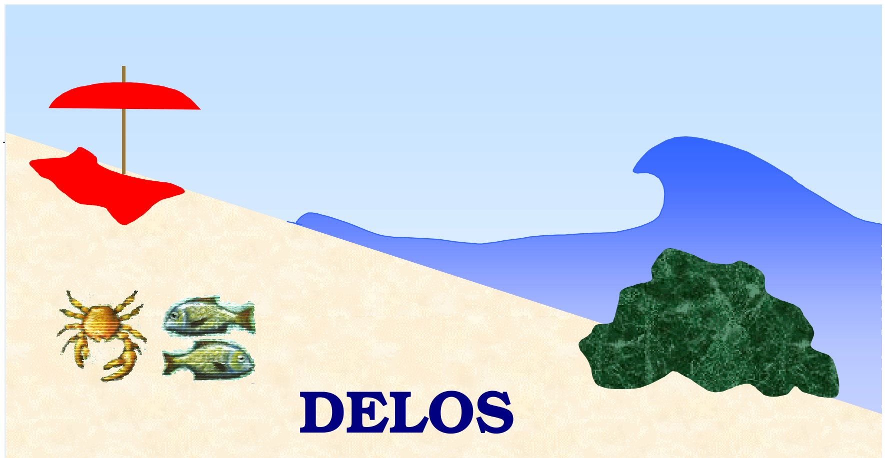
EU Fifth Framework Programme 1998-2002

Energy, Environment and Sustainable Development

Environmental Design of Low Crested Coastal Defence Structures



DELOS FINAL REPORT

Date of preparation: June 2004

Contract: n°EVK3-CT-2000-00041

Project co-ordinator: University of Bologna – DISTART

Project web page: www.delos.unibo.it

Participant informations
Contact Person

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SECTION 1

Management and resource usage summary, related to the reporting period

(Project 3rd and last year)

Contract No : **EVK3-CT-2000-00041**	Reporting period: **1.2.2003 – 29.2.2004**
Title: **Environmental Design of Low-Crested Coastal Defence Structures (DELOS)**	

1.1 Objectives of the reporting period

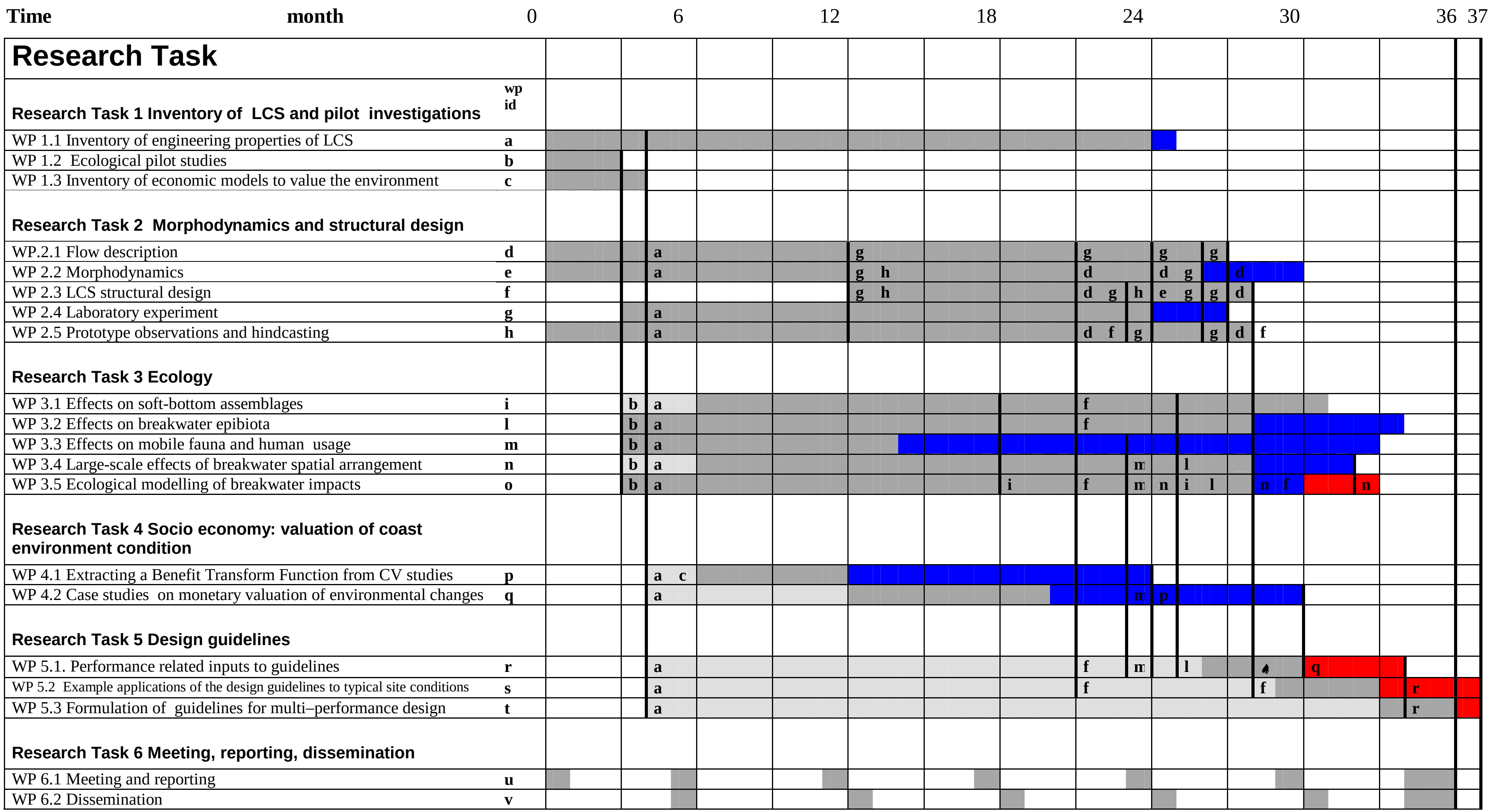
DELOS aims to promote effective and environmentally compatible design of low-crested structures (LCS) to defend European shores against coastal erosion and at the same time preserve the littoral environment and the coast economic development.
Specific objectives are:

1. to provide an inventory of existing LCS
2. to analyse LCS hydrodynamic and stability and their effects on beach morphology
3. to investigate the impacts of LCS on biodiversity and functioning of coastal assemblages
4. to develop a general methodology for Integrated Coastal Zone Management based on Contingent Valuation monetary values
5. to provide validated operational guidelines for the design of LCS to local authorities planning shore defence measures.

A schematic time table of the 3rd Year of Delos Project.
(In Research Task 6 M means a project meeting, W a workshop, R a report to the Commission):

Research Task \ Months	2222233333333 5678901234567
1. Inventory of LCS and pilot investigation	X
2. Coast dynamics	XXXXXXXXX
3. Ecology	XXXXXXXXX
4. Socio-economy	XXXXXX
5. Design guidelines	XXXXXXXXXXXXX
6. Meeting, reporting & dissemination	W M R R R

1.2 Scientific/Technical progress made in different work packages according to the planned time schedule:



Notes:

Active
Sleeping
Declared delay
Estimated delay

|a : transaction from WP “a” to a current row WP

♠ {f, i, l, m, n}

The flow-chart presented before is substantially different from the flow-chart in the Description of Work because several delivery date had been postponed by WP leaders during the second and third year of the project.

Comparison between planned and used manpower during the Third year of DELOS Project for each Work Package and Partner

DELOS WP			**Manpower Table – Third Year**																	
WP List			**Person-months per participant**																	
			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
1.1	Inventory of engineering properties of LCS	***Planned***	**0**		**0**	**0**	**0**		**0**	**0**								**0**		
		Used 3rd year	**0**		**0**	**0**	**0**		**0**	**0**								**0**		
1.2	Ecological pilot studies	***Planned***		**0**							**0**		**0**				**0**			
		Used 3rd year		**0**							**0**		**0**				**0**			
1.3	Inventory of economic models to value the environment	***Planned***	**0**											**0**						
		Used 3rd year	**0**											**0**						
2.1	Flow description	***Planned***	**3**		**3.5**		**3**	**3**	**0.5**	**0**		**2**			**0**	**0**			**1**	
		Used 3rd year	**3**		**10**		**3**	**3**	**0.5**	**12**		**1**							**1**	
2.2	Morphodynamics	***Planned***			**2**	**1**		**3**	**5.4**			**3.8**						**0.5**		
		Used 3rd year			**2**	**1**		**3**	**5.4**			**3.8**						**0.5**		
2.3	LCS Design	***Planned***	**5**		**4**	**1.5**	**3**			**1**						**0**			**2**	
		Used 3rd year	**5**		**4**	**1.5**	**3**			**1**						**0**			**2**	
2.4		***Planned***	**2**		**1**		**0**	**3**	**0**	**0**		**0**				**0.1**				
		Used 3rd year	**2**		**0**		**0**	**3**		**0**		**0**				**0.7**				

Comparison between planned and used manpower during the Third year of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
2.5	Prototype observations and hindcasting	***Planned***	**0**		**4**	**3**	**0**								**0**			**4**		
		Used 3rd year	**4**		**4**	**3**	**0**								**0**			**4**		
3.1	Effects on soft-bottom assemblages	***Planned***		**0**							**9**				**0**		**1**			
		Used 3rd year		**12**							**9**				**1.7**		**1**			
3.2	Effects on breakwater epibiota	***Planned***		**12**			**0.5**				**0.7**						**3**	**0**		**8**
		Used 3rd year		**15**			**0.5**				**0.7**						**3**	**0**		**8.0**
3.3	Effects on mobile fauna and human usage	***Planned***		**0**							**5.4**						**2**	**0**		
		Used 3rd year		**0**							**5.4**						**2**	**0**		
3.4	Large-scale effects of breakwater spatial arrangement	*Planned*		**4**							**2.3**		**0**				**0**			
		Used 3rd year		**16**							**2.3**		**0**				**0**			
3.5	Ecological modelling of breakwater impacts	*Planned*		**1**							**1.8**		**6**		**0**		**0.4**			
		Used 3rd year		**1**							**1.8**		**6**		**0**		**0.4**			
4.1	Extracting a Benefit Transfer Function from CV studies	*Planned*	**6-0**		**0**									**0**						
		Used 3rd year			**0**									**0**						
4.2	Case studies on monetary valuation of environmental changes	*Planned*	**4**		**1**									**2.4**						
		Used 3rd year	**4**		**1**									**2.4**						

Comparison between planned and used manpower during the Third year of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
5.1	Performance-related inputs to guidelines	*Planned*	**3**	**1.5**			**0**		**0.87**	**2**			**2**	**1.5**	**1**		**1.5**			
		Used 3rd year	**3**	**1.5**			**0**		**0.87**	**2**			**2**	**1.5**	**1**		**1.5**			
5.2	Example applications of the design guidelines to typical site conditions	*Planned* 1st year	**13**	**2**	**2**	**0**	**1.5**		**1-0.5**		**2**	**1**			**2.5**		**2**	**0.5**		
		Used 3rd year	**13**	**2**	**2**	**0**	**1.5**		**0.5**		**2**				**1**		**2**	**0.5**		
5.3	Formulation of guidelines for multi-performance design	*Planned*	**5**				**5.5**	**3**		**2**		**1**	**2**	**1**		**0.6**		**0.5**	**2**	
		Used 3rd year	**5**				**5.5**	**3**		**3**			**2**	**1**		**0.6**		**0.5**	**2**	
6.1	Meetings, workshops and reporting	*Planned*	**4**	**2**	**3**	**1**	**1**	**1**	**0.33**	**0.5**	**1.4**	**0.2**	**2**	**1**	**0.3**	**0.3**	**0.5**	**1**	**1**	**0.2**
		Used 3rd year	**4**	**3.5**	**3**	**1**	**1**	**1**	**0.33**	**0.5**	**1.4**	**0.2**	**2**	**1**	**0.3**	**0.3**	**0.5**	**1**	**1**	**0.2**
6.2	Dissemination	*Planned*	**2**	**3**	**0.5**	**1.5**				**0.4**	**1**		**1**	**2**			**0.6**	**0.4**		
		Used 3rd year	**2**	**3**	**0.5**	**1.5**				**0.4**	**1**		**1**	**2**			**0.6**	**0.4**		

