CORRELATION BETWEEN BIOTIC FACTORS AND ABIOTIC FACTORS

- FOCUSED ON THE CASE STREAMS IN GYEONGGI DISTRICT, KOREA-

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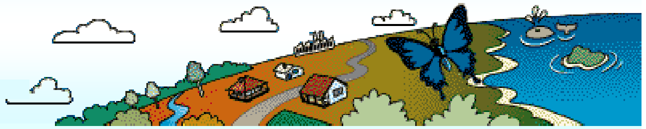
1. INTODUCTION



- **Correlation between biotic and abiotic factors**
  - ✓ **Classification of stream typology**
  - ✓ **Evaluation of ecological stream status**
- **LfU (Landesanstalt für Umweltschutz) Baden-Württemberg (1998)** **(State Institute for Environment Protection)**
  - ✓ **Classification of 'silicates stream' and 'carbonate stream'**
- **LfU Baden-Württemberg (2000)**
  - ✓ **Classification of stream type**
- **AQEM (2001) - European Water Project** **(The Development and Testing of an Integrated Assessment System for the Ecological Quality of Streams and Rivers throughout Europe using Benthic Macroinvertebrates)**
  - ✓ **Determination of representative benthic macro-invertebrates by stream types**
  - ✓ **Development of integrated method for assessing streams using benthic macro-invertebrates**

2. RESEARCH PROCEDURE

Survey of River Structure

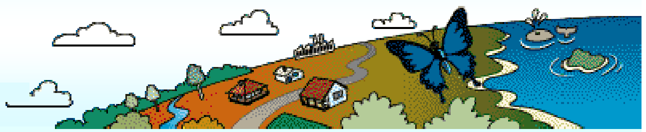
- ✓ Survey sheet
- ✓ Stream typology
- ✓ Structural quality classes
- ✓ Nine elements dependent on stream typology

Survey for Biotic Factors and Water Quality Items

- ✓ Vegetation
- ✓ Benthic macro-invertebrates
- ✓ Water quality items

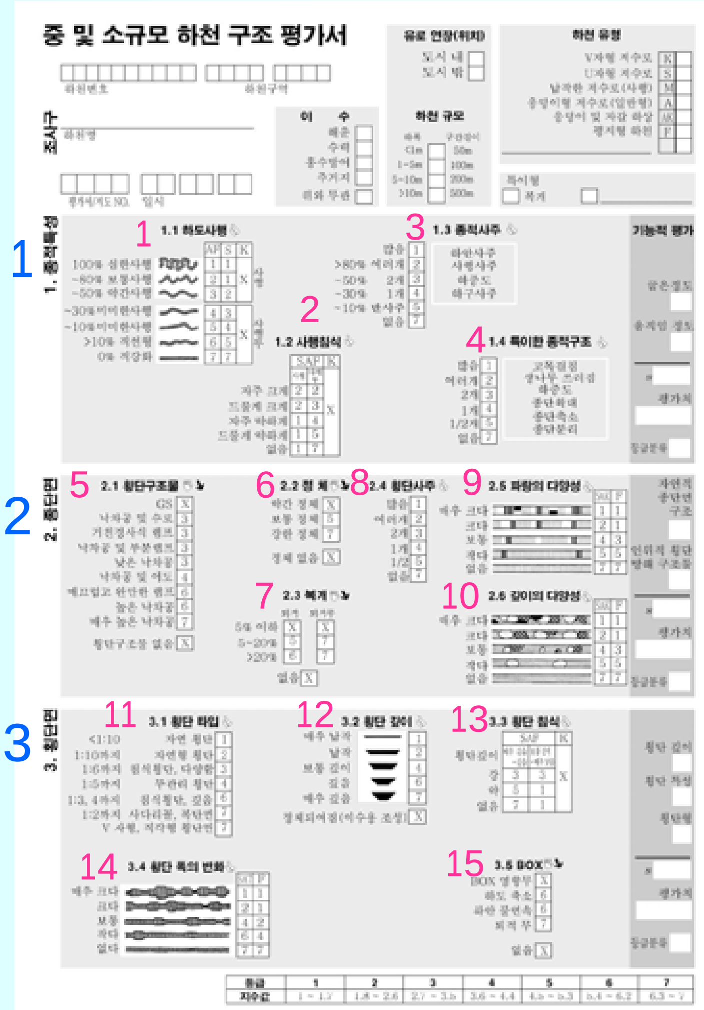
Correlation Analysis

- ✓ RDA (Redundancy Analysis)
- ✓ CCA (Canonical Correspondence Analysis)



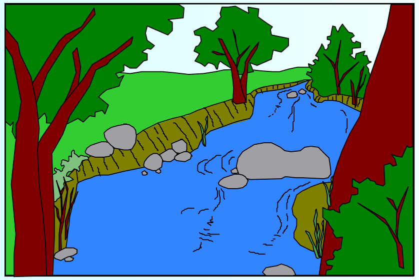
2. RESEARCH PROCEDURE

Survey Sheet for Physical River Structure

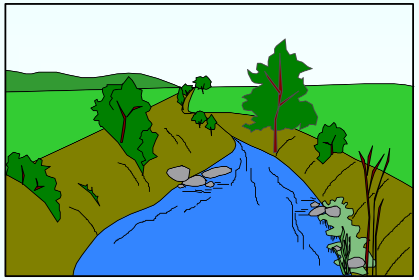


6 Items
25 Elements

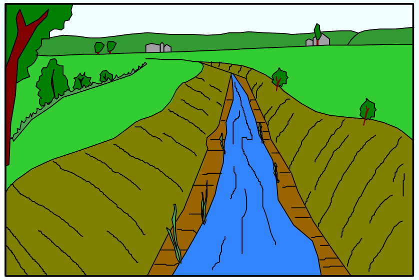
Structural Quality Classes (LAWA, 2000)



