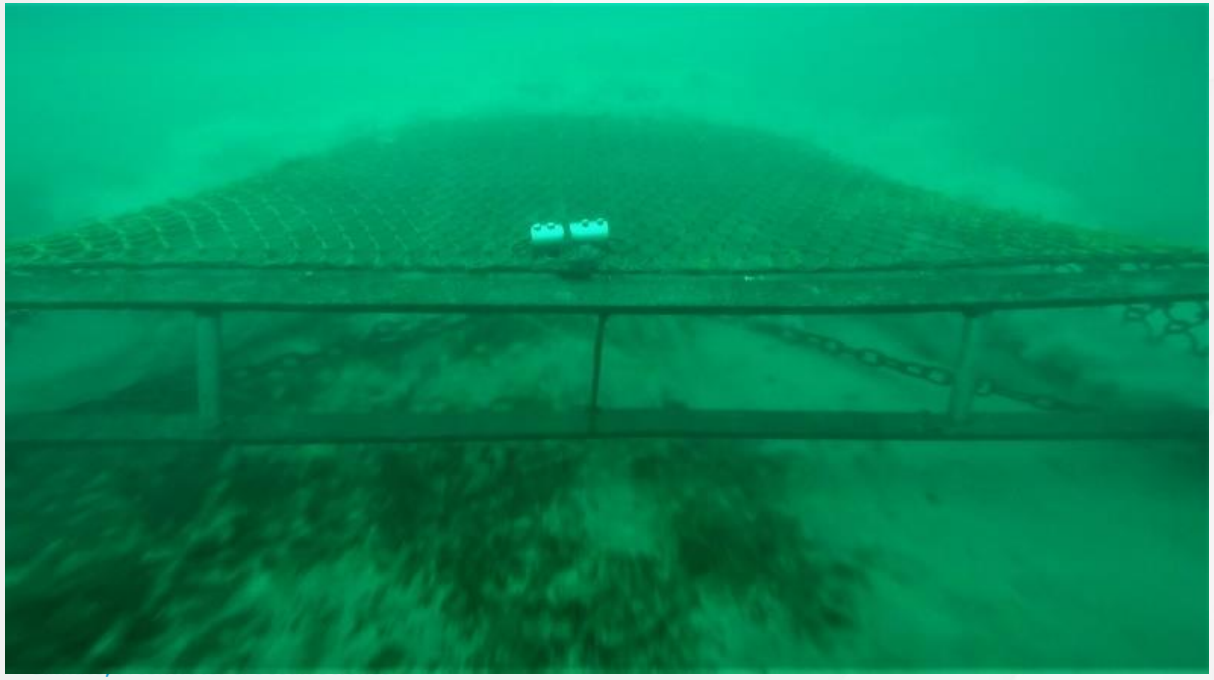


TBGB Scallop EBM issues

Despite the severe reduction in commercial fishing TBGB scallop abundance has remained low with evidence now pointing to habitat degradation the likely main cause.

The main degradation agents are:

- Past and ongoing bottom damage from scallop dredges and trawl nets
- Increased sedimentation and nutrient loadings form largely land-based activities (i.e. farming, forestry, urban development).



A SDM approach to TBGB scallop EBM decision making

A SDM approach to TBGB scallop EBM decision making

SDM Requirements

1. A set of stakeholder ecosystem objectives
2. A set of alternative management strategies for achieving these objectives
3. A method by which the "performance" of alternate management options can evaluated against stakeholder objectives

Provided by and agreed to by stakeholders and managers

Alternative management strategies

1 2 3 ...

Provided by and agreed to by stakeholders

Stakeholder Objectives

A
B
C
D
.
.

"Performance" outcome scores

Management outcome "Performance outcome scores" as derived from applying best available science understanding.

A SDM approach to TBGB scallop EBM decision making

Based on meetings with the main stakeholders including some local iwi we identified 5 TBGB scallop management **objectives:**

1. INCREASE: TBGB Scallop Productivity and accessibility
2. RESTORE: TBGB benthic biodiversity
3. RESTORE: Ecosystem health
4. INCREASE: Scallop Fishery Profitability
5. INCREASE: Fishery Profitability (finfish)

Also based on stakeholder input, we chose to investigate the relative utility of the following **management measures:**

1. Reduce bottom contact fishing (dredge & trawl)
2. Reduce terrestrial sediment run-off
3. Decrease nutrient inputs from terrestrial sources
4. Undertake seabed restoration