Comparison between planned and used manpower during the Third year of DELOS Project for each Work Package and Partner

		UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
Total	*Used 3rd year*	45	54	26.5	8	17.5	13	7.6	18.9	23.6	5	13	7.9	4	1.6	11	6.9	6	8.5

Table with comparison between planned and used financial resources during the 3rd Year of DELOS Project for each Work Package and Partner

DELOS WP			Financial resources –Third Year																	
WP List			Financial resources (Euro) per participant for the 3rd reporting period																	
			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
1.1	Inventory of engineering properties of LCS	*Planned* 3rd Year																		
		Used 3rd Year																		
1.2	Ecological pilot studies	*Planned* 3rd Year																		
		Used 3rd Year																		
1.3	Inventory of economic models to value the environment	*Planned* 3rd Year																		
		Used 3rd Year																		
2.1	Flow description	*Planned* 3rd Year	8795.26		6660.00			19276				11339							2100	
		Used 3rd Year	**9297.54**		**6660.00**			**18647**	**3508**	**25481.79**		**5922**							**2100**	
2.2	Morphodynamics	*Planned* 3rd Year			1332.00	521.25		19276	7968			29044.76						1885		
		Used 3rd Year			**1332.00**	**2356.60**		**18647**	**37880**			**28514.43**						**930**		
2.3	LCS Design	*Planned* 3rd Year	14658.76		2664.00	78187	3367			0									2100	
		Used 3rd Year	**16057.11**		**2664.00**	**3534.91**	**308**			**6380**									**2100**	

Table with comparison between planned and used financial resources during the 3rd Year of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
2.4	Laboratory experiments	*Planned* 3rd Year	5863.50					19276								0				
		Used 3rd Year	**5917.75**					**18647**								**7000**				
2.5	Prototype observations and hindcasting	*Planned* 3rd Year	11727		2664.00	1563.75												15075		
		Used 3rd Year	**12677.33**		**2664.00**	**7069.81**												**7450**		
3.1	Effects on soft-bottom assemblages	*Planned* 3rd Year		6924							47206.28				16646		11959			
		Used 3rd Year		**9271**							**37189.66**				**16646**		**13459**			
3.2	Effects on breakwater epibiota	*Planned* 3rd Year		11098							10489.04						19061			42522
		Used 3rd Year		**19544**							**2896.00**						**24710**			**47554.85**
3.3	Effects on mobile fauna and human usage	*Planned* 3rd Year									20978.08						2100			
		Used 3rd Year									**22309.90**						**18329**			
3.4	Large-scale effects of breakwater spatial arrangement	*Planned* 3rd Year		21611							13108.52						7683			
		Used 3rd Year		**32918**							**9507.06**									
3.5	Ecological modelling of breakwater impacts	*Planned* 3rd Year		2000							9831.38		49000				3532			
		Used 3rd Year		**2000**							**7430.14**		**49000**				**4993**			
4.1	Extracting a Benefit Transfer Function from CV studies	*Planned* 3rd Year																		
		Used 3rd Year																		

Table with comparison between planned and used financial resources during the 3rd Year of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
4.2	Case studies on monetary valuation of environmental changes	*Planned* 3rd Year	11727.01		666.00									22189						
		Used 3rd Year	**12677.33**		**666.00**									**22189**						
5.1	Performance-related inputs to guidelines	*Planned* 3rd Year	8795.26	1000					10303	10000			7000	13868	9792		10427			
		Used 3rd Year	**9297.54**	**1250**					**6103**	**7860**			**7000**	**13868**	**9792**		**15074**			
5.2	Example applications of the design guidelines to typical site conditions	*Planned* 3rd Year	20522.27	1500	1332.00	521.25			6869		2619.48				9792		12403	1885		
		Used 3rd Year	**22816.69**	**1500**	**1332.00**	**1178.3**			**5612**		**8258.96**				**9792**		**18528**	**930**		
5.3	Formulation of guidelines for multi-performance design	*Planned* 3rd Year	14658.76					19276		11000			14000	9245		3570		1885	2100	
		Used 3rd Year	**16057.26**					**18647**		**16160**			**14000**	**9245**		**4672**		**930**	**2100**	
6.1	Meetings, workshops and reporting	*Planned* 3rd Year	23454.02	3050	1998.00	521.25	8334	6.643	5035	13000	4614.74	3000	20500	9245	2938	3000	7758	3770	2100	
		Used 3rd Year	**26196.47**	**9935**	**1998.00**	**2356.6**	**6819**	**9160**	**2315**	**22617.79**	**5782.24**	**9901.7**	**20500**	**9245**	**2938**	**3000**	**10160**	**1860**	**2100**	
6.2	Dissemination	*Planned* 3rd Year	11727.01	2000	333.60	781.87				11000	2619.48		7000	18491			5677	1500		
		Used 3rd Year	**12677.18**	**3683**	**333.60**	**1178.3**				**12834.94**	**4134.36**		**7000**	**18491**			**6769**	**744**		

Table with comparison between planned and used financial resources during the 3rd Year of DELOS Project for each Work Package and Partner

		UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
Total	*Planned* 3rd Year	131928.86	49133	17649.6	4691.24	11701	83747	30175	45000	111467.0	43383.76	97500	73038	39168	6570	80601	26000	8400	42522
	Used 3rd Year	**143672.23**	**80101**	**17649.6**	**17674.53**	**7127**	**83747**	**53314**	**91334.52**	**97508.32**	**44338.13**	**97500**	**73038**	**39168**	**14672**	**112022**	**12844**	**8400**	**47554.85**

In blue: Total cost with UE financial contribution of 50%

		UB as COO
Total co-ordination costs	*Planned* 3rd Year	29242.16
	Used 3rd Year	**29978.10**

Deliverables produced (available on DELOS web site)**:**

D14 Assessment of direct effects on mobile fauna and indirect predation effects on surroundings
D15 Determination of enhancement of fish stocks and other biological resources
D17 Calibrated 3D near field flow preliminary model
D20 Quasi 3D morphodynamic complex model
D21 One-line morphodynamic model for LCS
D23 Report on turbulent flow velocities in the surface region of LCS, preliminary version
D28 CV study reports
D31 Wave basin experiments final form
D32 Wave channel experiment final form
D33 Assessment of direct and indirect effects on soft-bottom assemblages
D34 Identification of impact time-courses on surrounding assemblages
D37 Calibrated morphological models for beach evolution due to LCS
D38 Identification of design features to minimise bioerosion of breakwaters
D40 Assessment of positive and negative “corridor” effects on species dispersal
D42 Calibrated 2DH far field wave flow final model
D43 Structural design report for LCS, final version
D44 Report on turbulent flow velocities in the surface region of LCS, final version
D45 Identification of design features to maintain biodiversity of soft-bottom assemblages
D46 Identification of design features to maintain biodiversity of epibiota
D47 Evaluation of the potential of breakwaters as a tool to aid conservation of coastal assemblages
D48 Model of suitable habitats for key-species on breakwaters as a function of local hydrodynamics
D49 Habitat evaluation procedure of sediments around different types of breakwaters
D50 Meta-population model as a function of large-scale distribution of breakwaters
D51 Modeling results to Research Task 5 – Design guidelines
D52 Report on scale effects for LCS, final version
D53 Engineering, ecological and socio-economical input to design guidelines
D54 Case studies report
D55 Proceedings of Workshop3
D58 Study sites report, 3rd year
D55bis Proceeding Last Meeting

1.3 Deviations from the work plan or /and time schedule and their impact to the project

The deviations from original work plan are:

WP 2.4
No important deviations, activities are completed. Reporting was delayed but the results of the laboratory experiments have been known to partners for a long time. Therefore the delay did not cause any delay in other workpackages.
WP 3.1
No significant deviations from the original work plan have been observed except a delay in the collaboration between CSIC and UPC (relationships between hydrodynamics and sediment dynamics and benthic infauna in Altafulla) which results are not yet been implemented.
WP 3.2
There were no deviations from the original work plan for this third year. Additional studies were set up in 2003 to investigate interesting issues arisen from the development of research activities during the first two years of the project.
WP 3.3
There are no significant deviations for the original work plan. As already explained in previous DELOS reports fish surveys including the effect on drift algae on fish and mobile fauna were extended to the third year, to confirm interesting patterns observed in year 1 and 2.
WP 3.4
No deviations have occurred with respect to the original work plan in terms of inputs to design guidelines and deliverables. However, because of the particularly interesting results from the WP 3.4, and because of the importance that long term data sets have on the quality of ecological studies, the analysis of the dynamics and population genetic structure of the model species *Patella caerulea*, and experiments on the second model species *Codium fragile* have been carried on until the end of the project in January 2004
WP 4.2
The scheduled programme was fully respected. The revision of the data did not involved any change of the final report D28/A.
WP5.3
It was not possible to deliver a complete draft of the guidelines according to the time schedule (within the third year). The problem has been that other work packages and deliverables have been delayed, which has caused delay of the inputs to the guidelines. The work for completing the guidelines is expected to go on for a couple of months after the last year.

1.4 Co-ordination of the information between partners and communication activities

Workshop 3 in Thessaloniki

31 Participants
(including end-users, reviewers and EU members)

Institution	**N° of person**
University of Bologna UB	2
Aalborg University AAU	2
University of Cantabria UCA	1
LIM-UPC	1
Marine Ecology, Marine botany UGOT	3
University of Twente UTW	1
University of Southampton UoS	1
Aristotle Univ. Of Thessaloniki AUTH	4
Scienze Ambientali Fondazione Flaminia FF	2
DSIC – University of Roma Tre UR3	2
MODIMAR s.r.l.	1
Technical University Denmark, ISVA	1
DHI Water & Environment	2
CSIC, CEAB	2
Infram	1
The Marine Biological Association	2
University of Aarhus	2
External reviewers	1

3rd Year Meeting in Ostia

41 Participants
(including end-users, reviewers and EU members)

Institution	**N° of person**
University of Bologna UB	7
Aalborg University AAU	2
University of Cantabria UCA	2
LIM-UPC	1
Marine Ecology, Marine botany UGOT	3
University of Twente UTW	1
University of Southampton UoS	1
Aristotle Univ. Of Thessaloniki AUTH	1
Scienze Ambientali Fondazione Flaminia FF	6
DSIC – University of Roma Tre UR3	3

MODIMAR s.r.l.	1
Technical University Denmark, ISVA	2
DHI Water & Environment	1
CSIC, CEAB	3
Delft Hydraulics, DH	1
The Marine Biological Association	3
External reviewers	2
EU members	1

SECTION 2

Executive publishable summary, related to the reporting period

(Project 3rd and last year)

Contract No : **EVK3-CT-2000-00041**	Reporting period: **1.2.2003 – 29.2.2004**
Title: **Environmental Design of Low-Crested Coastal Defence Structures (DELOS)**	

Contract n°	EVK3-CT-2000-00041	Reporting period:	1.2.2003-29.2.2004
Title	**Environmental Design of Low Crested Coastal Defence Structures – DELOS**		

Objectives:

DELOS third year activities aimed:

- to complete research activities started in the previous two years, in particular: the analyses of the new experimental data sets; the validation and calibration of hydrodynamic and morpho-dynamic numerical models by means of experimental and field data; the assessment of ecological impacts due to low-crested structures (LCSs) from the data collected by periodical surveys in selected areas; the check of the Benefit Transfer function; the analyses of social impact of defence structures based on the results of the interviews;
- to integrate results among engineers, economists and ecologists for producing selected input to design guidelines;
- to prepare guidelines for the design of low crested structures;
- to provide dissemination of results through the final meeting, the website and thematic papers to be printed on Coastal Engineering journal.

Scientific achievements:

DELOS third year achievements are summarised by themes as follows.

Engineering

The complete analyses carried out on the new experimental data sets allowed to a better understanding of hydrodynamics and morphodynamics induced by LCSs and to provide new formulae for structure stability, wave transmission and reflection, location and intensity of scour around the structures due to breaking and steady streaming.