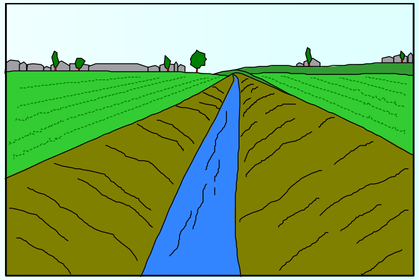
Natural State-1, 2



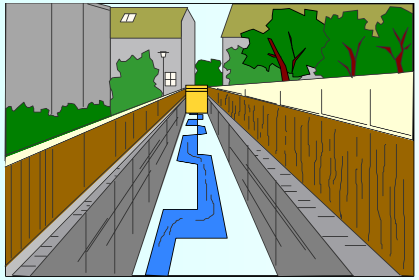
Natural State-3



Natural State-4



Natural State-5

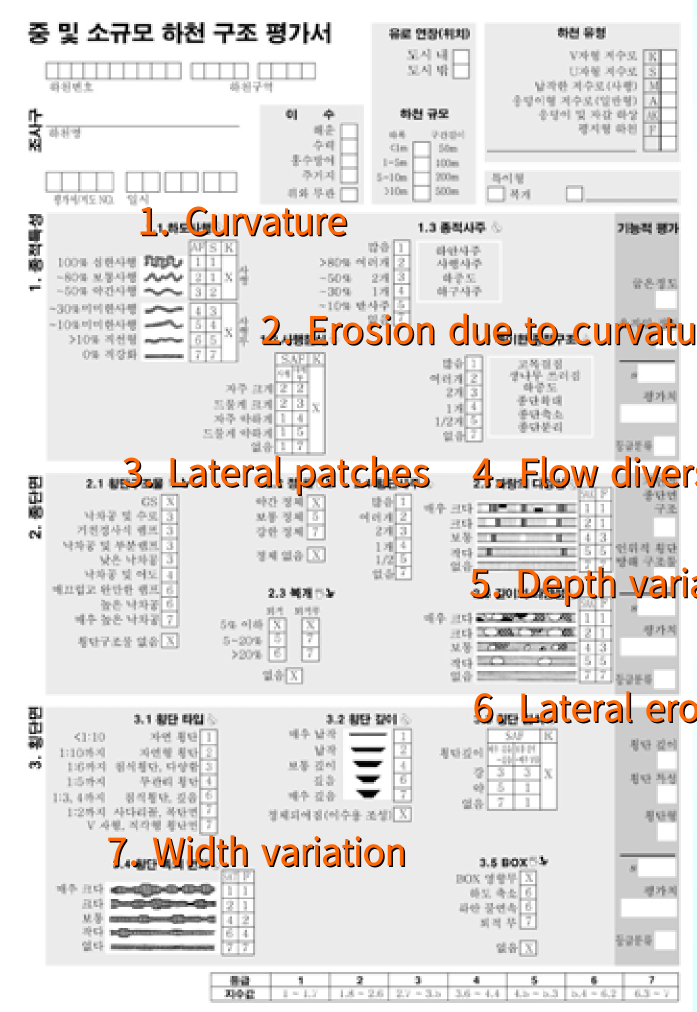


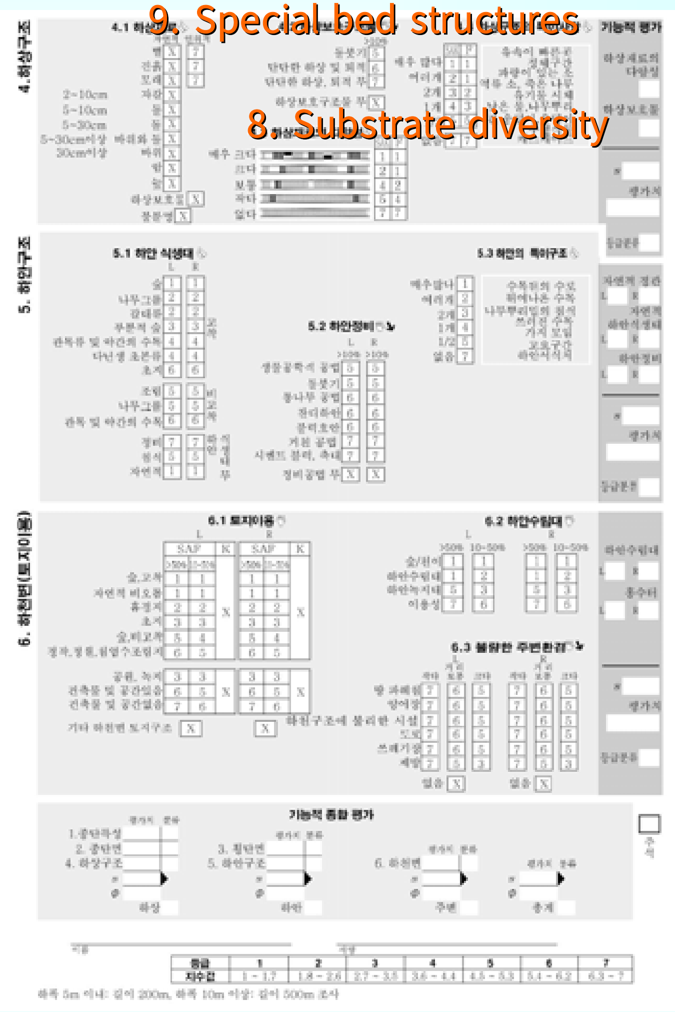
Natural State-6, 7

Class	State	Range	EU-WFG Ecological Condition
1	Unchanged	1.0-1.7	Very Good
2	Slightly Changed	1.8-2.6	
3	Moderately Changed	2.7-3.5	Good
4	Distinctly Changed	3.6-4.4	Fair
5	Obviously Changed	4.5-5.3	Poor
6	Strongly Changed	5.4-6.2	Very Poor
7	Completely Changed	6.3-7.0	

2. RESEARCH PROCEDURE

Nine Elements Dependent on Stream Typology





2. RESEARCH PROCEDURE

◆ 0. Stream Typology (LAWA, 2000)


K (Gorge)


K (V-shaped)


S (U-shaped)


M (Meandering)


A (Trough)


A (Alluvial)


F (Silt)


F (Sand)

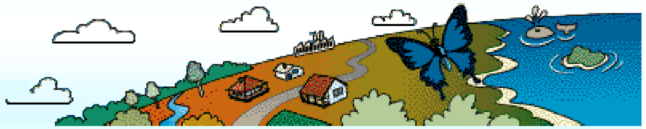

F (Gravel)


F (Organism)


F (Lowland)


F (Lowland, Artificial)