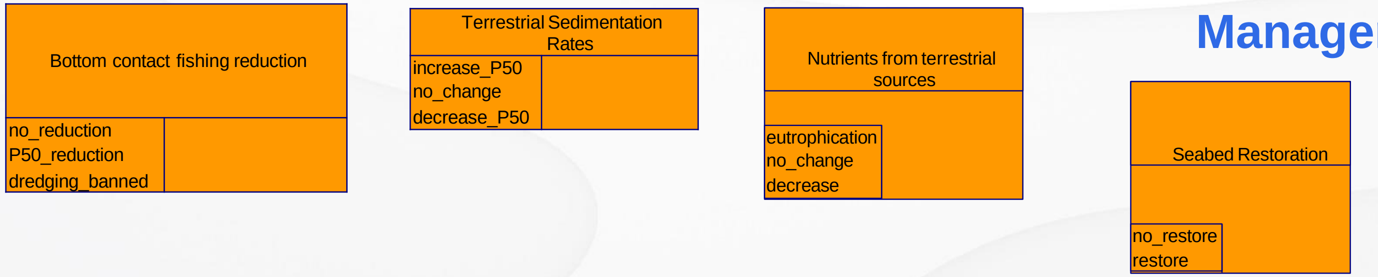
A SDM approach to TBGB scallop EBM decision making

The goal of our BDN model is to predict the likely state of the TBGB scallop ecosystem **10 years** into the future pursuant to various alternative management actions or decisions, and on the basis of this to identify the best overall set of management options i.e. ones that best meets a given set of stakeholder objectives.

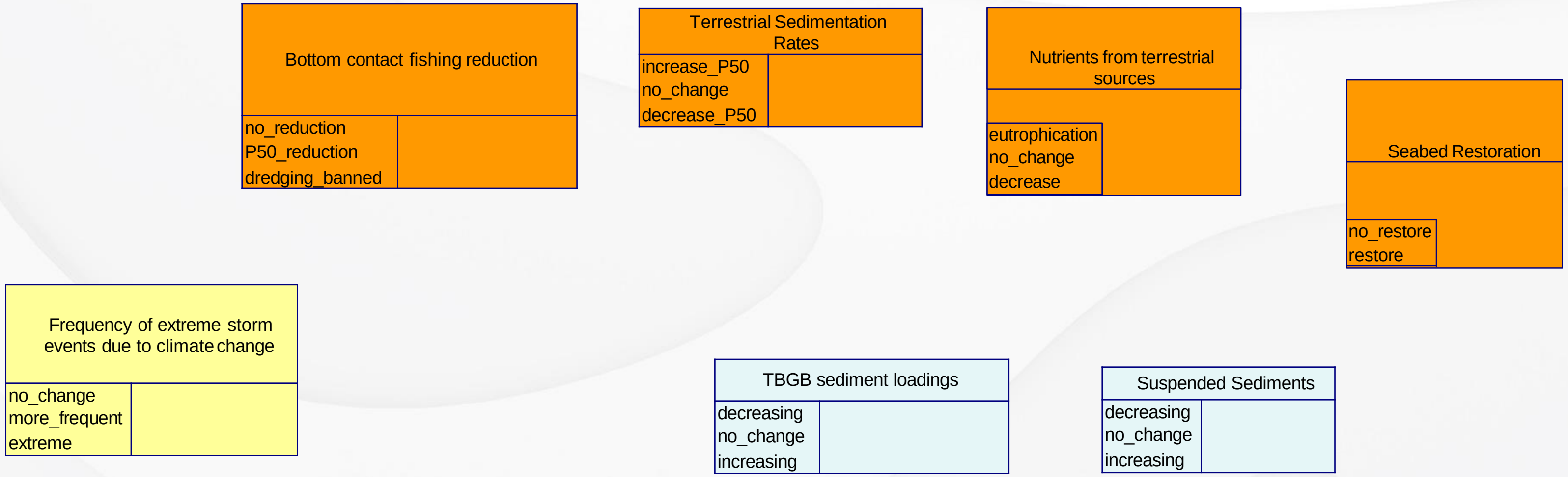
Tasman Bay and Golden Bay Scallop BDN model Structure