Numerical models have been validated against experimental data, in particular:

- the hydrodynamic 2DV RANS VOF model developed by UCA, which gave useful information on overtopping and filtration processes;
- the 3D Navier-Stokes hydrodynamic model by DHI, which appeared able to accurately represent transients but is still under development;
- the Delft 3D model, which reproduces hydrodynamics, morphodynamics and some ecological aspects.

Ecology

Ecological effects of LCSs appear to be site-specific reflecting the complexity and variability of natural systems. Major effects on coastal assemblages have been identified based on which major criteria that LCS design shall address are:

- To promote the development of salubrious areas in the protected zone by increasing the water flow through the structures;
- to avoid large-scale effects of habitat loss, fragmentation and community changes by reducing to the minimum LCSs length;
- to facilitate settlement/persistence of algae and marine invertebrates and reduce ephemeral green algae, by increasing structure stability, minimising maintenance works and managing human usage;
- to avoid disturbances for abundance and composition of epibiotic assebmblages due to siltation and scouring, for instance by increasing the berm width;
- to promote settlement of organisms and enhance diversity by increasing armour geometry complexity and heterogeneity;
- to avoid exsiccation of colonising organisms by assuring structure submergence even in low-tide.

Economics

The construction of LCSs for beach protection in Lido di Dante and Pellestrina was

'justified' from an economic point of view by the CVM surveys carried out in the second year.
The error due to improper calibration of the coefficients in the Benefit Transfer Function has been assessed.
LCS design criteria shall account for the preferences that people expressed:

- submerged structures for aesthetic reasons;
- groins for water quality and recreational activities.

Global result

Major results from the different tasks have been integrated and prepared as input to design guidelines. An example application of the guidelines to a selected site allowed to check strengths and weakness of the draft document and to require specific contributions.
Titles and contents of selected conclusive articles to be printed in a Special Issue of Coastal Engineering have been discussed and preparation of the paper has been started.
The DELOS web-site have been regularly updated with project advances and a Final Meeting open to end users was hold to disseminate project results.

Socio-economic relevance and policy implications:

DELOS addressed these primary contributions to Community social objectives:
Preservation, protection and improvement of coastal environments
Analysis to forecast effects of low crested defence structures on the littoral environment and associated assemblages of animals and plants was performed to enhance the sustainable development and natural value of these systems.
The study generated insights into ways to use artificial structures to restore or enhance local productivity and biodiversity.
Improving the quality of life, health and safety
The knowledge and guidelines developed within DELOS may guarantee an effective protection of European sandy coasts, which would give secure benefits in terms of maintenance and improvement of suitable areas for tourism.
Knowledge and amelioration of hydrodynamic conditions around the structures can give positive effects on swimming safety.
The structures may also provide a focus for recreational and food gathering activities, in some areas benefiting fisheries for littoral gastropod molluscs.
The development of *Design Guidelines* for LCSs will result in more frequent choice of this type of structures instead of higher and more visible ones. The negative visual impact can thus be reduced, which is generally perceived as equating with higher habitat quality by the public. Design guidelines take into account also the effects of breakwater morphology and location on colonising epibiota, in order to limit colonisation by species that are seen as a nuisance when torn off the structures and transported to the sandy beaches (e.g. green algae and kelp detritus) while promoting assemblages that are similar to those on natural hard sea-beds and rocky shores.

Conclusions:

The Project met all the expected objectives; further research is however felt necessary on several topics, e.g.: biological effects forecasting, morpho-dynamic modelling, extension of benefit valuation function beyond touristic use.
Further work is needed to complete the thematic papers summarising DELOS results to be published in Coastal Engineering journal; deep revision is also necessary to provide a final version of design guidelines to be published by Elsevier.

Keywords:

Low crest, Coastal structures, Hydrodynamics, Erosion, Ecology, Functioning, Design, Valuation.

Publications (cumulative list):

Peer Reviewed Articles

Authors	Date	Title	Journal	Reference
Archetti R., Tirindelli M., Lamberti A.	2003	Field measurements of hydrodynamics around a beach defense system.	Proc. Coastal Structures 2003 ASCE	
M. Di Risio, R. Archetti , G. Bellotti, M. Soldati	2003	Nearshore waves and currents at Pellestrina	Proc. of the *VI* MEDCOAST 7 10 October 2003. Ravenna. Italy.	Ed E. Ozhan (Ed.) pp 2145 2154.
Archetti R. Tirindelli M., Gamberini, G., Lamberti A.	2003	Analysis of currents around a low crested barrier: comparison between field and numerical results.	Proc. of the *VI* MEDCOAST 7 10 October 2003. Ravenna. Italy.	Ed E. Ozhan (Ed.) pp 1731 1740.
Silva Marzetti	March 2003	'Valuation of the benefits from the coastal defence systems of some Italian sites: Venice and its lagoon, Lido di Dante, Ostia and Trieste'	ELOISE conference, Gdansk	
Silva Marzetti and Alberto Lamberti	Octob er 2003	'Economic and Social Valuation of the Defence System of Venice and its Lagoon (Italy)'	MEDCOAST 03, Ravenna (Italy)	E.Ozhan (ed)
Silva Marzetti and Barbara Zanuttigh	Octob e, 2003	'Economic and Social Valuation of Beach Protection in Lido di Dante (Italy)	MEDCOAST 03, Ravenna (Italy)	E.Ozhan (ed)
Zanuttigh, B. & A. Lamberti	2004	Circulation induced by wave breaking over submerged breakwaters: experimental results and numerical simulations	ASCE, Journal of Waterway	Under revision
Lamberti, A & B. Zanuttigh	2003	Coastal monitoring, ecological surveys, socio-economic valuation and numerical modelling in Lido di Dante, Italy	3rd ELOISE Conference, Danzica, 24-27 March	
Lamberti, A., Zanuttigh, B. & M. Tirindelli	2003	3D Hydrodynamic tests with low-crested structures: analysis of overtopping and velocity fields	Proceedings ISOPE 2003, Honolulu, 22-26 May	International society of Offshore and Polar Engineering, vol. 4, pg. 562-569
van der Meer, J. W., Wolters, A., Zanuttigh, B. and M. Kramer	2003	Oblique wave transmission over low-crested coastal defence structure	Coastal Structures, Portland, Oregon, 26-29 August	
Lamberti, A., Zanuttigh, B. & M. Kramer	2003	Wave and current flow around low-crested coastal defence structures	Coastal Structures, Portland, Oregon, 26-29 August	
Zyserman, J., A., Zanuttigh, B. & E. Damgaard	2003	Validation of simple and advanced wave models against 3D model measurements	Coastal Structures, Portland, Oregon, 26-29 August	
Martinelli, L.,	2003	Comparison of directional wave analysis	IAHR 2003,	

Zanuttigh, B. & A. Lamberti		methods on laboratory data	XXX Congress, Salonicco, Grecia, 24-29 August	
Zanuttigh, B., Guerrero, M. & A. Lamberti	2003	3D experimental analysis and numerical simulations of hydrodynamics around low-crested structures	IAHR 2003, XXX Congress, Salonicco, Grecia, 24-29 August	
Lamberti, A., Zanuttigh, B. & M. Tirindelli	2003	Evaluation of overtopping processes on low-crested structures	MEDCOAST 2003, Ravenna, 7-11 October	Ed E. Ozhan (Ed.) pp pp.1929-1940
Zanuttigh, B., Lamberti, A & M. Guerrero	2003	3D hydrodynamics around low-crested structures: experimental results and numerical simulations	MEDCOAST 2003, Ravenna, 7-11 October	
Lamberti, A., Zanuttigh, B. & L. Martinelli	2003	Wave run-up, overtopping and transmission over Low Crested Structures	ICCE 2004, Lisbona, July 2004	Accepted
Martinelli, L., Zanuttigh, B., Clementi, E., Guerrero, M. & A. Lamberti	2003	Experimental analysis and 2DH numerical simulations of morphodynamics around Low-Crested Structures	ICCE 2004, Lisbona, July 2004	Accepted
Barbanti, C., Archetti, A., Pahpitis, D. & B. Zanuttigh	2003	Hydrodynamics and morphodynamics at a protected beach: the study site of Pellestrina, Italy	ICCE 2004, Lisbona, July 2004	Accepted
Van der Meer, J., Briganti, R., Wang, B. & B. Zanuttigh	2003	Wave transmission at Low Crested Structures including oblique wave attacks	ICCE 2004, Lisbona, July 2004	Accepted
Zanuttigh, B. & L. Martinelli	2004	Hydrodynamics induced by low-crested rubble-mound structures: wave basin experimental analysis and 2DH numerical simulations	XXIX Convegno Nazionale di Idraulica e Costruzioni Idrauliche, Trento, 7-10 September	Submitted
Zanuttigh, B..	2004	Wave reflection induced by permeable and impermeable low-crested coastal defence structures	XXIX Convegno Nazionale di Idraulica e Costruzioni Idrauliche, Trento, 7-10 September	Submitted
Tirindelli M. & Lamberti A	2004	Evaluation of Wave-Induced Loads on Low-Crested Structure Elements	ICCE 2004, Lisbon, Portugal	Abstract accepted
Tirindelli M. & Lamberti A.	2004	Forze Impulsive Indotte da Onde Frangenti su Massi di Barriere Sommerse e su Organismi Colonizzatori	Hydraulic National Conference 2004, Trento, Italy	Abstract accepted
Tirindelli M., Cuomo G., Allsop N.W.H. & Lamberti A.	2003	Wave-in-deck forces on jetties and related structures	Proceedings ISOPE 2003, Honolulu, Hawaii,	International society of Offshore and Polar

				Engineering, Vol. 3, pg. 823-830
Tirindelli M. & Lamberti A.	2004	Evaluation of Wave-Induced Loads on Low-Crested Structure Elements	ICCE 2004, Lisbon, Portugal	Abstract accepted
Garcia, N., Lara J.L. and Losada, I.J.	2003 (June)	2-D numerical analysis of near-field flow at low-crested permeable breakwaters	Coastal Engineering, Elsevier	submitted
Losada, I.J., Lara, J.L., E.D. Christensen and Garcia, N.	2004	Breaking process, velocities and turbulence intensity around low-crested structures	Coastal Engineering, Elsevier	DELOS special issue
H. Burcharth; C. Vidal, Lamberti; L. Franco, A. Noli ; J. W. van der Meer INF	2004	Structural stability, toe protection against scour and construction peculiarities of low crested breakwaters	Coastal Engineering, Elsevier	DELOS special issue
M. Kramer, B. Zanuttigh , M. Tirindelli , J.W. van der Meer, C. Vidal, X. Gironella	2004	Laboratory experiments on low-crested breakwaters.	Coastal Engineering, Elsevier	DELOS special issue
A. S. Arcilla, J.P. Sierra, I. Cáceres, D. González, J.M. Alsina, F. Montoya & J. Galofré	2004	Beach dynamics in the presence of a low crested structure. The Altafulla case	J. of Coastal Research	SI 39 (in press)
Sundelof A., Åberg P.	Submitted (20031218)	Birth functions in two sex demographic models	Proceedings of the royal society of London, series B	
L. M. Granhag, J. A. Finlay, P. R. Jonsson, J. A. Callow and M. E. Callow	Submitted (20031017)	Roughness-dependent removal of settled spores of the green alga *Ulva* (*Enteromorpha)* exposed to hydrodynamic forces from a water jet	Biofouling	
Sundelof A., Åberg P., Jonsson P., Airoldi L., Abbiati M.,	In prep.	Regional dynamics of the intertidal limpet *Patella caerulea* in a typically structured environment		
Granhag L. M., Jonsson P., Moschella P., Thompson R. C,	In prep.	Relative importance of biological and hydrodynamic control of size and survival of the intertidal plant *Fucus spiralis*.		
Avgeris I., Karambas Th. et al	01/04	Modeling of waves and currents around submerged breakwaters	Coastal Eng.	
Bulleri F. Abbiati M., Airoldi L.	submitted	The colonisation of human-made structures by the invasive alga *Codium fragile* ssp. *tomentosoides* in the north Adriatic Sea (NE Mediterranean).	*Hydrobiologia*	submitted
G.Bellotti, R.Archetti e M.Brocchini	2003	Experimental validation and characterization of mean swash zone boundary conditions	Journal of Geophysical Research-Oceans	Vol. 108 (C8), 3250, 10.1029/2002JC001510, 2003
G. Bellotti, G. Beltrami & P. De Girolamo	2003	Internal generation of waves in 2D fully-elliptic mild-slope equation FEM models	Coastal Engineering	Vol. 49 (1-2), pp. 71-81, 2003
G. Bellotti	2004	A simplified model of rip currents systems around discontinuous submerged breakwaters	Under peer review on Coastal Engineering	
R. Briganti, R.E. Musumeci, G. Bellotti, M. Brocchini & E. Foti	2004	Boussinesq modelling of breaking waves: description of turbulence	Under peer review on Journal of Geophysical Research -	