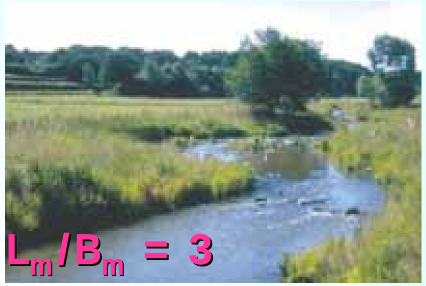
2. RESEARCH PROCEDURE



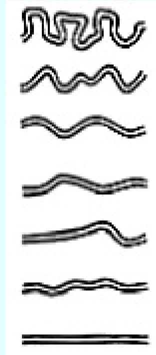
◆ 1. Curvature of channel

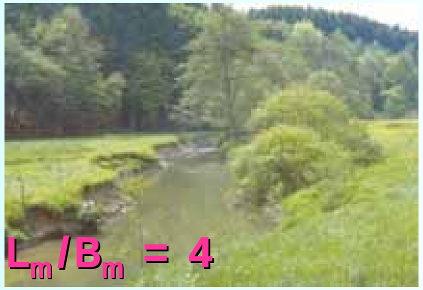
Severe, 60-90 °

Very Strong, 30-60 °



Strong, 10-40 °





Moderate, 20 °

Weak, 30-60 °

Stretched

Straight (Artificial)

Standard for estimation	Index by stream typology		
	A, F	S	M, K
Curvature			
Severe	1	1	×
Very Strong	2	1	
Strong	3	2	
Non-curvature			
Moderate	4	3	×
Weak	5	4	
Stretched	6	5	
Straight	7	7	

2. RESEARCH PROCEDURE

◆ 2. Erosion due to curvature


Cur. / Strong


Cur. / Strong


Cur. / Weak


Cur. / Weak


Non-Cur. / Strong


Non-Cur. / Strong


Non-Cur. / Strong


Non-Cur. / Weak

Standard for estimation	Index by stream typology		
	S, A, F		K, M
	Curva-ture	Non-curva-ture	
Frequently strong	2	2	
Rarely strong	2	3	
Frequently weak	1	4	×
Rarely weak	1	5	
None	1	7	

2. RESEARCH PROCEDURE

◆ 3. Lateral Patches

Riffle-pool/Distinct

Steps/Distinct

Bar/Distinct

Artificial Pool

Riffle-pool/Rudiment

Steps/Rudiment

Bar/Rudiment

Bar/Rudiment

Standard for estimation	Index by stream typology		
	M, A, F, S		K
	Narrow (B<5 m)	Wide (5 m<B)	
Abundant	1	1	
Several	2	1	
Two	3	2	×
One	4	2	
Half (Rudiment)	5	5	
None	7	7	7

2. RESEARCH PROCEDURE

◆ 4. Flow diversity

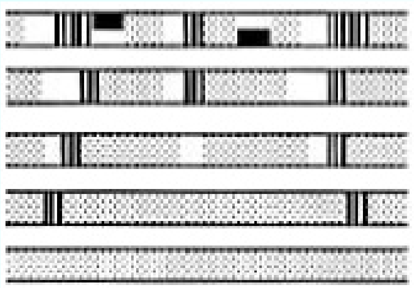

Smooth


Walking


Wavy


Crest-forming

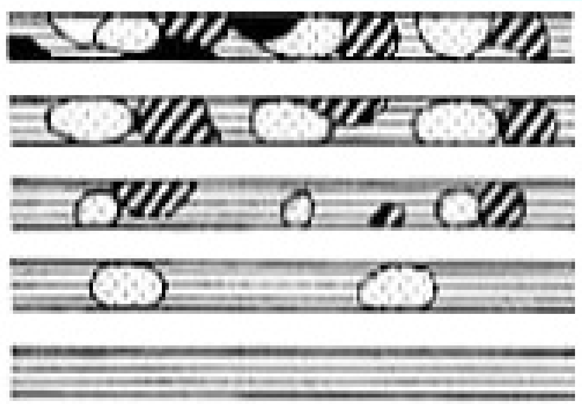

Rushing



Standard for estimation	Index by stream typology	
	M, A, K	F
Very High (Crest-forming, Rushing)	1	1
High (Wavy)	2	1
Moderate (Walking)	4	3
Low (Smooth)	5	5
None	7	7

◆ 5. Depth variation

Standard for estimation	Index by stream typology	
	M, A, K	F
Very High	1	1
High	2	1
Moderate	4	3
Low	5	5
None	7	7



2. RESEARCH PROCEDURE

◆ 6. Lateral erosion


Moderate/Strong


Deep/Strong


Very Deep/Strong


Very Deep/Strong


Moderate/Weak


Moderate/Weak


Very Deep/Weak


Very Deep/Weak

Standard for estimation	Index by stream typology		
	M, A, F, S		
Depth of cross-Section	Very Deep-Deep (B/H<4)	Moderate-Very shallow (B/H>4)	K
Strong	3	3	×
Weak	5	1	
None	7	1	

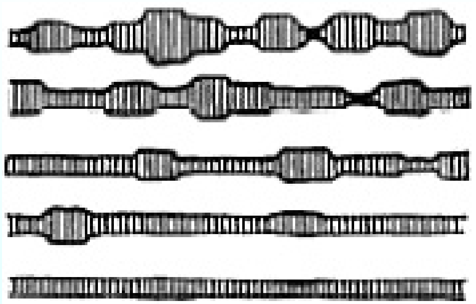
◆ 7. Width variation

None

Moderate

High

Very High



Standard for estimation	Index by stream typology	
	M, A, K, S	F
Very High	1	1
High	2	1
Moderate	4	2
Low	6	4
None	7	7

2. RESEARCH PROCEDURE

◆ 8. Substrate diversity


Clay/Silt/Loam


Silt & Mud

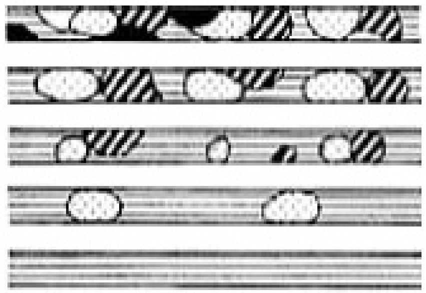

Sand


Gravel


Gravel and Stone

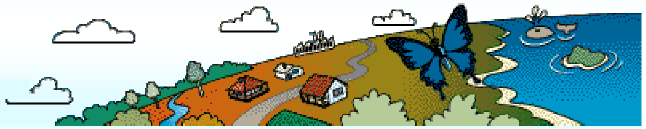

Block, Gravel & Stone


Bedrock



Standard for estimation	Index by stream typology	
	S, A, K	F
Very High	1	1
High	2	1
Moderate	4	2
Low	6	4
None	7	7

2. RESEARCH PROCEDURE



◆ 9. Special bed structures

Scour Hole

Deep Run

Hissing Spot

Darting Spot

Stream-pool

Still Side-pool

Reverse Side-pool

Macro-hydrophyte

Root Spot

Cascade

Standard for estimation	Index by stream typology	
	M, A, K	F
Abundant	1	1
Several	2	1
Two	3	2
One	4	3
Half (1/2)	5	5
None	7	7

