Evaluating the sustainability of dam projects: An ecosystem services approach

Case study:
Monitoring the performance of a dam

- Increasing demand for water abstraction
- Declining health of river ecology & loss of river values
- Solution: The Opuha dam in 1997
- Demand to evaluate its sustainability
- An ecosystem services approach is proposed

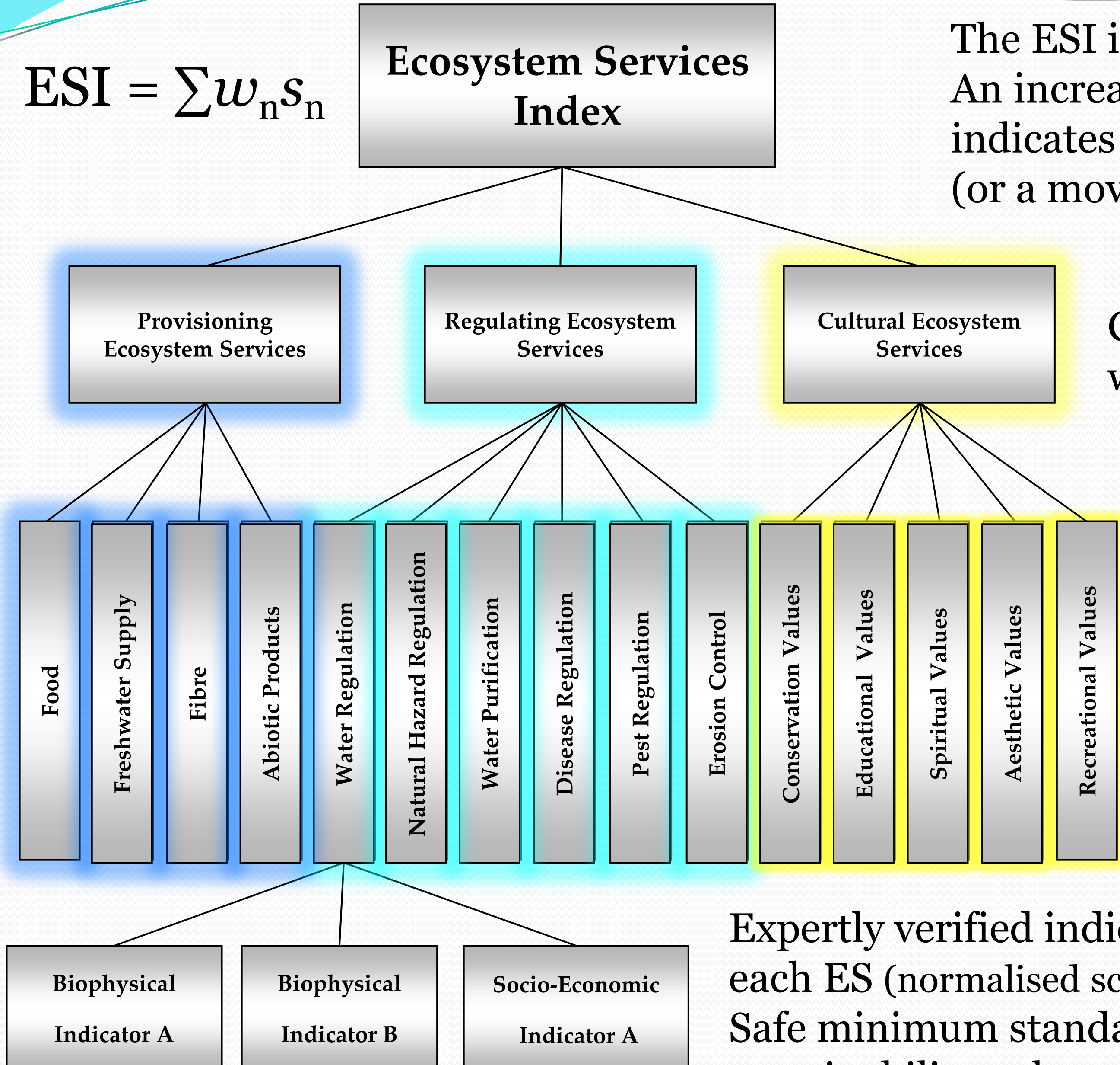
The ecosystem services approach

- **Step 1:** Ecosystem services (ES) are identified
- **Step 2:** Stakeholder representatives preferentially weight each ecosystem service.
- **Step 3:** Indicators which represent each ecosystem service are collated.
- **Step 4:** The preferential weights and indicator scores of each service are incorporated into a multi-criteria analysis which will produce the ESI.