Tasman Bay and Golden Bay Scallop BDN model Structure

Management decision nodes

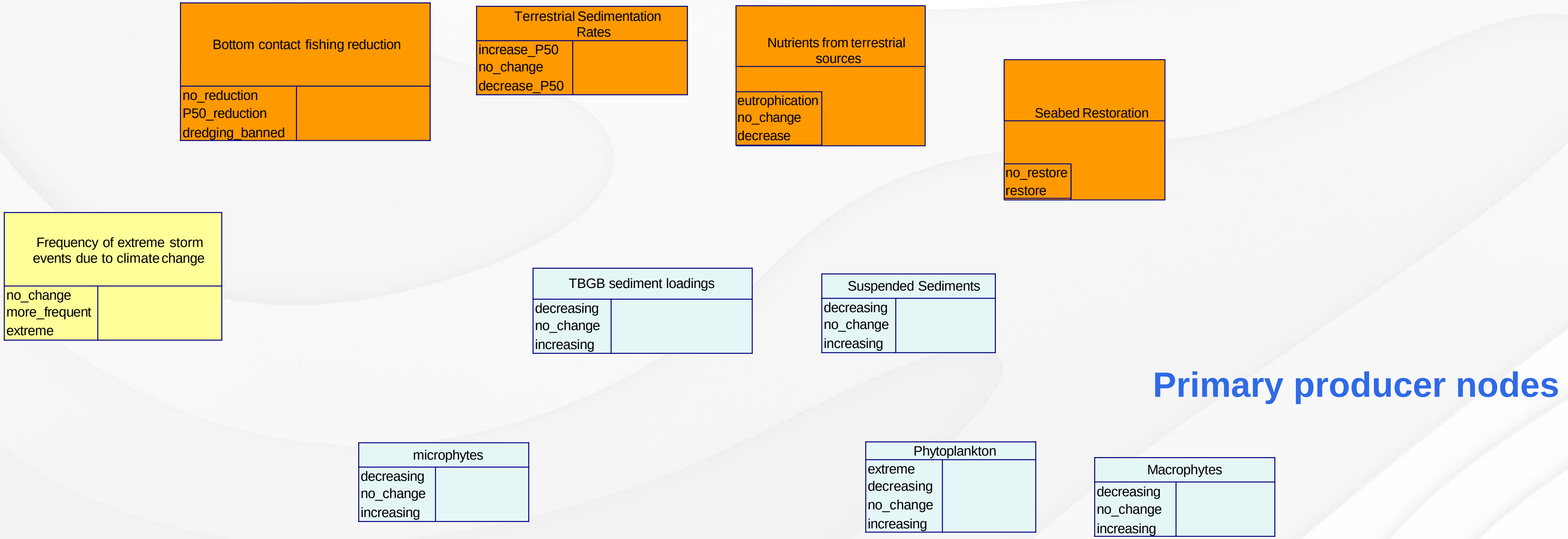


Tasman Bay and Golden Bay Scallop model BDN Structure

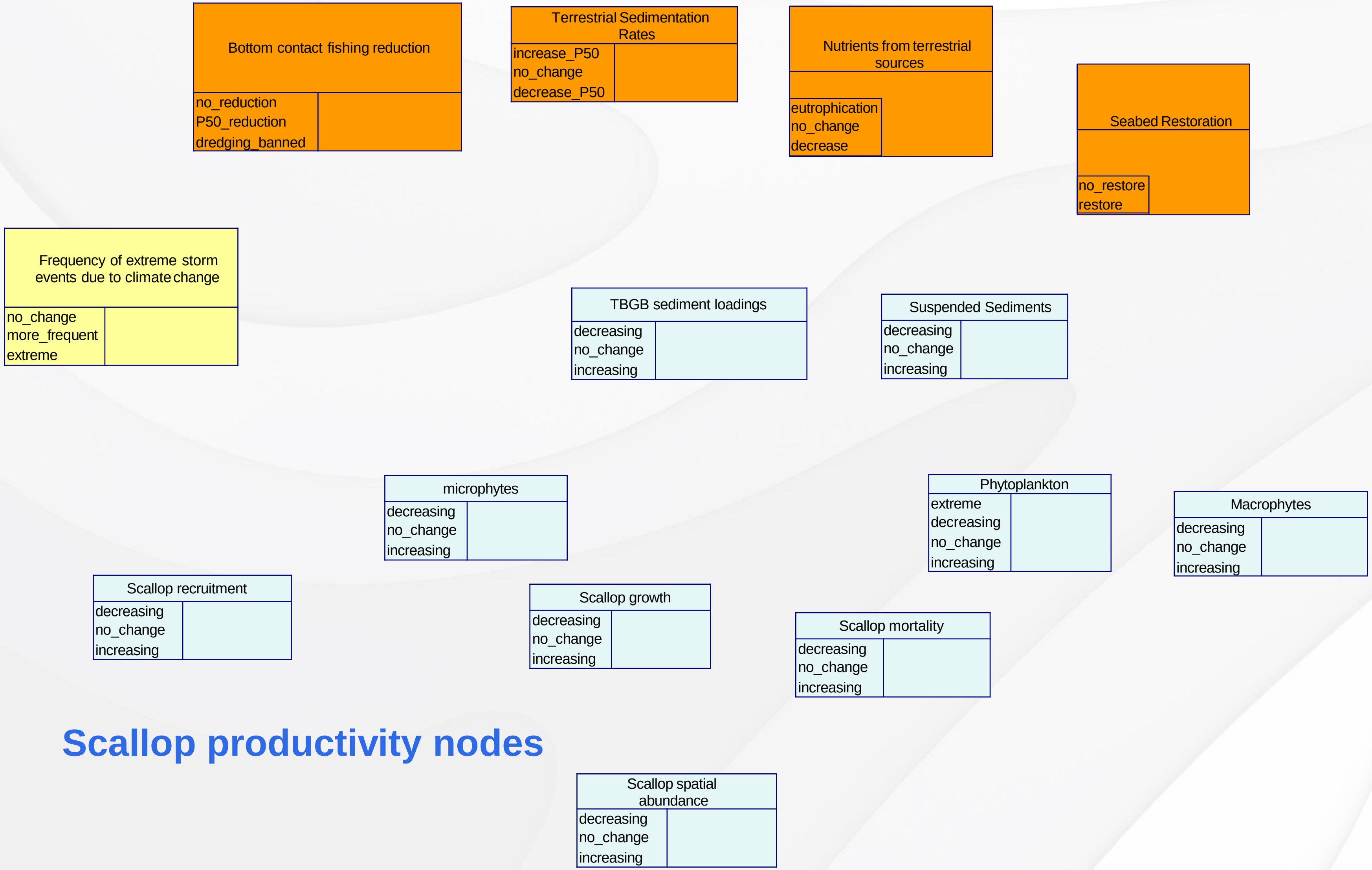


Abiotic Ecosystem Factor nodes

Tasman Bay and Golden Bay Scallop model BDN Structure



Tasman Bay and Golden Bay Scallop model BDN Structure



Tasman Bay and Golden Bay Scallop model BDN Structure

Bottom contact fishing reduction
no_reduction
P50_reduction
dredging_banned

Terrestrial Sedimentation Rates
increase_P50
no_change
decrease_P50

Nutrients from terrestrial sources
eutrophication
no_change
decrease

Seabed Restoration