Survey for Biotic Factors and Water Quality

- **Location**
  - ✓ length of 1 km showing best natural state at each stream
- **Vegetation**
  - ✓ Braun-Blanquet (1964) method → Phytosociology
  - ✓ Belt-transect → Emergent species along cross-section
- **Benthic macro-invertebrate**
  - ✓ Quantitative sampling : Surber (1937) net
  - ✓ Qualitative sampling : Hand-grab and collector
  - ✓ Dominance, Diversity, Evenness, Richness indices
- **Water quality**
  - ✓ Data of Water Quality Monitoring Network (Ministry of Environment, Korea)
  - ✓ pH, COD, BOD, DO, SS, T-N, T-P, NH3-N, PO4-P, water temperature, conductivity, and number of coliform

Correlation Analysis Method

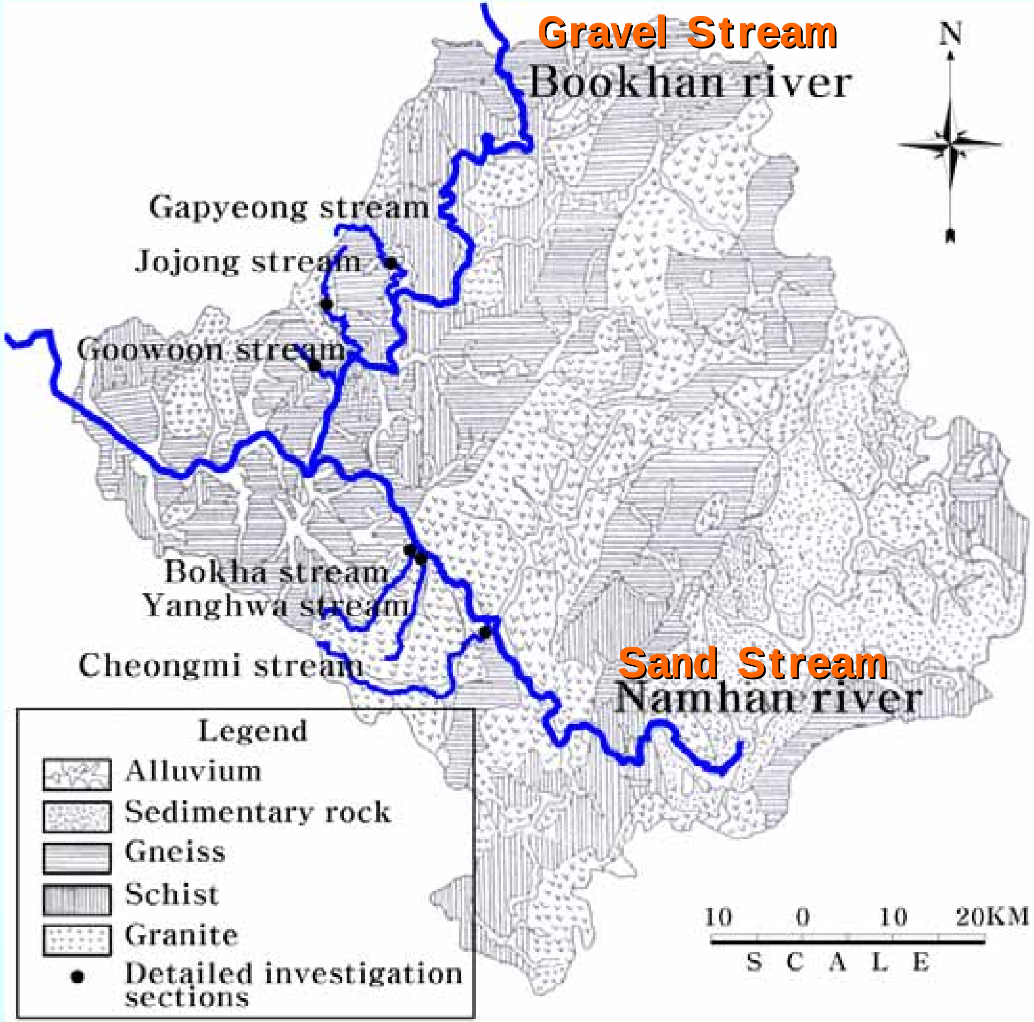
◆ Ordination

Multi-variate Analysis	Indirect Method	Principal Component Analysis
		Correspondence Analysis
		Detrended Correspondence Analysis
	Direct Method	ReDundancy Analysis
		Canonical Correspondence Analysis
		Detrended Canonical Correspondence Analysis

◆ Programs

- ✓ CANOCO 4.5 (ter Braak, C.J.F. and Šmilauer, P.; 2002): RDA, CCA
- ✓ SPSS 13 (Statistical Package for the Social Science): Pearson Correlation, PCA

Location and Geology of Survey Streams



Field Survey for River Structure

Curvature of channel (Very Strong)

Erosion due to curvature (Frequently Strong)

Lateral patches (One)

Flow diversity (Rushing → Very High)