Monitored over time the ESI can indicate sustainability

- **Potentially…** the cost-effectiveness of a storage option could then be ascertained by considering this ESI alongside project costs.

$$ESI = \sum w_n s_n$$

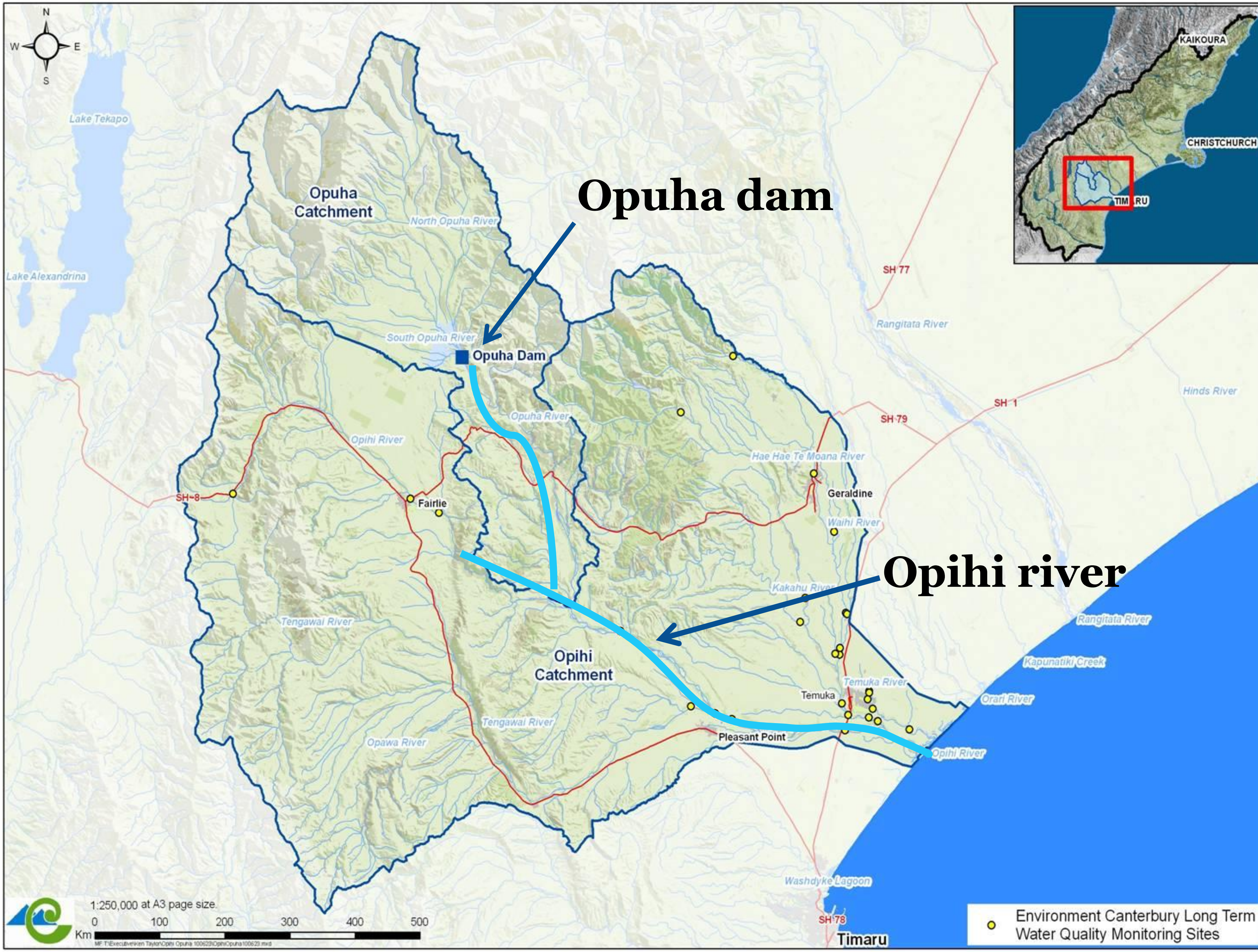


The ESI is monitored over time. An increasing index value indicates 'weak' sustainability (or a movement towards it)

Classes are preferentially weighted by stakeholders

ES are also preferentially weighted by stakeholders (w)

Expertly verified indicators monitor the state of each ES (normalised scores are aggregated). (s) Safe minimum standards allow strong sustainability to be monitored.



Opuha dam
Opihi river
N
S
E
W
KAIKOURA
CHRISTCHURCH
TIMARU
Lake Tekapo
Lake Alexandrina
Opuha Catchment
North Opuha River
South Opuha River
Opuha Dam
Opuha River
Opihi River
SH 77
SH 79
SH 1
SH 8
SH 78
Rangitata River
Hinds River
Hae Hae Te Moana River
Geraldine
Waihi River
Fairlie
Kakahu River
Tengawai River
Opihi Catchment
Temuka River
Temuka
Kapunatiki Creek
Orari River
Pleasant Point
Opawa River
Washdyke Lagoon
Timaru
1:250,000 at A3 page size.
0
100
200
300
400
500
Km
Environment Canterbury Long Term Water Quality Monitoring Sites