no_restore
restore

Frequency of extreme storm events due to climate change
no_change
more_frequent
extreme

TBGB sediment loadings
decreasing
no_change
increasing

Suspended Sediments
decreasing
no_change
increasing

Bioturbators
decreasing
no_change
increasing

microphytes
decreasing
no_change
increasing

Benthic Biogenic Structure
decreasing
no_change
increasing

Phytoplankton
extreme
decreasing
no_change
increasing

Macrophytes
decreasing
no_change
increasing

Scallop recruitment
decreasing
no_change
increasing

Scallop growth
decreasing
no_change
increasing

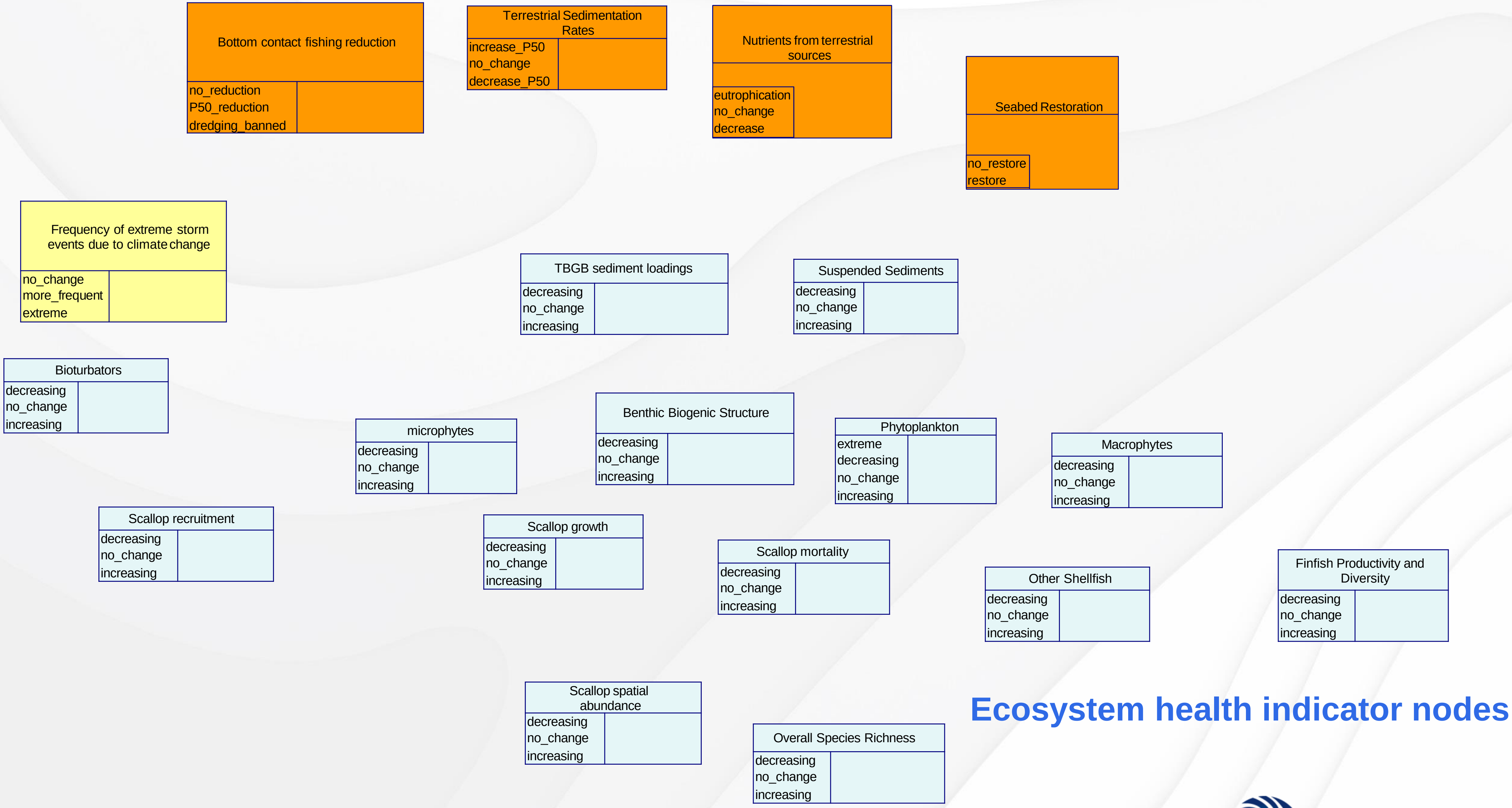
Scallop mortality
decreasing
no_change
increasing