			Oceans	
R. Briganti, J. Van der Meer, M. Buccino & M. Calabrese	2003	Wave transmission behind low crested structures	Proocedings of the 4th International Conference on Coastal Structures (in print)	
G. Bellotti e M. Brocchini	2003	On swash zone boundary conditions for wave-averaged models	Proceedings of the XXVIII International Conference on Coastal Engineering, Cardiff	Vol. 1, pp. 895-903
M. Di Risio, R. Archetti, G. Bellotti & M. Soldati	2003	Nearshore waves and currents at Pellestrina	Proceedings of the Sixth International Conference on the Mediterranean Coastal Environment, MEDCOAST 03	Vol. 3, pp.2145-2154
G. Bellotti	2003	A simplified model for estimating rip currents flow parameters: application to a study case	Proceedings of the Sixth International Conference on the Mediterranean Coastal Environment, MEDCOAST 03	Vol. 3, pp.1983-1990
M. Brocchini, G. Bellotti e R. Archetti	2003	The swash zone as a boundary layer	Book of Abstracts of the Euromech Colloquium N. 451	pp. 23-24, eds. E. Foti and J Fredsoe
R. Musumeci, R. Briganti, G. Bellotti, M. Brocchini	2004	Boussinesq modelling of breaking waves: description of turbulence	Accepted for presentation at the XXIX International Conference on Coastal Engineering	
R. Briganti & M. Brocchini	2004	Breaking criterion and roller modelling in Boussinesq-type models	Accepted for presentation at the XXIX International Conference on Coastal Engineering	
R. Briganti, R.E. Musumeci, G. Bellotti, M. Brocchini e E. Foti	2004	Sull'idrodinamica di onde frangenti (On the hydrodynamic of breaking waves)	Abstract submitted to the XXIX Convegno di	

			Idraulica e Costruzioni Idrauliche, Trento (Italy)	
G. Bellotti	2004	A simple model for estimation of rip currents flow parameters	Abstract submitted to the XXIX Convegno di Idraulica e Costruzioni Idrauliche, Trento (Italy)	
L. Franco, M. Di Risio, C. Riccardi, P. Scaloni, M. Conti	2004	Monitoring the Ostia central beach LCS case study (in Italian)	Under peer review on Studi Costieri	
Panizzo A., Briganti R., Van Der Meer J., Franco L.	2003	Analysis of wave transmission behind LCS using neural networks	Proceedings of the 4th International Conference on Coastal Structures	
Contini P., Mita M., Codispoti N., Briganti R., Franco L.	2003	Shoreline evolution in presence of detached breakwaters. Analysis by means of One line Model	Preoceeding of Medcoast 03 Conference	1763-1774
B.M. Sumer, L. H. C. Chua, N-S Cheng and J. Fredsøe	2003	The influence of turbulence on bedload sediment transport	Journal of Hydraulic Engineering ASCE	vol. 129, pp. 585-596, 2003.
R. Miller, A. Roulund, B.M. Sumer, J. Fredsøe, C. Truelsen and J. Michelsen	2003	3-D Numerical modelling of flow around a groin".		In: I. Nezu and N. Kotsovinos (eds.), Proceedings of the XXX. IAHR Congress, Thessaloniki, Greece, 24-29.August, 2003, AUTh, Thessaloniki, Greece, vol. II, pp. 385-392.
N. Drønen, H. Karunarathna, J. Fredsøe, B.M. Sumer and R. Deigaard	2002	An experimental study of rip channel flow	Coastal Engineering	Vol. 45, 223-238, 2002
K. Gislason, J. Fredsøe and B.M. Sumer	2003	"Morphodynamic modelling in front of vertical and sloping walls".		Coastal Structures 2003, 26-29.August, 2003, Portland, Oregon, U.S.A., Abstract
Hakeem Johnson	2003	Wave modelling in the vicinity of submerged breakwaters	Coastal Engineering	Submitted for review
I. Losada, J.L. Lara and Erik D. Christensen	2004	Breaking process, velocity and turbulence intensity around low-crested structures	Coastal Engineering, special issue DELOS	Manuscript in preparation
H. Johnson, Th. Karambas, J. Avgeris, B. Zanuttigh, I.	2004	Modelling of waves and currents around submerged breakwaters	Coastal Engineering, special issue	Manuscript in preparation

Caceres,G. Bellotti, M. Brocchini			DELOS	
J. Zyserman and B. Zanuttigh	2004	Local scour and erosion around –crested coastal defence structures. Part 2: Far field erosion and morphological effects	Coastal Engineering, special issue DELOS	Manuscript in preparation
Martin D., Fabio Bertasi, Marina A. Colangelo, Matthew Frost, Stephen J. Hawkins, Enrique Macpherson, Paula S. Moschella, Maria Paola Satta, Richard C. Thompson, Mindert deVries, Victor U. Ceccherelli.	2004	Ecological impacts of low crested structures on soft bottoms and mobile infauna: how to evaluate the consequences of an unavoidable modification of the native habitats	Coastal Engineering special issue DELOS	In prep
Moschella P., Abbiati M., Åberg P., Airoldi L., Anderson J.M., Bacchiocchi F., Dinesen G.E., Gacia E., Granhag L., Jonsson P., Satta M.P., Sundelöf A., Thompson R.C., Hawkins S.J.	2004	Low crested structures as artificial habitats for marine life: what grows where and why?	Coastal Engineering special issue DELOS	In Prep.
Airoldi L., Abbiati M., Hawkins, Jonsson P.R., Martin D., Moschella P., Thompson R., Åberg P	2004	An ecological perspective on deployment and design of low crested structures.	Coastal Engineering special issue DELOS	In Prep.
Carreras-Carbonell, P., M. Pascual, E. Macpherson	2004	Isolation and Characterization of microsatellite loci in *Tripterygion delaisi* reveal microgeographical differentiation.	Molecular Ecology Notes	In press
M. Frost M. de Vries	Jan. 2004	Prediction of the impact of LCS on biotopes in the coastal zone	Ecology (in prep.)	
D. Martin, F. Bertasi, M. A. Colangelo, M.Frost, S.J. Hawkins, E. Macpherson, P. S. Moschella, M.P. Satta, R. C. Thompson, M. deVries, V. U. Ceccherelli.	2004	Ecological impacts of low crested structures on soft bottoms and mobile infauna: how to evaluate the consequences of an unavoidable modification of the native habitats	Coastal Engineering	In prep
Moschella P., Abbiati M., Åberg P., Airoldi L., Anderson J.M., Bulleri F., Dinesen G.E., Gacia E., Granhag L., Jonsson P., Satta M.P., Sundelöf A., Thompson R.C., Hawkins S.J.	2004	Low crested structures as artificial habitats for marine life: what grows where and why?	Coastal Engineering	In Prep.
Airoldi L., Abbiati M., Hawkins, Jonsson P.R., Martin D., Moschella P., Thompson R.,	2004	An ecological perspective on deployment and design of low crested structures.	Coastal Engineering	In Prep.

Åberg P.				
Granhag L., Thompson R., Moschella P., Johnsson P.	2004	To be defined	To be defined	In Prep.

Non refereed literature

Authors/Editors	Date	Title	Event	Reference	Type[1]
Marzetti Silva	2003	'Economic Valuation of the Recreational Beach Use - The Italian Case-Studies of Lido Di Dante, Trieste, Ostia and Pellestrina Island'		D28/A; DELOS webpage	Report
Marzetti Silva	2003	Willingness to Pay for the Defence of Venice (Italy) as World Heritage Site		D28/B-I; DELOS webpage	Report
Marzetti Silva Leopoldo Franco, Alberto Lamberti and Barbara Zanuttigh	2003	Preferences about Different Kinds of Low Crested Structures and Beach Materials – The Italian Case-Studies of Lido di Dante, Ostia and Pellestrina Island		D28/C; DELOS webpage	Report
Zanuttigh, B & A. Lamberti	2003	Experimental results and numerical simulations on two detached breakwaters with a gap in between	DELOS, 2nd Year Meeting, Santander, Spagna, 16-19 Febbraio		
Zanuttigh, B & A. Lamberti,	2003	Hydrodynamics around a breakwater oblique to the coast	DELOS, Fall Meeting, Salonicco, Greece, 1-4 Octobere		
Zanuttigh B. & A. Lamberti.	2003	3D Hydrodynamic tests at Aalborg University, Final Form, DK	DELOS, March 2003		
Tirindelli M.	2004	Wave-induced forces on maritime structures	PhD thesis		
Hans Burcharth	February 2003	"Outline of LCS design guidelines"	DELOS D57 & D36 (2nd year meeting)	www.delos.unibo.it	Proceeding
Morten Kramer & Hans Burcharth	February 2003	Various proceedings for the 2nd year meeting in Santander	DELOS D36	www.delos.unibo.it	Proceedings and oral presentations
Kramer, M., Zanuttigh, B., Baoxing, W., Van der Meer, J.W., Lamberti, A., and Burcharth, H.F.	June 2003	"Wave basin experiments"	DELOS D31	www.delos.unibo.it.	Internal report
Hans Burcharth (coordinator of the document)	July, Sept., Oct., Dec. 2003	4 draft versions of the "LCS Design Guidelines"	DELOS D57	None. Final draft will be available from www.delos.unibo.it	Internal report
Morten Kramer & Hans Burcharth	August and December 2003	"Stability of Low-Crested Breakwaters in Shallow Water Short Crested Waves"	Coastal Structures 2003 conference	Proc. Coastal Structures 2003 Conference, Portland, Oregon, USA.	Oral presentation (August) and proceeding (December)

Morten Kramer	October 2003	D53, part about results of WP2.4 "Laboratory experiments"	DELOS D53	www.delos.unibo.it.	Internal report
Morten Kramer & Hans Burcharth	October 2003	Various proceedings	For the 33 month meeting in Thessaloniki	www.delos.unibo.it	Proceedings and oral presentations
Morten Kramer	November 2003	"Wave conditions at the Danish study site locations"	WP3.2, prepared for BIAU	Will probably be included in D58, which will be available from www.delos.unibo.it.	Internal report
Various authors within participants in WP2.3	December 2003	"Structural design final report"	DELOS Delivery no 43	www.delos.unibo.it.	Internal report
M. Kramer, B. Zanuttigh, J.W. van der Meer, C. Vidal and F.X. Gironella	February 2004	"Laboratory experiments on low-crested breakwaters"	DELOS' special issue of Coastal Engineering.	DELOS' special issue of Coastal Engineering.	Paper
H. Burcharth, C. Vidal, A. Lamberti, L. Franco, A. Noli and J. van der Meer	February 2004	"Structural stability, toe protection against scour and construction peculiarities of low crested breakwaters"	DELOS' special issue of Coastal Engineering.	DELOS' special issue of Coastal Engineering.	Paper
Losada, I.J., Lara J.L. and Garcia, N.	August 2003	2-D Experimental and numerical analysis of wave interaction with low-crested breakwaters including breaking and flow recirculation	Coastal Structures 03	Book of Abstracts and Proceedings	Oral presentation and proceedings
Lara, J.L., Losada, I.J. and Vidal, C.	May 2003	Experimental and numerical analysis of slope permeability on breaking processes	Spanish conference on Ports and Coastal Engineering	Book of Abstracts and Proceedings	Oral presentation and proceedings
Garcia, N., Lara, J.L, Losada, I.J.	September 2004	Etude numerique l'interaction houle/brise-lames franchissables.	VIII èmes Journées Nationales Génie Côtier-Génie Civil,	Book of Abstracts and Proceedings	Oral presentation and proceedings
Garcia, N., Lara, J.L, Lomonaco, P., Losada, I.J.	September 2004	Flow at low-crested structures under breaking conditions	ICCE 2004	Book of Abstracts and Proceedings	Abstract accepted
Garcia, N.	In preparation	Analysis of wave and LCS interaction			Doctoral Thesis
J.M. Alsina, I. Cáceres, A.S. Arcilla, D. González, J.P. Sierra & F. Montoya	09/03	Morphodynamics in the neighbourhood of a submerged breakwater	RCEM'03	Proc. 3rd Symposium on River, Coastal and Estuarine Morphodyn., pp. 1018-1028	Poster
C. Mösso, J.P. Sierra, D. González, J.M. Alsina, I. Cáceres & A.S. Arcilla	05/03	Estructuras de baja cota de coronación en las costas del Estado español como alternativa a las estructuras convencionales	VII Jornadas Españolas de Puertos y	Proc. VII Jornadas Españolas de Puertos y Costas	Oral presentation