Step 1: Ecosystem services of the river are identified

- 15 ES are identified for the Opihi River



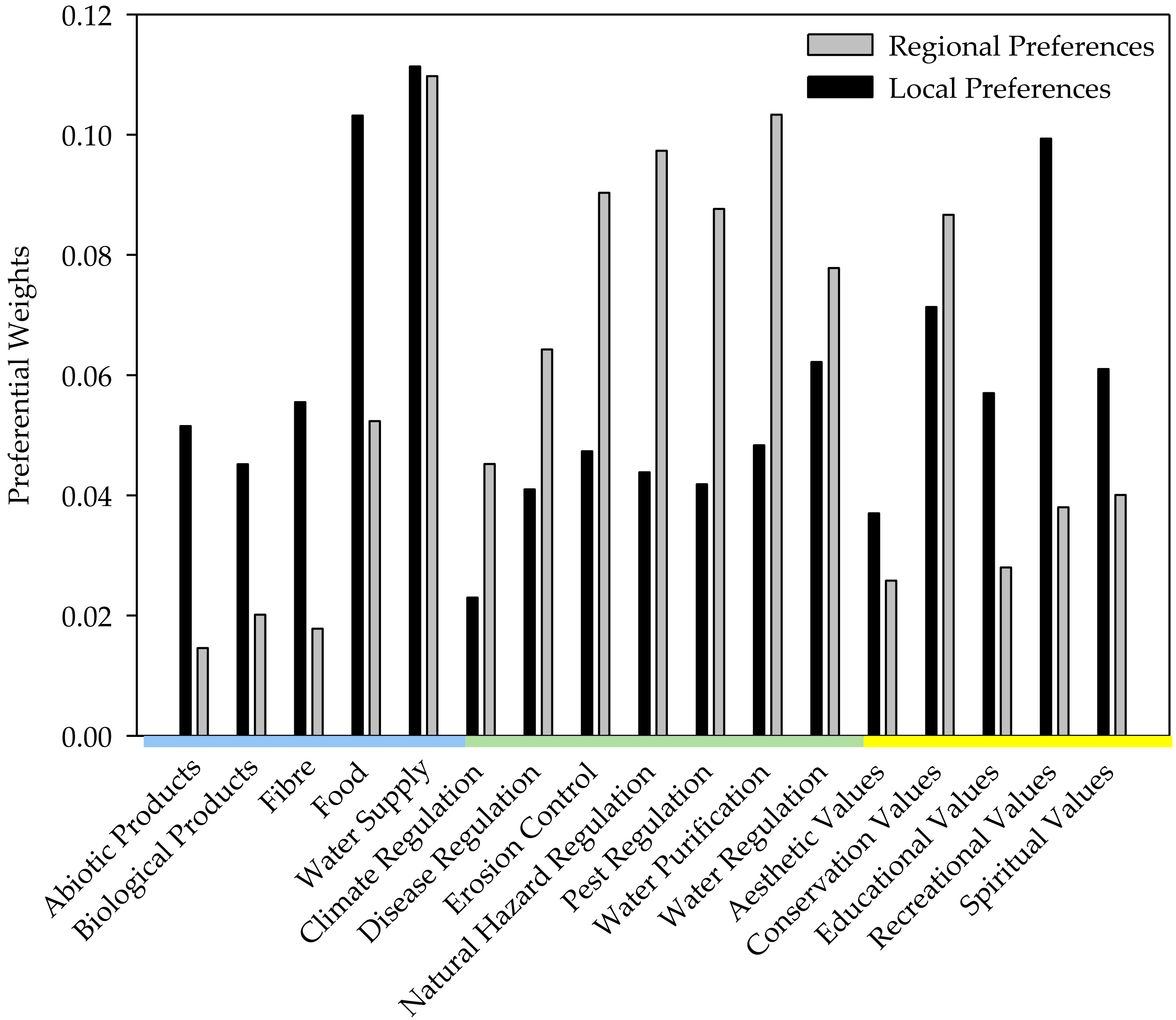



Class of ES	Ecosystem service	Examples of ecosystem service
Provisioning	Abiotic Products	Gravel extraction for road chip and concrete
	Biological Products	***Not applicable***
	Fibre	Flax, driftwood
	Food	Game fisheries (*e.g*. salmon, trout), native fisheries (*e.g*. eel, whitebait, flounder)
	Water Supply	Irrigation, hydroelectric production, municipal water use, industrial water use, stock water use
Regulating	Climate Regulation	***Not applicable***
	Disease Regulation	Parasite and toxic algae regulation
	Erosion Control	Stabilization of river banks
	Natural Hazard Regulation	Flood and drought protection
	Pest Regulation	Invasive non-native species (*e.g*. Algae)
	Water Purification	Removal of pollutants
	Water Regulation	River flow regulation (*e.g*. minimum river flows)
Cultural	Aesthetic Values	Perceived beauty
	Conservation Values	Endangered native species (*e.g*. black-billed gull), significant landscapes (*e.g*. Opihi Lagoon)
	Educational Values	Historical/archaeological values & knowledge systems
	Recreational Values	Sailing, rowing, kayaking, fishing, duck hunting, picnicking, swimming, walking
	Spiritual Values	Māori values (*e.g*. mauri)

Step 2: Stakeholder preferences

- A one-to-nine scale was used, where one represents neutrality or indifference between the pairing and nine represents an overwhelming preference for one ES over the other.

Provisioning Ecosystem Service	Overwhelming preference	Strong preference	Medium preference	Weak preference	Indifference	Weak preference	Medium preference	Strong preference	Overwhelming preference	Provisioning Ecosystem Service
Food	9	7	5	3	1	3	5	7	9	Abiotic Products


Regional Preferences
Local Preferences
Preferential Weights
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Abiotic Products
Biological Products
Fibre
Food
Water Supply
Climate Regulation
Disease Regulation
Erosion Control
Natural Hazard Regulation
Pest Regulation
Water Purification
Water Regulation
Aesthetic Values
Conservation Values
Educational Values
Recreational Values
Spiritual Values

Step 3: Expertly verified indicators which represent each ecosystem service are collated and their safe minimum standards recorded.

-The evaluation period was 1989 to 2008.

-(Dam construction 1997)

An example using the provisioning class of ecosystem services…

*Light blue sections reflect *available* indicators.