3. RESULTS

**Depth variation
(Very High)**

**Lateral erosion
(Very Deep/Strong)**

**Width variation
(Moderate)**

**Substrate diversity
(Moderate)**

3. RESULTS

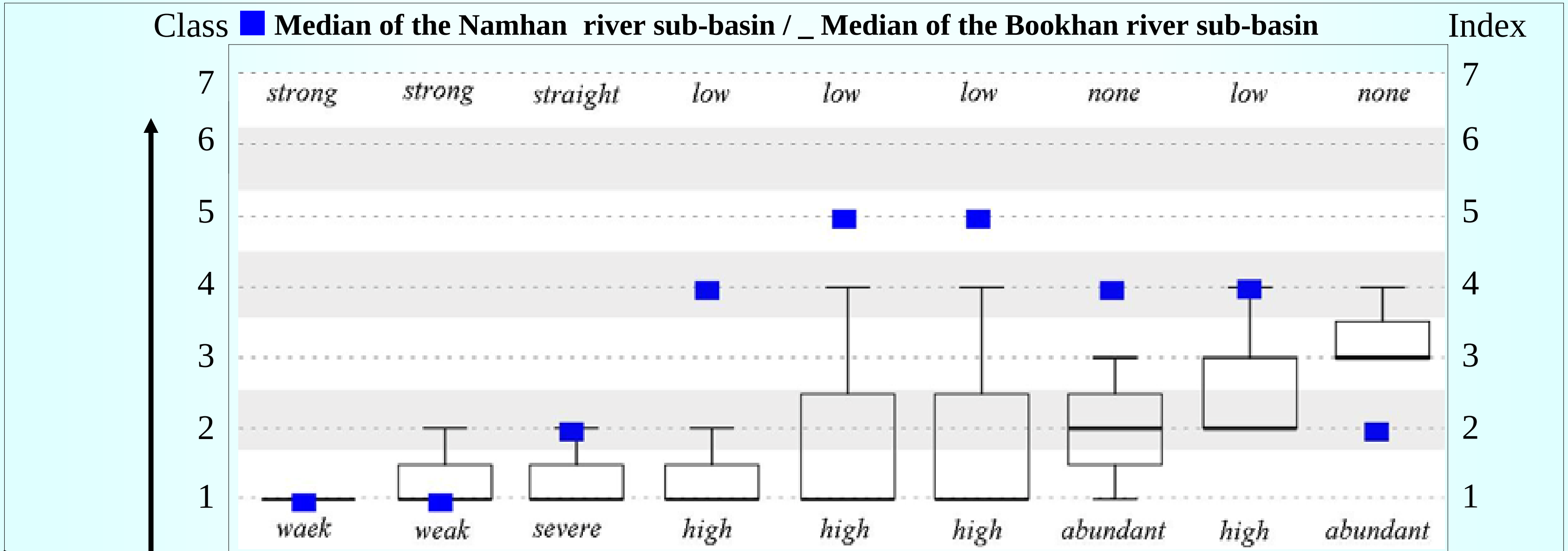
Special bed Structures
(Darting Spot)

Special bed Structures
(Still Side-pool)

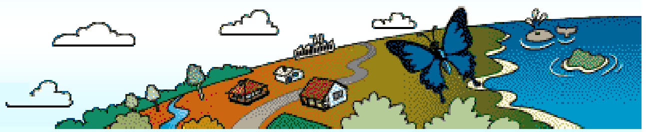
Special bed Structures
(Root Spot)

3. RESULTS

Hydromorphological Structure



Variable / Average Index	Erosion due to curvature	Lateral erosion	Curvature of channel	Substrate diversity	Flow diversity	Depth variation	Special bed structures	Width variation	Lateral patches
Namhan river sub-basin	1.7	1.3	2.0	4.0	4.7	4.7	4.7	4.7	1.7
Bookhan river sub-basin	1.0	1.3	1.3	1.3	2.0	2.0	2.0	2.7	3.3



Benthic Macro-invertebrate

- **62 species :** 1:*Tipulide* sp.1, 2:*Tipulide* sp.2, 3:*Nothopsyche* KUa, 4:*Kamimuria* KUa, 5:*Baetis fuscatus*, 6:*Calopteryx atrata*, 7:*Ranatra chinensis*, 8:*Glossosoma* KUa, 9:*Chironomidae* sp. 1, 10:*Laccophilus difficilis*, 11:*Micronecta sedula*, 12:*Hydaticus grammicus*, 13:*Baitis thermicus*, 14:*Goerodes* KUa, 15:*Ecdyonurus levis*, 16:*Macromia daimoji*, 17:*Whitmania edentula*, 18:*Semisulcospira libertina*, 19:*Erpobdella lineata*, 20:*Ephemera orientalis*, 21:*Paraleptophlebia chocolata*, 22:*Sympetrum eroticum*, 23:*Ecdyonurus kibunensis*, 24:*Cercion calamorum*, 25:*Whitmania pigra*, 26:*Unio douglasiae*, 27:*Anax nigrofasciatus*, 28:*Ephemera strigata*, 29:*Rhyacophila* KUa, 30:*Lymnaea auricularia*, 31:*Muljarus japonicus*, 32:*Cincticostella levanidovae*, 33:*Orthetrum albistylum speciosum*, 34:*Platycnemis phillopoda*, 35:*Epeorus pellucidus*, 36:*Drunella aculea*, 37:*Aquaris paludum*, 38:*Davidius lunatus*, 39:*Hippeutis cantori*, 40:*Limnodrilus gotoi*, 41:*Ischnura asiatica*, 42:*Rhantus pulverosus*, 43:*Baetiella tuberculata*, 44:*Sieboldius albardae*, 45:*Stenopsyche bergeri*, 46:*Gabbia misella*, 47:*Hesperocorixa kolthoffi*, 48:*Physa acuta*), 49:*Wormaldia* KUa, 50:*Laccotrephes japonensis*, 51:*Rhoenanthus coreanus*, 52:*Corbicula fluminea*, 53:*Semisulcospira tegulata*, 54:*Hydropsyche* KUa, 55:*Iron aesculus*, 56:*Macrobrachium nipponense*, 57:*Anodonta woodiana*, 58:*Semisulcospira coreana*, 59:*Stylurus annulata*, 60:*Potamonectes hostilis*, 61:Dytiscidae sp. 1, 62:Dytiscidae sp. 2
- **Common species**