			Costas	(in press)	
J.M. Alsina, A. S. Arcilla, D. González, I. Cáceres & J.P. Sierra	05/03	Estructuras de baja cota de coronación y morfodinàmica costera a medio término	VII Jornadas Españolas de Puertos y Costas	Proc. VII Jornadas Españolas de Puertos y Costas (in press)	Oral presentation
I. Cáceres, A.S. Arcilla, J.M. Alsina, D. González & J.P. Siierra	05/03	El papel del rebase y del flujo de masa en el diseño funcional de estructuras de baja cota de coronación	VII Jornadas Españolas de Puertos y Costas	Proc. VII Jornadas Españolas de Puertos y Costas (in press)	Oral presentation
D. González, A. S. Arcilla, J.P. Sierra & P.L.-F. Liu	05/03	Modelado numérico de la transmisión de oleaje a través de estructuras porosas emergidas	VII Jornadas Españolas de Puertos y Costas	Proc. VII Jornadas Españolas de Puertos y Costas (in press)	Oral presentation
A.S. Arcilla, I. Cáceres, J.M. Alsina, D. González & J.P. Sierra	10/03	Beach dynamics in the presence of a LCS, obviously Altafulla	33rd month meeting DELOS project	Proc. 33rd month meeting DELOS project	Oral presentation
Granhag L. M.	Jan 2003	Statistic and mechanistic analyses of relationship between local hydrodynamics and epibiota on LCS from Elmer (UK) and Ravenna (Italy)	2nd year meeting DELOS (Santander, ES)		Oral pres.
Sundelöf A.	June 2003	Keep on rockin' in the free world	Half-time seminar, Göteborg (SE)		Oral pres.
Sundelöf A.	July 2003	Keep on rockin' in the free world	Tjärnö marine biological station (SE)		Oral pres.
A. Sundelöf, P. R. Jonsson, M. Abbiati, L. Airoldi, P. Åberg	Oct 2003	D50 and input to Guidelines	33rd Month Meeting Thessalonik i		Oral pres.
Sundelöf A.	Oct 2003	Keep on rockin' in the free world	Kuusamo (FI)		Oral pres.
Avgeris I., Karambas Th., Prinos, P.	09/03	Boussinesq modelling of wave interaction with porous submerged breakwaters	ICCE2004	Book of Abstracts (in preparation)	Abstract
Avgeris I., Karambas Th., Prinos, P., Koutitas, C.	09/03	D42: Validated 2DH Boussinesq model		www.delos.unibo .it	Report
Avgeris, I., Karambas, Th., Prinos, P., Koutitas C	09/03	2DH modelling of wave-induced currents due to detached porous LCS	Thessalonik i Workshop	www.delos.unibo .it	Oral Presentation -Paper
Avgeris, I., Karambas, Th. Et al	02/04	Modeling of waves and currents around submerged breakwaters	Rome Final Meeting	www.delos.unibo .it	Oral Presentation -Paper
Airoldi, L., Camorani, E., Bacchiocchi, F., Ceccherelli, V.U., & Abbiati, M.	2003	Effects of coastal defence structures on the distribution of hard-bottom species	6th Internationa l Conference on The Mediterrane an Costal	*Proceedings of the 6th International Conference on The Mediterranean Costal*	Oral Presentation and proceedings

			Environment (MEDCOAST 03	*Environment* (MEDCOAST 03),Ravenna, Italy	
Bacchiocchi F., Abbiati M., Colosio F., Jonsson, P.R., Airoldi L	2003	Assemblages on human – made structures in the North Adriatic Sea.	6th International Conference on The Mediterranean Costal Environment (MEDCOAST 03)	*Proceedings of the 6th International Conference on The Mediterranean Costal Environment* (MEDCOAST 03), Ravenna, Italy	Poster and proceedings
Bacchiocchi F., Abbiati M., Airoldi L.,	8-10 September 2003	Distribution and dynamics of intertidal epibiota on coastal defences structures in the North Adriatic Sea.	13th Conference of the Ecological Society of Italy (S.It.E).	*Riassunti del XIII Congresso S.It.E.*, Como, Italy	Abstract and Oral Presentation
Bertozzi F., Lunghi S., Costantini F., Abbiati M.	8-10 September 2003	Applicazione di tecniche biochimiche e molecolari allo studio della variabilità genetica di *Patella cerulea* nel Nord Adriatico	13th Conference of the Ecological Society of Italy (S.It.E).	*Riassunti del XIII Congresso S.It.E.*, Como, Italy	Abstract and Oral Presentation
Bertasi F., La Morgia A., Colangelo M. A., Seccherelli V.U.	8-10 September 2003	Effetti delle barriere frangiflutti sulla comunità macrobentonica a differenfi fasce batimetriche.	13th Conference of the Ecological Society of Italy (S.It.E).	*Riassunti del XIII Congresso S.It.E.*, Como, Italy	Abstract and Oral Presentation
Moschella P.S., Bacchiocchi F., Airoldi L., Thompson R.C., Hawkins S.J.H.	8-12 September 2003	Ecological implications of coastal defence structures in a macro-and microtidal system.	38th European Marine Biology Symposium.	*Abstracts of the 38th European Marine Biology Symposium, Aveiro, Portugal*	Abstract and Oral Presentation
Bulleri F., Airoldi L., Abbiati M.	8-12 September 2003	The colonisation of artificial reefs by the invasive alga *Codium fragile ssp. Tomentosoides* in Adriatic Sea (north-east Mediterranean).	38th European Marine Biology Symposium.	*Abstracts of the 38th European Marine Biology Symposium, Aveiro, Portugal*	Abstract and Oral Presentation
Carrera M., Anderson J., Åberg P., Abbiati M., Airoldi L.	8-12 September 2003	Dynamics of the limpet *Patella caerulea* on man-made structures in the North Adriatic Sea.	38th European Marine Biology Symposium.	*Abstracts of the 38th European Marine Biology Symposium, Aveiro, Portugal*	Abstract and Poster
Abbiati M.	6-17 October 2003	'Introduction to topic 3 "Effects of human activities in altering genetic characteristics and gene flow in the marine environment"	MARBENA electronic conference	Proceedings of the e-conference 'Genetic Biodiversity in Marine Ecosystems – Measurement,	Proceedings

				Understanding and Management', pp 31-34	
Viard F and Abbiati M.	6-17 October 2003	'Summary of discussion on topic 3 "Effects of human activities in altering genetic characteristics and gene flow in the marine environment"	MARBENA electronic conference	Proceedings of the e-conference 'Genetic Biodiversity in Marine Ecosystems – Measurement, Understanding and Management', pp 49-50	Proceedings
Airoldi L., Bacchiocchi F., Bulleri F., Abbiati M.	2003	Effects of structures for coastal protection on the distribution of hard – bottom species in the North Adriatic Sea.	Annual Meeting of the Italian Botanical Society	*Riassunti della Riunione Scientifica Annuale del Gruppo di Lavoro per l'Algologia, Trieste*	Oral presentation
Francesca Bacchiocchi	2004	Distribution, structure and variability of intertidal assemblages on human-made structures in the North Adriatic Sea		PhD Thesis, pp 202 University of Parma.	Thesis
Matteo Cossu	2004	Impatto delle opere di difesa costiera sui popolamenti di fondi duri: Effetti delle dimensioni delle barriere flangiflutti.		Master Thesis, pp. 81 Dept. of Environmental Science, University of Bologna.	Thesis
R. Briganti, G. Bellotti, M. Brocchini		Modelization of wave breaking in Boussinesq-type models	2nd DELOS workshop (Santander)	DELOS project web page	Oral presentation
G. Bellotti, R. Briganti, M. Brocchini	2003	Interaction of breaking long waves with LCSs	33rd month DELOS Meeting (Thessaloniki)	DELOS project web page	Oral presentation
A. Panizzo, R. Briganti, L. Franco, J. Van Der Meer	2003	Analysis of wave transmission behind low crested structures using neural networks	33rd month DELOS Meeting (Thessaloniki)	DELOS project web page	Oral presentation
MODIMAR-CVN	2003	Monitoring of Venice littorals: Report on meteoceanographical studies 2001			Internal report
MODIMAR-CVN	2003	Monitoring of Venice littorals: Report on meteoceanographical studies 2002			Internal report
A. Panizzo, R. Briganti, L. Franco, J. Van Der Meer	2003	Analysis of wave transmission behind low crested structures using neural networks			Presentation at the 33rd DELOS Meeting at Thessaloniki
B.M. Sumer	1-2.October, 2003	Scour around submerged breakwater	DELOS Thessaloniki Workshop		Oral presentation
B.M. Sumer	12-	Local-scour and erosion	DELOS		Oral

	13.February, 2004	around low crested coastal defence structures	Ostia Workshop		presentation
B.M. Sumer, J. Fredsøe, M. Dixen, K. Gislason, A.F.D. Penta and A. Lamberti	February 2004	Local scour and erosion around low crested coastal defence structures. Part 1. Local scour at roundhead and along the trunk		1st draft, the paper to be submitted to the Special Issue of DELOS in Coastal Engineering	Paper
C. Truelsen, B.M. Sumer and J. Fredsøe	October 2003	Scour around spherical bodies and the self-burial		A paper submitted for journal publication, and currently under review	Paper
B.M. Sumer	16-20, January, 2002	Progress in ISVA's work regarding WP 2.1, WP 2.2 and WP 2.4	DELOS Barcelona Workshop	Three presentations in this event	Oral presentation
J. Fredsøe, B.M. Sumer, A. D. Panta, K. Gislason and F. Jakobsen	April 2003	Flow and Scour at the Trunk Section of Submerged Breakwaters		Internal Report, Technical University of Denmark, MEK, Coastal and River Engineering Section (formerly ISVA), 101 p.	Report
B.M. Sumer, J. Fredsøe, M. Dixen and F. Jakobsen	April 2003	Scour around the Round Head of a Submerged Rou8ble-Mound Breakwater		Internal Report, Technical University of Denmark, MEK, Coastal and River Engineering Section (formerly ISVA), 103 p.	Report
Erik D. Christensen, Barbara Zanuttigh and Julio A. Zyserman	26-29 August 2003	Validation of numerical models against laboratory measurements of waves and currents around low-crested structures	Conference	Coastal Structures ´03, Portland, USA	Proceedings
Hakeem Johnson	19-24 September 2004	Coastal area morphological modelling in the vicinity of groins	Conference	29th ICCE, Lisbon, Portugal	Accepted abstract
Julio A. Zyserman and Hakeem Johnson	19-24 September 2004	Modelling morphological processes in the vicinity of low-crested detached breakwaters	Conference	29th ICCE, Lisbon, Portugal	Accepted abstract
P. Moschella, L. Airoldi, Bacchiocchi, E. Gacia, P. Satta, L. Granhag, P. Jonsson, R. C. Thompson, S. J. Hawkins		Ecological implications of coastal defence structures in a macro- and microtidal system	Meeting in Thessalonica		Oral presentation
P. Moschella, L. Airoldi, F. Bacchiocchi, M. Abbiati, R.Thompson, S.Hawkins.	2003	Ecological implications of coastal defence structures in a macro- and microtidal system.	38th European Biological Symposium, Aveiro,	Proceedings of the 38th European Biological Symposium, Marine	Abstract

			Portugal, 8-12 September 2003.	Biodiversity Pattern and Processes Assessment, Threats, Management and Conservation, p.91.	
P.A. Moschella (Editor)	2003.	Assessment of direct and indirect effects of breakwaters on colonising epibiota.	D35 for WP3.2.	BIAU input included.	DELOS Report.
Dinesen, G.E. & Cedhagen, T.	2003.	Epibiota diversity of Danish Coastal Defence Structures.	Workshop, Thessaloniki, Greece.		Oral Presen-tation.
Kramer, M. & Dinesen, G.E.	2004.	Prototype observations in Denmark: Study site report.	D58 for WP2.5.		DELOS Report.