Other Shellfish
decreasing
no_change
increasing

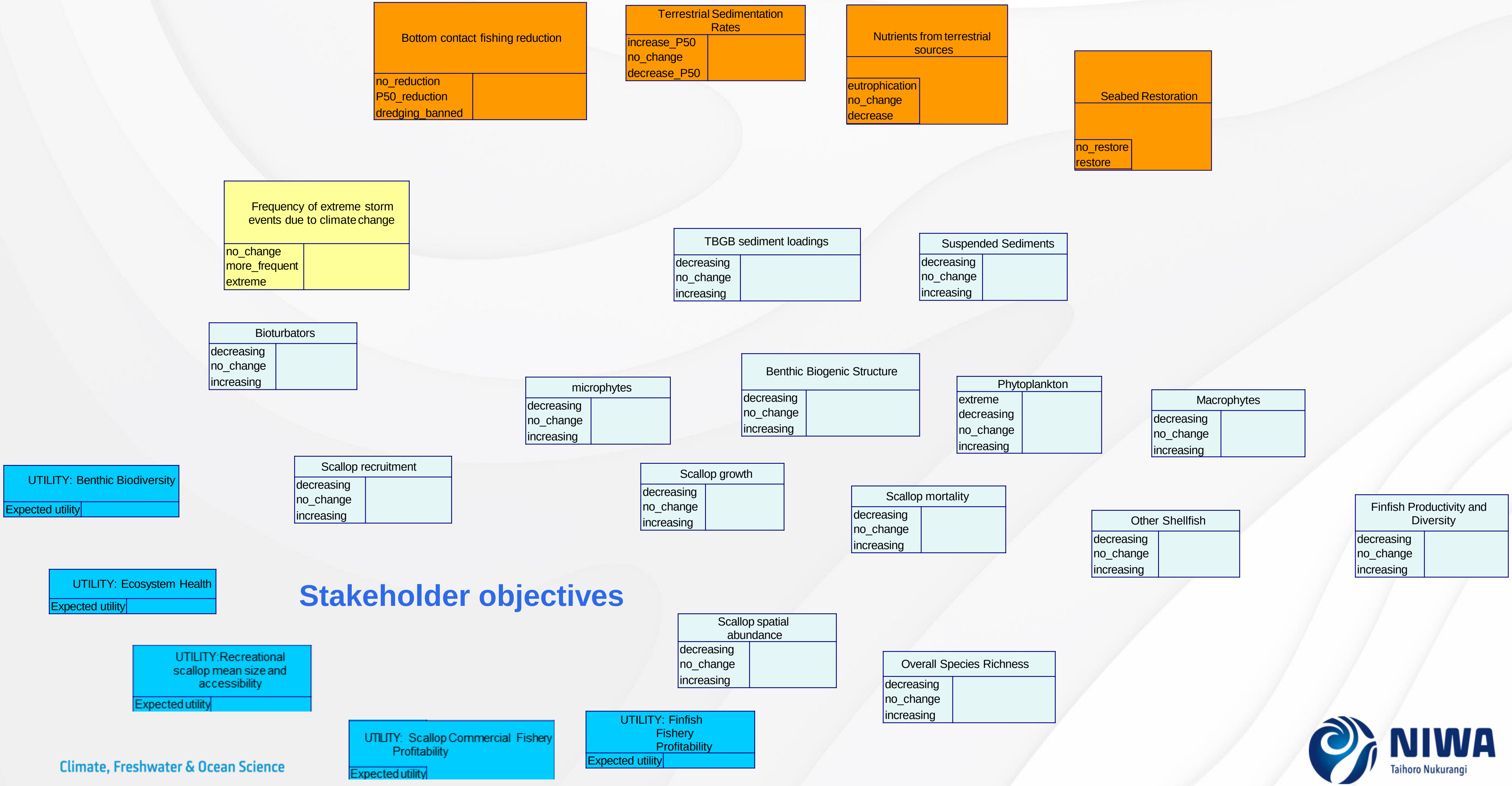
Benthic habitat formers and nutrient cycler nodes

Scallop spatial abundance
decreasing
no_change
increasing

Tasman Bay and Golden Bay Scallop model BDN Structure



Tasman Bay and Golden Bay Scallop model BDN Structure



How Expert Elicitation was used to build the TBGB BDN model

Our Expert Elicitation process took place over a two-day workshop and comprised a group of nine NIWA and Cawthron Institute scientist who's joint knowledge on TBGB marine ecosystem processes and resource management spanned a broad range of disciplines.