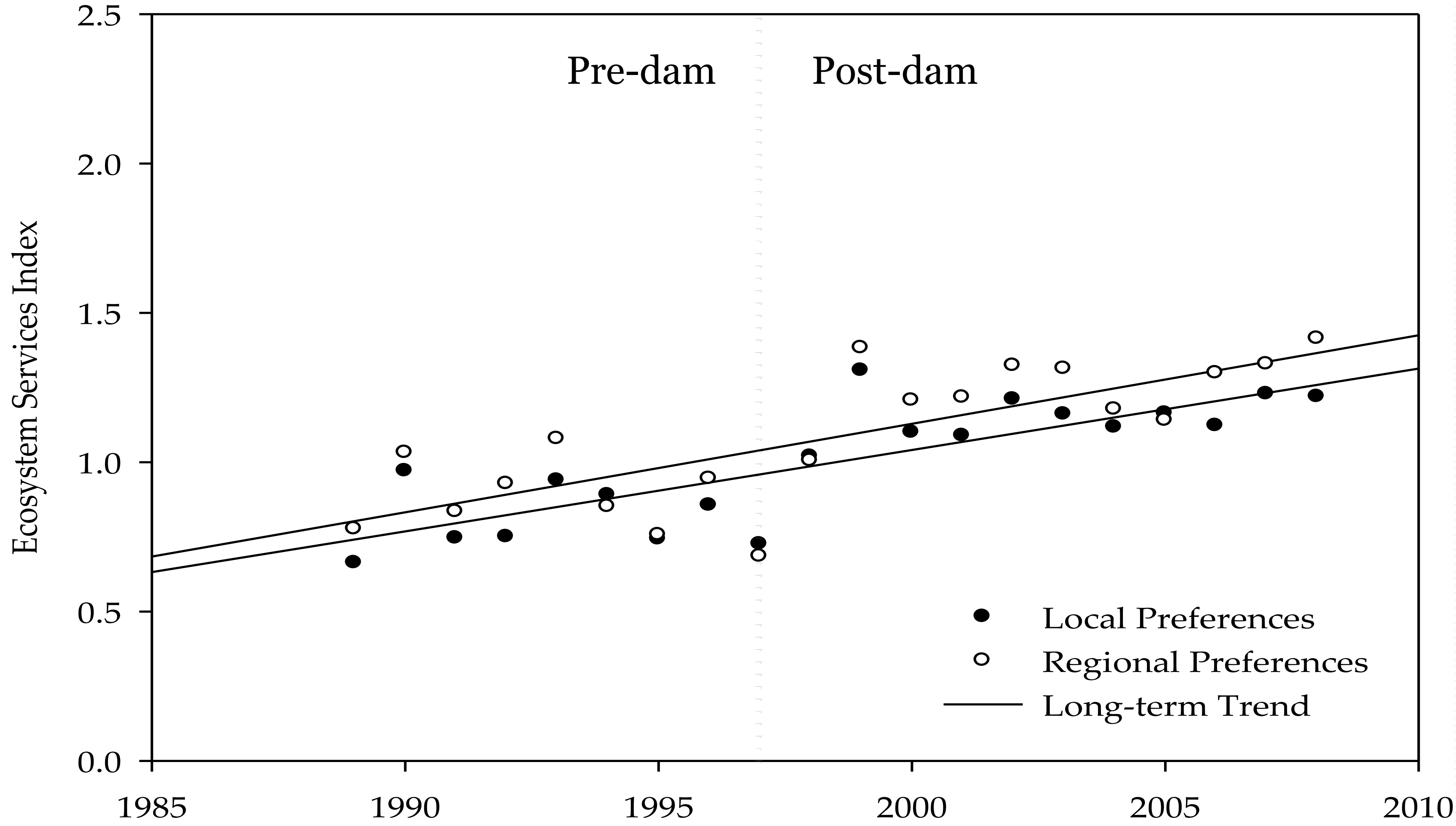
Class	Ecosystem service	Environmental indicators	Socio-economic indicators
Provisioning ecosystem services	Abiotic Products	Mean River Bed Level (m)	Profitability of Gravel Resource ($)
		Volume of Gravel Extracted (m^3)	
	Fibre	Number of Fibrous Species	Number of People Actively Collecting Fibrous Materials
		Total Biomass of Fibrous Species (kg)	
	Food	Annual Periphyton Cover (%)	Commercial Fishery Employment
		Average Weight of Fish Caught (kg)	Cultural Health Index
		Benthic Community Metabolism (R^2)	Fish Taste
		Biochemical Oxygen Demand (mg/l)	Number of People Actively Collecting Food
		Days River Mouth Closed	
		Dissolved Oxygen Level (ml/l)	
		Number of Mahinga Kai Species	
		Number of Salmonids Caught	
		pH Level	
		Presence of Riparian Vegetation	
		Spawning Numbers	
		Turbidity (NTU)	
		Water Temperature (^{0}C)	
	Water Supply	Irrigated Area (ha)	Economic Impact from Irrigation ($)
		River Flow Variability (σ^2)	
		Total Volume of Water Takes (m^3)	