Gravel stream	Sand stream	Gravel and sand stream
15	9	5

3. RESULTS

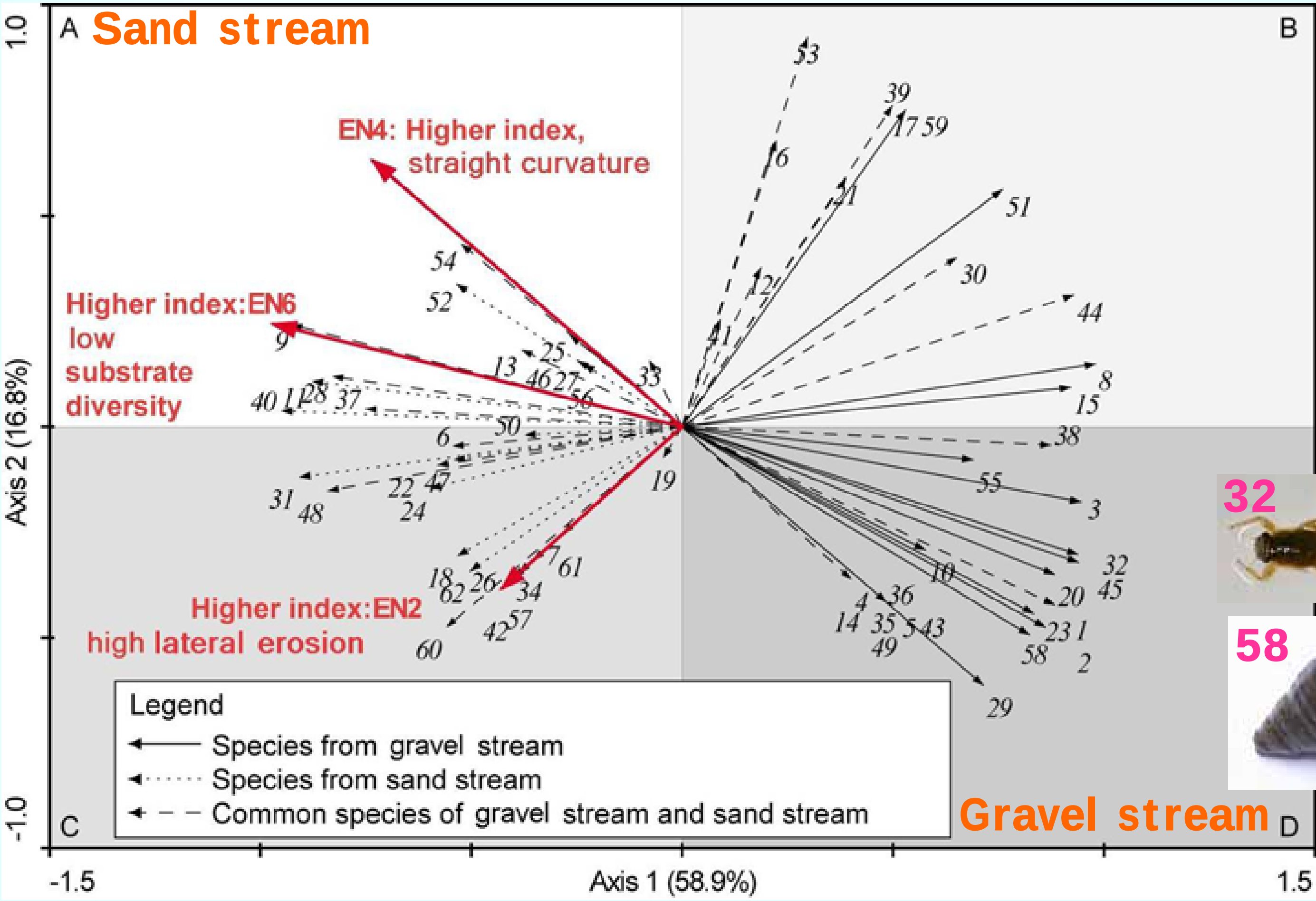
◆ Result of RDA for hydromorphological structure

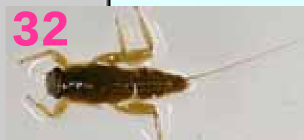
Result \ Axis	Axis 1		Axis 2		Total variable
Sum of all eigenvalues					1
Sum of all canonical eigenvalues					0.821
Eigenvalues (λ)	0.589		0.168		1
Cumulative percentage variance					
of species data	58.9		75.7		
of species-environment relation	71.7		92.2		
Species-environment correlations (R)	0.989		0.977		
Canonical coefficients (*c*) and intra-set correlations (*r*)	*c*	*r*	*c*	*r*	
of environmental variable EN2 (Lateral erosion)	-0.0575	-0.4265	-0.4708	-0.3829	
of environmental variable EN4 (Curvature)	0.5015	-0.7316	1.7271	0.6294	
of environmental variable EN6 (Substrate diversity)	-1.3867	-0.968	-1.0978	0.2435	

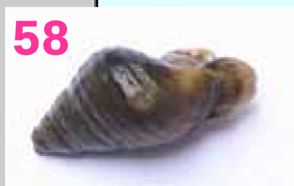
- ✓ Three environmental variables by forward selection.
- ✓ 'Axis 1-EN6' and 'Axis 2-EN4' have strong influence.
- ✓ Axis 1 explains 58.9 % of variance of species and 71.7 % of species-environment correlation.
- ✓ Axis 2 explains 16.8 % of variance of species and 20.5 % of species-environment correlation.