{benthic and marine ecology, scallop and finfish stock assessment, ecological modelling, physical oceanography and ocean productivity, social science}

How Expert Elicitation was used to build the TBGB BDN model

Our “experts” were given four tasks:

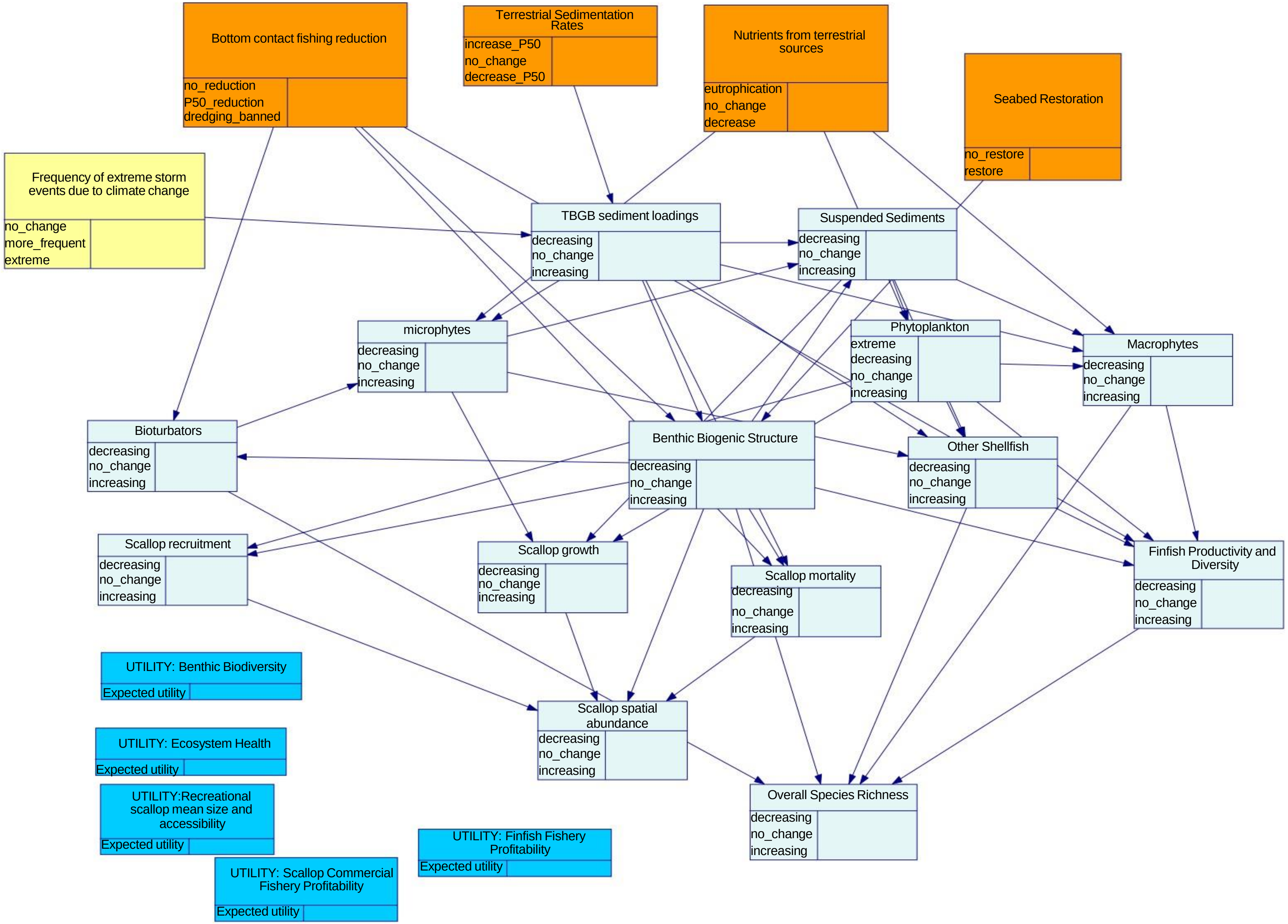
1. Construct a web of “cause and effect” relationships between the BDN model nodes

2. Define the magnitude of the relationship between BDN “parent” and “child” nodes in the form of Condition Probability Tables.

3. Specify the utility node - conditional nodes linkages

4. Specify how the utility scores were to be functionally derived

Task 1: TBGB BDN node cause and effect linkages as derived from expert consensus



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Task 2: Condition Probability Table derivations

Once the cause and effect relationships between the nodes had been established, each expert was then asked to provide their opinion as to likely probability state of each child node conditional on the state of each of the parent nodes.