[1]Type: Abstract, Newsletter, Oral presentation, Paper, Poster, Proceedings, Report, Thesis

SECTION 3

Detailed report organized by work pakages including data on individual contributions from each partner, related to the reporting period

(Project 3rd and last year)

Contract No : **EVK3-CT-2000-00041**	Reporting period: **1.2.2003 – 29.2.2004**
Title: **Environmental Design of Low-Crested Coastal Defence Structures (DELOS)**	

RT 2 COAST DYNAMICS

WP 2.1 Flow description

Participants: UB, UR3, AAU, ISVA, DHI, **UCA**, UPC, WL_DH, INF, AUTH

Objectives of the reporting period

To report the work undertaken under this WP.

Scientific / Technical Progress made in different work packages according to the planned time schedule

1. As reported earlier, the time-dependent three-dimensional Navier-Stokes (N.S) equations (with a K-omega model) with fully non-linear free-surface boundary conditions were solved to calculate the flow around a breakwater. The numerical results were validated against experimental data conducted in the present work (see WP 2.4 below). This includes the free surface elevation, horizontal and vertical velocities in the potential part of the flow and bed shear stress. A major paper summarizing the results of the study (including the morphological model and its implementation covering vertical wall, sloping wall and scour) is under preparation.
2. In parallel to the preceding work, an attempt was made to simulate the 3-D flow around a groin exposed to steady currents, as reported in the previous reporting period. Early results were presented at the last year's conference of the International Association for Hydraulic Research: R. Miller, A. Roulund, B.M. Sumer, J. Fredsøe, C. Truelsen and J. Michelsen 3-D Numerical modelling of flow around a groin". In: I. Nezu and N. Kotsovinos (eds.), Proceedings of the XXX. IAHR Congress, Thessaloniki, Greece, 24-29.August, 2003, AUTh, Thessaloniki, Greece, vol. II, pp. 385-392.
3. In addition to the previous two studies, the flow code used for the preceding work was implemented to study flow around a spherical body, simulating en element of scour-protection work. Both the flow around and forces on the body were calculated. A paper summarizing the results of this latter study also is under preparation.

Milestones and Deliverables obtained

Milestones: Calibration of N.-S. Solver and implementation.

Deliverables: The papers under 2 and 3 in the preceding section (Deliverable No: D19, D41).

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No deviation.

WP 2.2 Morphodynamics

Participants: UR3, MOD, ISVA, **DHI**, UPC, UoS

Objectives of the reporting period

To report the work undertaken under this WP.

Scientific / Technical Progress made in different work packages according to the planned time schedule

1. The NS code described under WP 2.1 was used in the prediction of near-field morphodynamics (scour/deposition) at the trunk section. A major paper summarizing the results of the study (including the morphological model and its implementation covering vertical wall, sloping wall and scour) is under preparation.
2. A presentation was made on morphodynamic modelling in front of vertical and sloping walls at the Coastal Structures 2003 Conference, 26-29.August, 2003, Portland, Oregon, U.S.A.: K.

Gislason, J. Fredsøe and B.M. Sumer: “Morphodynamic modelling in front of vertical and sloping walls”. Coastal Structures 2003, 26-29.August, 2003, Portland, Oregon, U.S.A.

3. For morphological calculations (such as for scour calculations around structures and around scour-protection elements - such as stones), it may prove essential to consider the influence of turbulence on sediment transport. A paper addressing to this question has been published: B.M. Sumer, L. H. C. Chua, N-S Cheng and J. Fredsøe: “The influence of turbulence on bedload sediment transport”. Journal of Hydraulic Engineering ASCE, vol. 129, pp. 585-596, 2003.

Milestones and Deliverables obtained

Milestones: Implementation.

Deliverables: The papers under 2 and 3 in the previous section (Deliverable No: D20).

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No deviation.

WP 2.3 LCS structural design

Participants: UB, UR3, MOD, AAU, **UCA**, INF, AUTh

Objectives of the reporting period

The objectives have been to develop new formulae for wave reflection and transmission; stability of LCS and to introduce a methodology for the structural design of LCS.

Scientific / Technical Progress made in different work packages according to the planned time schedule

UR3 and INF:

An analysis on wave transmission in the lee of LCS has been carried out in cooperation with INF. Data from UCA and UPC experiments have been analysed in order to evaluate wave transmission and reflection coefficients, modification of statistical wave parameters and wave energy density spectra. Final calibrated formulae and indication of the spectral change induced by wave transmission have finally been developed. A new approach for calculating wave reflection at overtopped LCS has also been proposed.

AAU:

Some of the results elaborated from the laboratory experiments concerning structure stability were presented at Coastal Structures'03 conference, Portland, OR, USA - August 26-30, 2003, and in the paper submitted for publication in the conference proceedings.

The paper “Structural stability, toe protection against scour and construction peculiarities of low crested breakwaters" by H. Burcharth, C. Vidal, A. Lamberti, L. Franco, A. Noli and J. van der Meer, which will be included in the DELOS’ special issue of Coastal Engineering is under preparation.

A draft of "Structural design final report", DELOS Delivery no 43 was assembled by AAU and forwarded to UCA.

UCA:

The activity of UCA in this WP has been carried out in three different directions. First of all, the UCA, based on its prior experience has developed an initial methodology for the evaluation of stability on LCS. This methodology has been presented to and discussed with the rest of the partners. Second, UCA has been working in adapting the Spanish Recommendations for Maritime Works (ROM) to the design of LCS. The Spanish Recommendations have been reviewed during the last year and are oriented towards a reliable design of coastal structures.. The third activity has been working on the first draft on LCS stability for the guidelines prepared by AAU

INF

Infram has collaborated intensively with UR3 on the development of a new semiempirical formulation for wave transmission on LCS considering spectral characteristics and

AUTh

Transmission and reflection coefficients have been correlated with wave and geometrical characteristics

Milestones and Deliverables obtained

D43: Structural design report for LCS

D44: Report on flow velocities in the surface region of LCS

Most of the work carried in this WP has been included into the guidelines.

The manuscripts for the Coastal Engineering Special Issue have been completed.

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No deviations from the workplan have been detected

WP 2.4 Laboratory experiments

Participants: UB, UR3, **AAU**, ISVA, DHI, UCA, UPC, INF

Objectives of the reporting period

Experimental work was finished during 2nd year. Only reports and additional publications such as conference proceedings regarding the experiments were remaining within WP2.4 during the last year.

Scientific / Technical Progress made in different work packages according to the planned time schedule

The deliverables in WP2.4 were delayed according to the planned time schedule but all activities are now finished. In addition to the deliverables publications such as conference proceedings and papers have been published during the last semester.

Milestones and Deliverables obtained

All deliverables in WP2.4 (D10, D24, D31, and D32) are completed and delivered.

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No important deviations, activities are completed. Reporting was delayed but the results of the laboratory experiments have been known to partners for a long time. Therefore the delay did not cause any delay in other workpackages.

WP 2.5 Prototype observations and hindcasting

Participants: UB, UR3, MOD, AAU, WL_DH, **UoS**

Objectives of the reporting period

The main focus of this reporting period was to further develop the understanding of the system, in relation to the hydrodynamics, sediment movement and morphodynamics in the close vicinity of the offshore breakwaters. Field measurements, numerical models (hydrodynamics and sediment transport) and sediment trend analyses were used towards the understanding of the interaction between the breakwater scheme and the beach. These approaches were applied, independently and in combination.

Scientific / Technical Progress made in different work packages according to the planned time schedule

1. 2D Hydrodynamic Model (Mike 21), for Elmer

and the hydrodynamic model is operational and was used for the investigation of sediment mobility The compution sediment transport pathways. For the calibration of the sediment transport, field observations obtained under low wave conditions were used.

2. Wave Propagation model

A monochromatic wave propagation model was set up and used both for the regional, far field and near field area of the breakwater scheme at Elmer. Three typical wave events were simulated, two of mild energy condition and one of high (storm) energy conditions. Sediment mobility was estimated from the model.

3. Sediment Sampling, at Elmer

Two sediment sampling campaigns were undertaken at Elmer: (a) one during the summer, representing tidally dominated conditions; and (b)one following a storm event, representing wave dominated condition.

The surficial sediment samples were analysed using a settling tower (for the determination of settling velocities), mechanical sieving (for grain size distribution determinations) and microscopes (for mineralogical composition analysis). Using statistical parameters, as calculated on the basis of the settling velocities and the grain diameters, the sediment trends were computed for both data sets; these have provided information on sediment transport pathways. The summer campaign is considered representative of (mainly) tidal forcing, in the presence of mild wave condition, whereas the fast-response sampling following the storm considered to be more representative of wave dominated conditions

4. Data Analysis

Further analysis of the hydrodynamic data from the 1st campaign (July, 2001) has been undertaken, towards the calibration of the model. Preliminary quality assessment has been performed to ensure that the data collected from the 2nd campaign (March, 2003) were appropriate. A quality check was also performed on the topographic data obtained with the kinematic GPS. Statistical parameters for the tidal and wave environment were extracted.

5. Lido di Dante

At Lido di Dante, the currents are driven mainly by the prevailing wind-wave pattern. Interaction of the main current system with the LCS and groins over the area leads to the formation of eddy circulation at both heads of the LCS, and rip-currents towards the gap in the middle of the LCS.

During the surveys with drifters it was observed that currents strongly increase from the Northern cell to the Southern cell for waves coming from NE. Current intensity reaches the maximum values at the roundheads, where intensities as high as 1.8 m/s were simulated, and at the central gap, whereas is less intense along the barrier where it reached intensity 1.0 m/s offshore but only 0.4 m /s leeward, where, the submerged connectors produce a calm area. Wave intensity is obviously higher seaward than leeward the barrier. These currents are responsible of a strong erosion at the southern roundhead of the LCS. Velocities trough the gap are due to tide oscillation and during severe storms to wind and waves: measured currents can reach up to 0.5 m/s, confirming the simulation results. These currents are responsible of the strong erosion at the gaps, therefore special maintenance is requested at the gap and at the roundheads.

From the comparison between wave height inside and outside the LCS a wave transmission coefficient ranging from 0.35 – 0.65 was estimated. As expected, k_t increases with swl. Comparing the swl in and outside the structures we can see a strong set up during intensive storms ranging between 0 to 0.4 m, for very high wave height.

A deep eroded area are created at about 70m from the two roundheads, due to the strong vortices that are induced at the roundheads during storms. Another deep erosion area at the gap was observed. It is also interesting to note the sand accumulation at the seaward side of the LCS. The periodical ecological surveys undertaken over the area and on the structures provide information on the biological composition. The epibiota reveals that mussels (*Mytilus galloprovincialis*,) and green algae (*Enteromorpha intestinalis)* are present, both to seaward and leeward the structures, but are more abundant to seaward. Oysters (*Ostrea edulis* and *Crassostrea gigas*) and microfilm are more abundant to leeward of the barrier. Oysters, in particular, are practically absent to seaward (around 5%). In relation to the hydrodynamics and ecological data, some conclusions can be drawn; these show that both mean and extreme values of hydrodynamic fluxes strongly affect the barrier colonisation (Bacchiocchi et al., 2003).

6. Pellestrina

At Pellestrina, the main currents occur: along the shoreline; the submerged barriers; and the roundheads of the emerged groins, where the highest waves form rip-current or vortex. Current intensity can reach maximum velocity of 1.5 – 2 m/s in the above mentioned zones, but the average velocity is about 0.5 m/s. Sediment transport is correlated strictly to the hydrodynamic conditions, so it is blocked partially by the submerged cross-shore connectors; likewise, by the submerged long-shore barrier. Sediment budget analysis has revealed an equilibrium trend, with low annual erosion of about 2.8% of the nourished sand.