3. RESULTS

◆ RDA ordination graph for hydromorphological structure







3. RESULTS

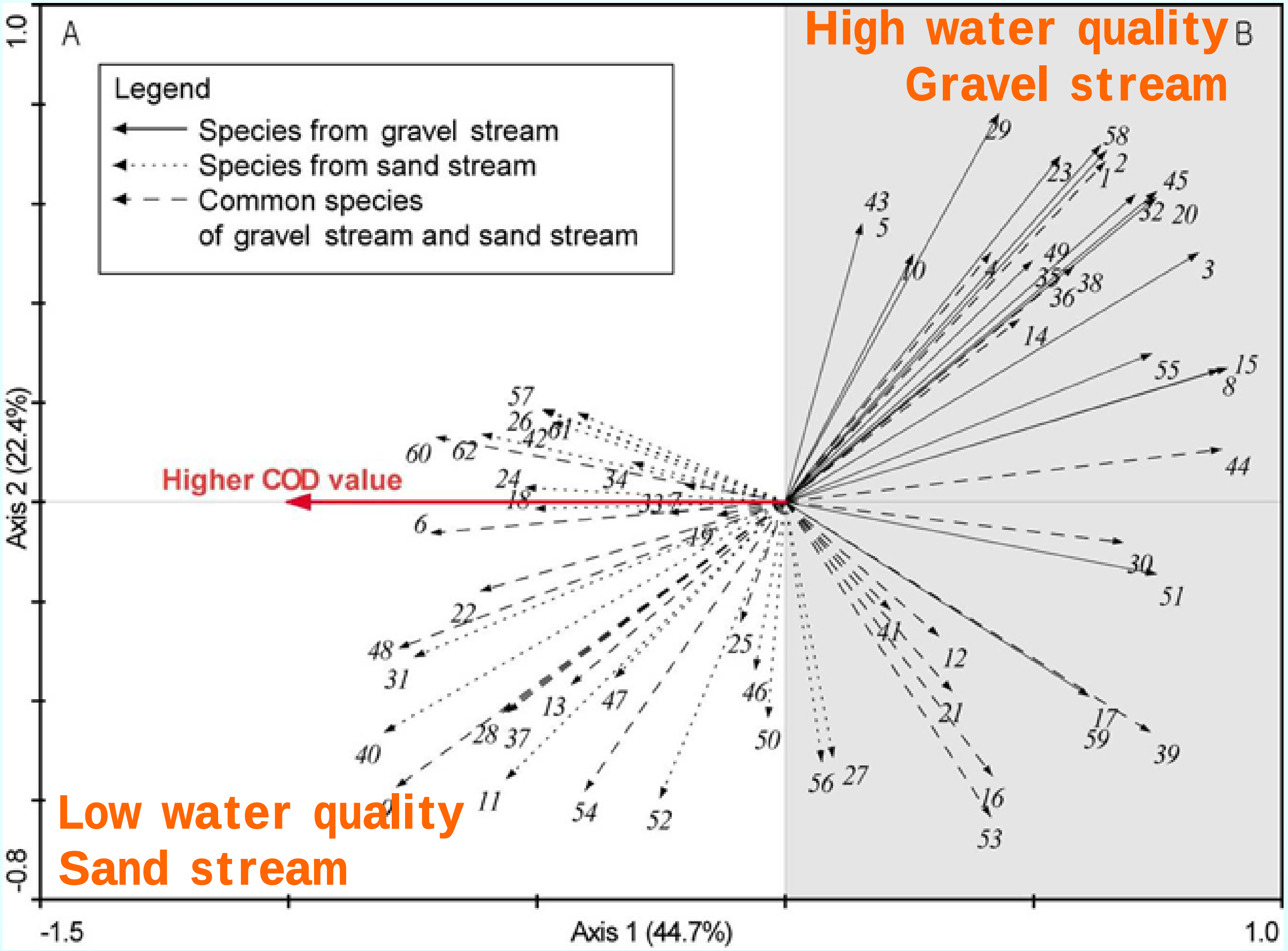
◆ Result of RDA for COD

Result \ Axis	Axis 1		Axis 2		Total variable
Sum of all eigenvalues					1
Sum of all canonical eigenvalues					0.447
Eigenvalues (λ)	0.447		0.224		1
Cumulative percentage variance					
of species data	44.7		67		
of species-environment relation	100		0		
Species-environment correlations (R)	0.868		0		
Canonical coefficients (*c*) and intra-set correlations (*r*)	*c*	*r*	*c*	*r*	
of environmental variable COD	-1	-1	0	0	

- ✓ **One environmental variables by Pearson correlation and forward selection of PCA.**
- ✓ **Axis 1 explains 44.7 % of variance of species and 100 % of species-environment correlation.**
- ✓ **Axis 2 explains 22.4 % of variance of species though it is not attributed by environmental variables.**

3. RESULTS

◆ RDA ordination graph for COD



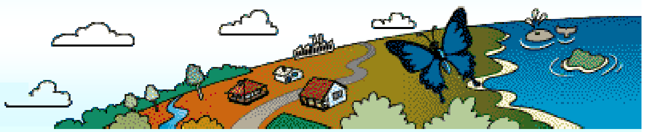
Plants from Belt-transect

- **116 species :** 1:*Ailanthus altissima*, 2:*Galium spurium*, 3:*Setaria vidis*, 4:*Rorippa indica*, 5:*Ampelopsis brevipedunculata* V. *heterophylla*, 6:*Salix gracilistyla*, 7:*Youngia sonchifolia*, 8:*Pteridium aquilinum* V. *latiusculum*, 9:*Staphylea bumalda*, 10:*Securinega suffruticosa*, 11:*Oxalis corniculata*, 12:*Stephanandra incisa*, 13:*Carex lanceolata*, 14:*Festuca ovina*, 15:*Trigonotis peduncularis*, 16:*Vicia unijuga*, 17:*Impatiens noli-langere*, 18:*Corydalis ochotensis*, 19:*Actinidia arguta*, 20:*Maackia amurensis*, 21:*Acer palmatum*, 22:*Commelina communis*, 23:*Bilderdykia dumetora*, 24:*Parthenocissus tricuspidata*, 25:*Carex siderosticta*, 26:*Aceriphyllum ossii*, 27:*Ambrosia artemisiifolia* V. *elatior*, 28:*Alopecurus aequalis* V. *amurensis*, 29:*Woodsia manchuriensis*, 30:*Kummerowia striata*, 31:*Berberis koreana*, 32:*Hypericum ascyron*, 33:*Impatiens textori*, 34:*Bidens frondosa*, 35:*Aster pilosus*, 36:*Cardamine leucantha*, 37:*Angelica decursiva*, 38:*Duchesnea chrysantha*, 39:*Stellaria alsine* V. *undulata*, 40:*Weigela subsessilis*, 41:*Rhus chinensis*, 42:*Hosta longipes*, 43:*Torilis japonica*, 44:*Rubus crataegifolius*, 45:*Morus bombycis*, 46:*Crataegus pinnatifida*, 47:*Rhododendron yedoense* V. *poukhanense*, 48:*Vicia angustifolia* V. *segetilis*, 49:*arex dispalata*, 50:*Menispermum dauricum*, 51:*Amphicarpaea edgeworthii* V. *trisperma*, 52:*Lycopus ramosissimus* V. *japonicus*, 53:*Acer ginnala*, 54:*Lespedeza bicolor*, 55:*Aster yomena*, 56:*Malus sieboldii*, 57:*Chelidonium majus* V. *asiaticum*, 58:*Onoclea sensibilis* V. *interrupta*, 59:*Potentilla fragarioides* var. *major*, 60:*Persicaria hydropiper*, 61:*Hemerocallis fulva*, 62:*Lactuca indica* var. *laciniata*, 63:*Youngia denticulata*, 64:*Callicarpa japonica*, 65:*Trisetum bifidum*, 66:*Viola mandshurica*, 67:*Artemisia japonica*, 68:*Arthraxon hispidus*, 69:*Lespedeza maximowiczii*, 70:*Spiraea prunifolia* for. *simpliciflora*, 71:*Viola acuminata*, 72:*Quercus serrata*, 73:*Boehmeria spicata*, 74:*Lysimachia vulgaris* V. *davurica*, 75:*Gleditsia japonica* V. *koraiensis*, 76:*Aristolochia contorta*, 77:*Hemistepta lyrata*, 78:*Plantago asiatica*, 79:*Rosa multiflora*, 80:*Lilium tigrinum*, 81:*Aster scaber*, 82:*Pueraria thunbergiana*, 83:*Viola verecunda*, 84:*Euonymus alatus* for. *ciliato-dentatus*, 85:*Oenanthe javanica*, 86:*Metaplexis japonica*, 87:*Pinus densiflora*, 88:*Quercus mongolica*, 89:*Rubia cordifolia* V. *pratensis*, 90:*Salix koreensis*, 91:*Persicaria perfoliata*, 92:*Robinia pseudo-acacia*, 93:*Rosa multiflora*, 94:*Artemisia selengensis*, 95:*Phragmites communis*, 96:*Bromus japonicus*, 97:*Quercus aliena*, 98:*Morus alba*, 99:*Miscanthus sinensis* V. *purpurascens*, 100:*Beckmannia syzigachne*, 101:*Dioscorea batatas*, 102:*Agropyron tsukushiense* V. *transiens*, 103:*Stellaria aquatica*, 104:*Oenothera odorata*, 105:*Rumex crispus*, 106:*Fraxinus rhynchophylla*, 107:*Persicaria thunbergii*, 108:*Erigeron canadensis*, 109:*Clematis apiifolia*, 110:*Carex dispalata*, 111:*Phalaris arundinacea*, 112:*Erigeron annuus*, 113:*Humulus japonicus*, 114:*Equisetum arvense*, 115:*Artemisia princeps* V. *orientalis*, 116:*Phragmites japonica*