Task 2: Condition Probability Table derivations

Example: The Sediment Loadings child node CPT

			child node		
			TBGB Sediment Loadings		
parent node	**parent node weight**	**parent category**	**decreasing**	**no_change**	**increasing**
Terrestrial Sedimentation Rates		increase_P50			
		no_change			
		decrease_P50			
Frequency of extreme storm events due to climate change		no_change			
		more_frequent			
		Extreme			

Example: The Sediment Loadings child node CPT

			child node		
			TBGB Sediment Loadings		
parent node	**parent node weight**	**parent category**	**decreasing**	**no_change**	**increasing**
Terrestrial Sedimentation Rates		increase_P50			
		no_change	2%	96%	2%
		decrease_P50			
Frequency of extreme storm events due to climate change		no_change			
		more_frequent			
		Extreme			

Each expert was asked to provide probability estimates for each child node category state for a given parent node state independent of other parent node states.

Example: The Sediment Loadings child node CPT

			child node		
			TBGB Sediment Loadings		
parent node	**parent node weight**	**parent category**	**decreasing**	**no_change**	**increasing**
Terrestrial Sedimentation Rates		increase_P50	0%	0%	100%
		no_change	2%	96%	2%
		decrease_P50	100%	0%	0%
Frequency of extreme storm events due to climate change		no_change	0%	98%	2%
		more_frequent	0%	8%	92%
		Extreme	0%	0%	100%

Example: The Sediment Loadings child node CPT

			child node		
			TBGB Sediment Loadings		
parent node	parent node weight	parent category	decreasing	no_change	increasing
Terrestrial Sedimentation Rates	1	increase_P50	0%	0%	100%
		no_change	2%	96%	2%
		decrease_P50	100%	0%	0%
Frequency of extreme storm events due to climate change	0.5	no_change	0%	98%	2%
		more_frequent	0%	8%	92%
		Extreme	0%	0%	100%

The final row table values were the median expert row scores re-standardised to sum to 1.

CPT interpolation

CPT complexity increases exponentially as the number of parent nodes increases.

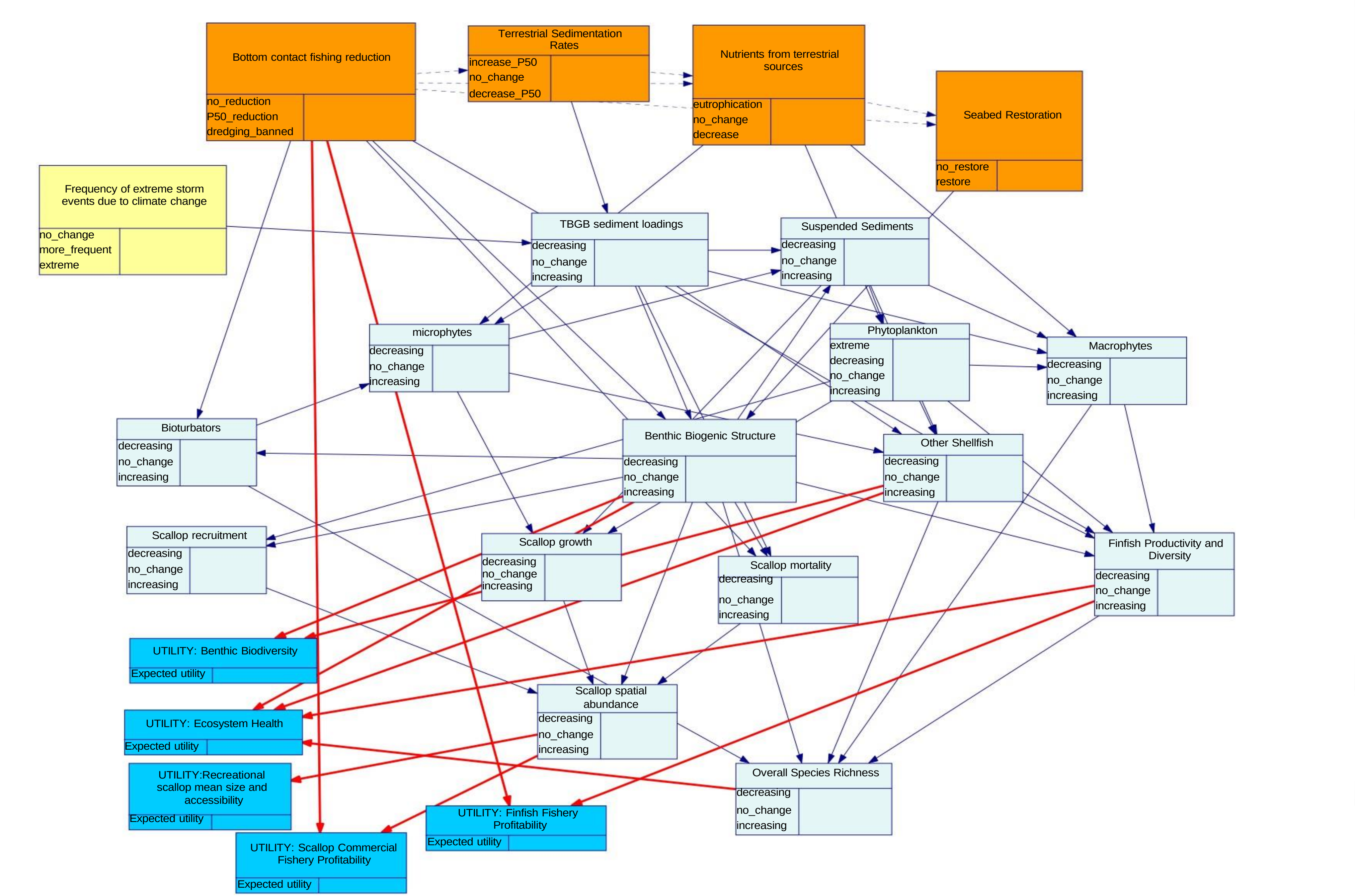
The final child-node CPT in below example has 9 parent node combinations.