Double counting

Indicator	Ecosystem service	Communicability (1-9 scale)	Data availability (1-9 scale)	Annual cost (1-9 scale)	Indicator cost-effectiveness
E. coli **Level**	Recreational Values	6.3	7.67	5	2.79
	Water Purification	7			2.93
Irrigated Area	Water Supply	8	9	2	8.5
	Natural Hazard Regulation	3			6
Minimum River Flows	Water Regulation	5	7	3	4
	Recreational Values	5			4
Number of Flood Flows	Natural Hazard Regulation	9	8.33	4.33	4
	Water Regulation	6.33			3.39
Qualitative Macroinvertebrate Community Index	Conservation Values	7	7	6.33	2.21
	Water Purification	6.33			2.11
pH Level	Water Purification	7	7	3	4.67
	Food	5			4

Step 4: Using the ESI to evaluate for weak sustainability

$ESI = \sum w_n s_n$ ★ ESI / # indicators in that year



Key findings of case study

- Fifteen ES were identified from the river
- Since dam construction the river has progressed towards both weak and strong sustainability in its provision of ES.

  (Interpretation of this finding needs to acknowledge the state of the river pre-dam)
- There exists a need to develop a standardised set of effective indicators of river ES

  -Alternatively ES could be decomposed into more tangible benefits, allowing improved correlation with indicators.

Thank you

Lincoln University
Te Whare Wānaka o Aoraki
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Safe minimum standards

Ecosystem Service	Indicator	Safe Minimum Standard	
		Threshold	Source
Abiotic Products	Mean River Bed Level	40.93m	Boyle & Surman, 2007
Fibre	Number of Fibrous Species	No decline	Expert
Food	Biochemical Oxygen Demand	Maximum 1mg/l	Expert
	Dissolved Oxygen Levels	Daily minimum 8ml/l	Expert
	Number of Salmonids Caught	500 caught	Expert
	Spawning Numbers	No undesirable trend	Expert
	Water Temperature	Daily minimum 4C & maximum 20C	ECan, 2010; Expert
Water Supply	Economic Impact from Irrigation	No decline	CMF, 2010
	River Flow Variability	No increase	CMF, 2010
	Total Volume of Water Takes	No undesirable trend	CMF, 2010

An Evaluation for strong sustainability

Ecosystem Service	Percentage of Years Failed	
	Opihi River	
	Pre-dam	Post-dam
Abiotic Products	0	0
Fibre	0	0
Food	3.3	20.5
Water Supply	37.5	0
Disease Regulation	0	18.2
Erosion Control	50	36.4
Natural Hazard Regulation	11.1	0
Pest Regulation	0	0
Water Purification	27.3	26.7
Water Regulation	69.6	18.2
Aesthetic Values	50	54.5
Conservation Values	3.3	2.6
Educational Values	0	0
Recreational Values	41.7	33.3
Spiritual Values	0	0
Total Percentage of Years Failed	**19.6**	**14.0**

The sustainability 'gap'