7. Denmark

For the case of Denmark, winds and waves are often very mild during the summer months and the water behind the breakwaters can, be of poor environmental quality. The limited water exchange traps seaweed behind the breakwaters smelling unpleasantly (a similar observation was made even in areas with stronger tidal currents and high water exchange (Elmer)). Since the construction of the breakwaters, the annual nourishment volume has been established on the basis of maintaining the beach. The breakwaters and the nourishment have stopped the ongoing erosion of the cliff at the site, securing the village and leaving the beach for recreational activities.

<u>*Milestones and Deliverables obtained*</u>

1. Scale effects report, final version.
2. 2nd year Study Site Report (end of February).
3. 2nd hydrodynamic deployment at Elmer.
4. 2D hydrodynamic model calibration.
5. Sediment Transport calibration
6. Wave propagation model
7. 3rd year Study Site Report (end of January).

Comment on activities carried out within RT2 (UCA)

Regarding the near field models, the University of Cantabria has been working on further validation and exploitation of the 2DV RANS model to evaluate several hydrodynamic magnitudes in the near field. Further validation has included comparisons with other data sets from the Cantabria experimental work as well as several cases from the large scale experiments from the Catalunya experimental set. Comparisons have shown an excellent agreement. Furthermore, in order to provide information to the morphodynamics and ecology group, several new runs have been carried out at the prototype scale considering a configuration equivalent to the ELMER case study. Results have provided velocity distributions around and inside the structures, as well as shear stresses on the upper layers of the structure. Most of the results have been summarised in a specific paper on velocities around LCS to be included in the DELOS special issue. Other results included in this paper have been obtained using the 3D numerical model developed by DHI. During the last period of the project the model application for LCS has been validated with a limited set of cases provided by the DELOS experimental work carried out in the Aalborg wave basin, since the model is computationally expensive. Comparisons between numerical and free surface records show a very reasonable agreement especially in front and above the structure. Even if the the model is still under development and not ready for standard engineering applications, results have shown that the potential applications of the model to analyse the three-dimensional flow around the structure are very high.

Most of the work carried out for far field models has been to develop a new method for incorporating the swash zone into wave-averaged circulation models and a new method for simulating wave breaking effects into Boussinesq-type models with satisfactory results.

Regarding the near-field morphodynamics (scour/deposition) most of the work has been at the trunk section to evaluate and model scour around structures and around scour-protection elements - such as stones). The numerical developed by ISVA has been compared with the experiments carried out by the same institution with satisfactory results. One of the main conclusion extracted from the last findings is that it may prove essential to consider the influence of turbulence on sediment transport. Some qualitative comparisons with field data have been carried out. The work carried out in this field has been summarized in two manuscripts prepared for the special issue.

Also very relevant has been the work carried out by WLDelft that has been working with the r Delft3D model to analyse morphodynamics, water quality and some biological impacts of LCS. High-resolution bathymetric data, surficial sediment distributions and hydrodynamic measurements from the study site of Elmer were made available to Delft Hydraulics for the calibration a 3D morphodynamic model. Results have been very satisfactory.

UR has carried out an analysis on wave transmission in the lee of LCS has been carried out in cooperation with INF. Data from UCA and UPC experiments have been analysed in order to evaluate wave transmission and reflection coefficients, modification of statistical wave parameters and wave energy density spectra. Final calibrated formulae and indication of the spectral change induced by wave transmission have finally been developed. A new approach for calculating wave reflection at overtopped LCS has also been proposed. This is a significant improvement since this kind of formulae are relevant not only for functional design but also to the morphodynamics modelling.

Furthermore, in relation to 3D LCS armour stability, two existing data sets Vidal et al (1992) and Burger (1995) were gathered together with data obtained in wave basin experiments within DELOS to develop a simplified stability formula for initiation of damage based on the fact that most of LCS's are built in shallow waters where wave height is depth-limited. Finally, based on the analysis of scour around LCS's carried out within DELOS, new formulae were proposed for the width of the toe berm protection, for both the front slope and the head sections.

A lot of time has been alloted to the preparation of the manuscripts to be included in the special issue. Most of the new information has been included in the design guidelines.

RT 3 ECOLOGY

WP 3.1 Effects on soft-bottom assemblages

Participants: FF, **CSIC**, WL_DH, MBA

Objectives of the reporting period

The objectives of this WP are:

a) To analyse the changes of the bottom sediments and detrital pathways related to the potential alteration of hydrodynamic regimes caused by the presence of LCS.

b) To identify and quantify the impacts, either positive or negative, on the composition, structure and functional organization of soft-bottom coastal assemblages surrounding LCS.

Particularly, the objectives of the reporting period focused on the extent of the area of influence on the surrounding soft bottoms and infauna of the LCS, taking into account the different environmental conditions (e.g. different tidal levels) at the four main study sites, Altafulla (Spain), Lido di Dante (Italy) and Elmer and Liverpool (UK).

Scientific / Technical Progress made in different work packages according to the planned time schedule

The three teams involved in the WP 3.1 completed field sampling and analysis of data on different biotic descriptors of the soft bottom macrobenthic communities around LCSs, as well as the analyses of the sediment descriptors, this allowing to assess the effects of breakwater design on soft- bottom habitat complexity and of the direct and indirect effects of LCS on soft- bottom assemblages.

Both sampling and data analysis have been completed as expected. The results provided the required data for the deliverable D34 "Area of influence of the LCS on the soft-bottom assemblages at a successive distances from the LCS".

A synthesis effort of the major findings of the experiments performed within the work-package has been used as a basis for the D45 on the identification of LCS design features allowing to maintain the biodiversity of soft-bottom assemblages.

All teams provided the required contributions to the guidelines related to the ecology task and to the WP 3.1 in particular. Moreover, the main results obtained through join works carried out in Spain (Mediterranean Sea), Italy (Adriatic Sea) and UK (English Channel and Atlantic Ocean) within the frame of the WP3.1 was produced as a contribution to D53 (Engineering, ecological and socio-economical input to design guidelines).

All teams will contribute to the Deliverable D58 (Study sites report, 3 rd year) with a extensive reports on the main results of the experiments on soft bottoms at Lido di Dante, Altafulla and Elmer for the Description of the case study sites.

A study on detailed mapping of sediment infauna around LCS at Elmer (UK) and a biotope study collaboration with Delft Hydraulics (NE), which was not included in the original work plan of WP3.1, provided further understanding of ecological effects of LCS on the soft-bottom system, as well as a useful tool for the assessment an prediction of environmental impacts of these structures.

Contributions to the Coastal engineering special issue are in course within the papers: Ecological impacts of low crested structures on soft bottoms and mobile infauna: how to evaluate and forecast the consequences of an unavoidable modification of the native habitats, Low crested structures as artificial habitats for marine life: what grows where and why? An ecological perspective on deployment and design of low crested structures.

All remaining studies have been carried out as planned.

Milestones and Deliverables obtained

According to the schedule accepted after proposals included in the First and Second Year Reports, the following deliverables have already been delivered: Assessment of effects of breakwater design on soft- bottom habitat complexity (Deliverable 18, month 18), The assessment of direct and indirect effects of LCS on soft- bottom assemblages (Deliverable 33, month 27), Assessment of the area of influence of the LCS on the surrounding soft bottoms at successive distances from the structures (Deliverable 34, month 27). Identification of design features allowing to maintain the biodiversity of soft- bottom assemblages around the LCS (Deliverable 45, month 30) and synthesis of the main results of the experiments on soft bottoms at Lido di Dante, Altafulla and Elmer (a contribution to Deliverable 53, Ecological and socio-economical input to design guidelines.

The teams involved in the WP 3.1 have successfully contributed to the implementation of the Design Guidelines, as well as in the monographic issue of Coastal Engineering.

Extensive reports on the main results of the experiments on soft bottoms at Lido di Dante, Altafulla and Elmer are currently in course (contributions to Deliverable D58, Study sites report, 3 rd year)

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No significant deviations from the original work plan have been observed except a delay in the collaboration between CSIC and UPC (relationships between hydrodynamics and sediment dynamics and benthic infauna in Altafulla) which results are not yet been implemented.

WP 3.2 Effects on breakwater epibiota

Participants: FF, AAU, CSIC, UGOT, UoS, **MBA,** BIAU

Objectives of the reporting period

During the third year partners worked on three different aspects of the project: 1) Completion of research activities 2) Production of deliverables 3) Dissemination of results.

The following research objectives were addressed in the reporting period:

- Identification of design features affecting the abundance, diversity and dynamics of epibiota
- Assessment of effects of epibiota on performance of LCS
- Identification of guidelines for a design of LCS which minimise ecological impacts and maximise desired effects on epibiota

Scientific / Technical Progress made in different work packages according to the planned time schedule

During the third year partners continued monitoring of studies and experiments started in year 1 and 2 and set up additional studies. These were:

1. Effect of surface complexity on diversity and abundance of epibiota (UK)
2. Effect of habitat complexity on diversity and abundance of epibiota (UK)
3. Biological interactions: effect of grazers on establishment and persistence of macroalgae on the exposed, seaward side of LCS (UK, joint experiment MBA-UGOT)
4. Evaluation of bioerosion effect on structure integrity and stability (UK)
5. Evaluation of total diversity on LCS and on single boulders and determination of thickness of epibiota (Denmark)
6. Seasonal characterisation of epibiotic assemblages (Spain)
7. Characterisation of abiotic factors affecting epibiota, including evaluation of water flow around the LCS, sediment suspension, siltation, and trials on scouring effect (Spain).
8. Analysis of the recruitment and dynamics of epibiota on LCS of different ages (Italy).
9. Evaluating the impact of disturbance from maintenance works (Italy).
10. Characterisation of the diversity and biomass of specie living on breakwaters (Italy).

Sampling and data analysis of the above studies were completed.

Laboratory analysis of studies and experiments finished in the 2^{nd} year (see 2^{nd} year reports) were completed and statistical analysis of data performed.

Dissemination of results from the above studies was done through project meetings, national and international conferences by all participating partners:

- Presentation of all results to the DELOS meeting in Thessaloniky (Greece) in October 2003.
- Two oral presentations and one poster to the 38th European Marine Biology Symposium, Aveiro, Portugal, 8-12 Sept. 2003.
- Two oral presentations to the 13th Conference of the Ecological Society of Italy (S.I.t.E), 8-10 Sept. 2003.
- One oral presentation and one poster to the 6th International Conference on The Mediterranean Costal Environment (MEDCOAST 03)

A paper on effect of LCS on distribution of an invasive alga was submitted by FF to the international journal Hydrobiologia and two papers are in final stage of preparation for the Coastal Engineering Special Issue. All partners are contributing to these two papers with title: 1) Low crested structures as artificial habitats for marine life: what grows where and why? 2) An ecological perspective on deployment and design of low crested structures.

Milestones and Deliverables obtained

Completion of Deliverables specific to this work package:

- Results on identification of environmental variables and design features of LCS affecting the epibiota were synthesised in D35 and D46
- Results on evaluation of effects of bioerosion on epibiota were synthesised in D38

A contribution of effects of epibiota on performance of LCS was given to D52 (Report on scale effects). Contributions to D58 (Study site report) were given for the case studies of Elmer (UK), Altafulla (Spain) and Lido di Dante (Italy).

Results from the above studies were essential for formulating guidelines for an environmentally sensitive design of LCS. Organisation, coordination and editing of ecological contributions to Design Guidelines (D57, D59).

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

There were no deviations from the original work plan for this third year. Additional studies were set up in 2003 to investigate interesting issues arisen from the development of research activities during the first two years of the project

WP 3.3 Effects on mobile fauna and human usage

Participants: FF, CSIC, UoS, **MBA**

Objectives of the reporting period

The following research objectives were addressed in the reporting period:

- Investigation of effects of LCS on abundance of fish and mobile fauna
- Investigation of effects of drift algal accumulation around the LCS on settlement of fish and crustaceans
- Investigation on effects of LCS on diversity and abundance of birds

Please note that studies and experiments on human usage of LCS were completed by the second year as originally planned.