			child node		
parent node	parent node weight	parent category	*TBGB Sediment Loadings*		
			decreasing	no_change	increasing
Terrestrial Sedimentation Rates	1	increase_P50	0%	0%	100%
		no_change	2%	96%	2%
		decrease_P50	100%	0%	0%
Frequency of extreme storm events due to climate change	0.5	no_change	0%	98%	2%
		more_frequent	0%	8%	92%
		Extreme	0%	0%	100%

It was possible to derive the 9 conditional probability outcomes for the different parent node state combinations from the above table given we were confident certain causality scalability assumptions held.

Our interpolation process was also able to take account of the parent node relative weighting scores.

Task 3: Specify objective utility node BDN linkages develop utility functions



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Task 4: Specify utility functions

The score range for all the Objective utility nodes was constrained between **-10** and **+10**.

-10 signifying the worst possible 10 yr outcome state

+10 signifying the best possible 10 yr outcome state

0 signifying neutrality, no change, or no improvement

All utility objectives contributed equally to the final overall utility score.

The relationship between parent-node state and utility score prediction was chosen to be approximately linear.

BDN model-based Management Strategy analysis for TGBG Scallops

BDN model-based Management Strategy analysis for TGBG Scallops

	status quo	*no seabed restoration*		*seabed restoration*		
		best overall	*best commercial*	*best overall*	*best commercial*	**Management Measure**
Stakeholder Objectives						Commercial trawl and dredge
						Terrestrial sedimentation inputs
						Terrestrial nutrient inputs
						Seabed restoration
INCREASE: TBGB Scallop Recreational scallop mean size and accessibility						*management scenario performance per objective*
RESTORE: TBGB benthic biodiversity						
RESTORE: Ecosystem health						
INCREASE: Scallop Fishery Profitability						
INCREASE: Fishery Profitability (finfish)						
						overall performance

negative utility
positive utility less than 50% of max
positive utility greater than 50% of max

BDN model-based Management Strategy analysis for TGBG Scallops

	status quo (do nothing)	*no seabed restoration*		*seabed restoration*		
		best overall	*best commercial*	*best overall*	*best commercial*	**Management Measure**
Stakeholder Objectives	no reduction					Commercial trawl and dredge
	no change					Terrestrial sedimentation inputs
	no change					Terrestrial nutrient inputs
	no_restore					Seabed restoration
INCREASE: TBGB Scallop Recreational scallop mean size and accessibility						*management scenario performance per objective*
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BDN model-based Management Strategy analysis for TGBG Scallops

	status quo (do nothing)	*no seabed restoration*		*seabed restoration*		
		best overall	***best commercial***	***best overall***	***best commercial***	**Management Measure**
Stakeholder Objectives	no reduction	dredging banned	reduction_50			Commercial trawl and dredge
	no change	decrease_50	decrease_50			Terrestrial sedimentation inputs
	no change	no change	no change			Terrestrial nutrient inputs
	no_restore	no_restore	no_restore			Seabed restoration
INCREASE: TBGB Scallop Recreational scallop mean size and accessibility						*management scenario performance per objective*
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	(do nothing)	***best overall***	***best commercial***	***best overall***	***best commercial***	**Management Measure**
Stakeholder Objectives	no reduction	dredging banned	reduction_50	reduction_50	no reduction	Commercial trawl and dredge
	no change	decrease_50	decrease_50	decrease_50	decrease_50	Terrestrial sedimentation inputs
	no change	no change	no change	no change	no change	Terrestrial nutrient inputs
	no_restore	no_restore	no_restore	restore	restore	Seabed restoration
INCREASE: TBGB Scallop Recreational scallop mean size and accessibility						*management scenario performance per objective*
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						overall performance

negative utility
positive utility less than 50% of max
positive utility greater than 50% of max

Conclusions:

BDNs are particularly suited for a structured decision making approach where the terms of reference have been clearly established with stakeholders and managers:

- Agreed stakeholder *management objectives;*
- Agreed *management options;*
- Agreed *management performance measurement criteria;*
- Agreed management timeframe.

BDN models are capable of being used interactively by stakeholders and managers to explore the relative effectiveness of alternative management measures.

BDN's intuitive "cause and effect" flow-diagram structure means they could be easily developed interactively with stakeholders to accommodate differing "word views".

Our experience suggests BDNs can be relatively quickly and easily constructed on the basis of expert opinion and knowledge, which means they could be introduced into the management engagement process early on.