- **Common species**

Gravel stream	Sand stream	Gravel and sand stream
29	7	9

3. RESULTS



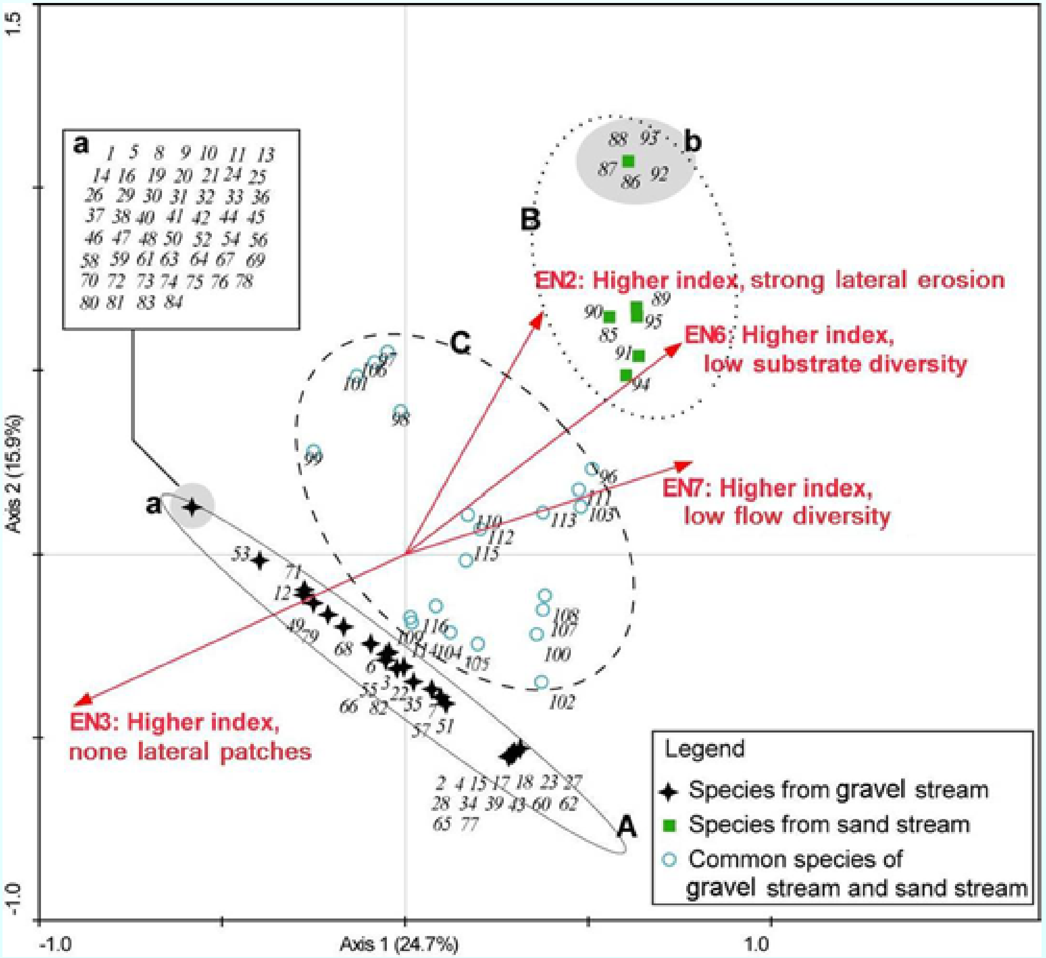
◆ Result of CCA for hydromorphological structure

Result \ Axis	Axis 1		Axis 2		Total variable
Sum of all eigenvalues					2.519
Sum of all canonical eigenvalues					1.495
Eigen values (λ)	0.624		0.398		1
Cumulative percentage variance					
of species data	24.7		40.6		
of species-environment relation	41.7		68.4		
Species-environment correlations (R)	0.997		0.979		
Canonical coefficients (*c*) and intra-set correlations (*r*)	*c*	*r*	*c*	*r*	
of environmental variable EN2 (Lateral erosion)	-0.5251	0.3741	0.7858	0.6571	
of environmental variable EN3 (Lateral patches)	-1.6684	-0.9007	1.2269	-0.4117	
of environmental variable EN6 (Substrate diversity)	-0.7324	0.7517	2.1906	0.573	
of environmental variable EN7 (Flow diversity)	0.3125	0.7816	-1.069	0.2493	

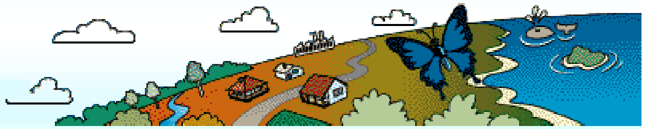
- ✓ **Four environmental variables by forward selection.**
- ✓ **'Axis 1-EN3' and 'Axis 2-EN6' have strong influence.**
- ✓ **Axis 1 explains 24.7 % of variance of species and 41.7 % of species-environment correlation.**
- ✓ **Axis 2 explains 15.9 % of variance of species and 26.7 % of species-environment correlation.**

3. RESULTS

◆ CCA ordination graph for hydromorphological structure



4. CONCLUSION



- **Benthic macro-invertebrates**
  - ✓ They have strong correlations with substrate diversity and curvature of channel.
  - ✓ They can be classified into two groups observed in a sand stream and gravel stream.
  - ✓ Concentration of COD was only selected as a significant factor influencing their habitats.
- **Plants**
  - ✓ They have strong correlations with lateral patches like bars, steps, and riffle-pools and substrate diversity.
  - ✓ They can also be classified into two groups observed in a sand stream and gravel stream.
- **Suggestion**
  - ✓ There can be significant differences in hydromorphological and ecological characteristics between a sand stream and gravel stream.

Thank You!