Scientific / Technical Progress made in different work packages according to the planned time schedule

Fish surveys were carried out in Spain and UK in 2003, to collect further data on diversity and abundance of fish and mobile fauna around LCS and in control areas. These data were then analysed together with the data collected during fish surveys carried out during the first and second year of the project. Results on effects of algal mats on new settlers and juvenile fish obtained in year 1 and 2 were further investigated in year 3 in the UK. Sampling was completed and data were analysed.

Results from these studies confirmed the patterns observed in the previous years, thus reinforcing the evidence for an enhancement of settlers and juvenile fish and crustaceans around the structures, especially for commercially important species such as sea bass (*Dicentrarcchus labrax*) and white sea brim (*Diplodus* spp.). Also, results showed a clear "nursery ground" effect of LCS through accumulation of drift algae around the structures.

Results from bird censuses showed that a variety of terrestrial and shore birds tend to aggregate on and around the structures, using the area for feeding and resting.

A synthesis of results from the above studies were presented to the DELOS meeting in Thessaloniky (Greece) in October 2003.

Results were also used for preparing a paper in the Coastal Engineering Special Issue with title "Ecological impacts of low crested structures on soft bottoms and mobile infauna: how to evaluate the consequences of an unavoidable modification of the native habitats".

Milestones and Deliverables obtained

Results on effect of LCS on fish and mobile fauna (including birds) were synthesised in D14 and D15. Results on human usage of LCS were synthesised in D16.

Whilst D16 was completed in year 2, D14 and D15 were produced in a preliminary form in year 2 but completed in year 3, to integrate results from the studies carried out in summer 2003.

Results from this work package were used to formulate design guidelines (D57 and D59) and to contribute to the study sites report (D58) for Elmer (fish and mobile fauna, birds and human usage), Altafulla (fish and mobile fauna) and Lido di Dante (human usage).

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

There are no significant deviations for the original work plan. As already explained in previous DELOS reports fish surveys including the effect on drift algae on fish and mobile fauna were extended to the third year, to confirm interesting patterns observed in year 1 and 2.

WP. 3.4 Large-scale effects of breakwater spatial arrangement

Participants: **FF**, CSIC, UGOT, MBA

Objectives of the reporting period

The main objectives of the reporting period were:

(1) to complete the analysis of the population demography of the model species *Patella caerulea*

(2) to complete the analysis of the population dynamics of the model species *Patella caerulea*

(3) to complete experiments on a second model species, the invasive alga *Codium fragile* ssp. *tomentosoides*

4) to complete the analysis of the genetic structure of the limpet *Patella caerulea*, and of the fish *Trypterygion delaisi xanthosoma*

5) to synthesise results in a form that could be input to the design guidelines

6) to disseminate results at conferences and through the publication in the special DELOS issue to be published in the journal Coastal Engineering

Scientific / Technical Progress made in different work packages according to the planned time schedule

All objectives were met as a result of the profitable collaboration between the partners involved. Major achievements of the reporting period have been presented at the DELOS meetings in Thessaloniki and Ostia, and can be summarised as follows:

1. the analysis of the population dynamics of the limpet *Patella caerulea* was completed. Results show that density of limpets varied over time as a function of location and size of LCS. No peak of recruitment was observed in 2003, when density of limpets returned to values similar to

those observed in 2001.

2. the analysis of the population demography of the model species *Patella caerulea* was completed. The frequency distribution of individual lengths of *Patella caerulea* specimens on each sampled breakwater was plotted for each sampling period and several population parameters (average density, proportion of new recruits, proportion of adult individuals surviving per boulder, and change in the overall size of population over one year) were estimated.

3. results of WP.3.4 have been synthesised as input to the design guidelines. At the DELOS meeting in Ostia it has been shown how artificial structures may affect surrounding areas up to affecting coastal assemblages at a regional coastline scale. By providing suitable habitats islands for colonisation of species, LCSs function as stepping stones, allowing the dispersal of hard bottom species beyond the limits set by the availability of suitable natural habitats. Thus, there is a risk that they promote the expansion of introduced species. Sound *eco*-regional strategic planning for coastal cells has been suggested as essential prerequisite to mitigate impacts of coastal defences

4. results of WP.3.4 have also been used as input to WP. 3.5. to develop a model to predict the effects of habitat area and quality, the spatial distribution of habitats, and the dispersal characteristics of the organisms on the persistence of populations in a network of habitat islands, as those created by schemes of numerous defence structures.

5. using biochemical markers no significant differences were found between samples of *Patella caerulea* collected on different substrates or between samples from different sites. Based on microsatellite loci analysis, the genetic pattern of *Patella caerulea* samples resulted to be similar. Low values of Nei's genetic distances between populations were found and the observed pattern reflects geographical distances among collections. The obtained results suggest that populations of *P. caerulea* over the investigated geographic range belong to a single breeding unit. Populations of *Tripterygion delaisi* were analysed at different spatial scales. Large genetic differentiation, increasing with the geographical distance, was found. No significant genetic differentiation was detected at the small spatial scale suggesting that restricted adult dispersal and larval retention alone would not be enough, as previously thought, to promote genetic differentiation at the studied scale. These results suggest that *T. delaisi* populations living on LCS are originated by nearby natural reefs, while other LCS located far from areas inhabited by this species are not easily colonised.

6. results of WP. 3.4. have been presented to end-users at the final DELOS meeting in Ostia, and have been incorporated in the manuscript "An ecological perspective on the deployment and design of low-crested and other hard coastal defence structures" by Airoldi L., Abbiati M., Hawkins, Jonsson P.R., Martin D., Moschella P., Sundelof A., Thompson R., Åberg P. that integrates results from this WP.

Milestones and Deliverables obtained

All the milestones and deliverables fixed in the original proposal were produced.

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No deviations have occurred with respect to the original work plan in terms of inputs to design guidelines and deliverables. However, because of the particularly interesting results from the WP 3.4, and because of the importance that long term data sets have on the quality of ecological studies, the analysis of the dynamics and population genetic structure of the model species *Patella caerulea*, and experiments on the second model species *Codium fragile* have been carried on until the end of the project in January 2004.

WP 3.5 Ecological modelling of breakwater impacts

Participants: FF, CSIC, **UGOT**, WL_DH, MBA

The research during the second part of Year 3 has focused on finalising the metapopulation modelling and preparing results from 3.5 into suitable formats for the Guidelines and manuscripts for a DELOS Special Issue. All rersults from 3.5 are included in the finished deliverables D48, D49 and D50.

Objectives of the reporting period

The overall objective with WP 3.5 is to predict the development of marine life on and around LCS as a function of the morphology, hydrodynamics and the spatial lay-out of structures. Models have been developed to link ecological knowledge to physical conditions. WP 3.5 is divided into 3 main parts:

1. Models predicting development of epibiota on the structures (D48)
2. Models predicting the development of biota around the structures (D49)
3. Models predicting the large-scale dynamics of epibiota on sets of LCS (D50)

During the reporting period the results reported in the deliverables D48, D49 and D50 have been adapted for specific inputs into Guidelines and manuscripts intended for the DELOS Special Issue. In addition, manuscripts targeted for ecological journals are in progress.

Scientific / Technical Progress made in different work packages according to the planned time schedule

The objective of the reporting period was to adapt results from WP 3.5 to Guidelines (WP 5.3) and the DELOS Special Issue (WP 6.1). To this end partners from FF, CSIC, UGOT and MBA met on two occasions, in Thessaloniki October 29 – November 3, 2003 and in Ravenna December 3-7, 2003. This work is now completed and included into draft documents.

Milestones and Deliverables obtained

The milestones have been achieved and the deliverables D48, D49 and D50 have all been reported and posted on the DELOS web site.

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No deviations reported.

Comment on activities carried out within RT3 (UGOT)

The progress in RT 3 has been as planned. No major deviations from the description of work are reported in the WP–leader reports. All deliverables from RT 3 were produced before the end of the project. During the last month of the project much time was devoted to the guidelines and to the three manuscripts for the special issue in coastal engineering

RT 4 SOCIO-ECONOMY

WP 4.1 Extracting a Benefit Transfer Function from CV studies

Participants: **UTW**

This WP was completed for the 4th semester. The final report had been sent to the project coordinator before the 2nd year management report.

WP 4.2 Case studies on monetary valuation of environmental changes

Participants: **UB**, UR3, UTW

Objectives of the reporting period

In the second semester 2003 the re-examination of the data about the Trieste survey by questionnaire was done.

Scientific / Technical Progress made in different work packages according to the planned time schedule

The British 'Yellow Manual' questionnaire for local residents worked well. It was adapted to the Trieste specific situation by including questions in order to evaluate the beach use not only in spring/summer but also in autumn/winter. The results justify the distinction between beach use value according to different seasons.

Milestones and Deliverables obtained

The final data about the Trieste case-study were presented at the Salonicco meeting in October 2003.

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

The scheduled programme was fully respected. The revision of the data did not involved any change of the final report D28/A.

Comment on activities carried out within RT4 (UTW)

Both WP were completed before the 5th semester. Their final reports had been sent to the project coordinator accordingly with the modified deadline. There is therefore no activity for any of the WP in RT 4 for the 6th semester. The partners involved and the results of RT have contributed to the formulation of the guidelines (RT5) and to the monographic volumes on relevant journals (WP 6.2) as foreseen in the DOW. Other dissemination activities (papers and presentations to scientific conferences) are also in progress and will continue after the project ends.

RT 5 DESIGN GUIDELINES

WP 5.1 Performance-related inputs to guidelines

Participants: UB, FF, AAU, DHI, UCA, UPC, **UGOT**, UTW, WL-DH, MBA

Objectives of the reporting period

The objective is to provide input to the design guidelines from engineering, ecological and socio-economical perspective of design of low crested structures.

Scientific / Technical Progress made in different work packages according to the planned time schedule

Since this WP is just the transfer of knowledge from RT 2, 3 and 4 to WP5.3 the scientific and technical progress is described in the specific WPs in each research task.

Milestones and Deliverables obtained

The milestone and the deliverable D53 were obtained in October 2003.

WP 5.2 Example applications of the design guidelines to typical site conditions

Participants: **UB**, FF, UR3, MOD, AAU, DHI, CSIC, UPC, WL-DH, UoS, MBA

Objectives of the reporting period

The objective was to apply design guidelines to selected prototype case. Due to the wide variety of available information Lido di Dante site in the 1995 situation was chosen. This condition corresponds to a beach under severe erosion, protected by three groynes. Five different alternatives were analysed including the no intervention one: one unique submerged barrier, prolongation of southern and northern existing groynes, emergent barriers, submerged barrier with connectors. Guidelines formulae were applied to reconstruct near shore wave climate, to design structure schemes, to verify structure stability, to predict maintenance plans. Numerical simulation were carried out with MIKE 21 tool developed Danish Hydraulic Institute, for simulating waves (Nearshore Spectral Waves and Parabolic Mild Slope waves modules), currents (HydroDynamic module) and sediments (Sediment Transport Quasi 3D module). For each alternative six typical wave conditions were tested, plus a low wave summer condition to estimate the presence of current dead zones and the higher residence period for ecological purposes. Alternatives were then discussed together with economists and ecologists with special attention to erosive-depositional tendencies. The final selected alternative was optimised based on numerical results; a regional instead of local perspective was also addressed.

Scientific / Technical Progress made in different work packages according to the planned time schedule

The preparation of the example application allowed to accurately revise the text produced for the Guidelines WP 5.3.

Milestones and Deliverables obtained

Chapter 12 of Design Guidelines

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

No deviations

WP 5.3 Formulation of guidelines for multi-performance design

Participants: UB, MOD, **AAU**, ISVA, UCA, UPC, UGOT, UTW, INF, UoS, AUTH

Objectives of the reporting period

The objective was to complete drafts of the various chapters in the guidelines, and in the end of the period to unite them into one draft of the document "LCS design guidelines".

Scientific / Technical Progress made in different work packages according to the planned time schedule

Many inputs were produced for the design guidelines during third year and several draft versions of the united draft of the guidelines circulated among partners. In the end of the period a large part (about 2/3) of the chapters were finished in a preliminary draft version. For further detail see the comments on activities in RT5 below.

Milestones and Deliverables obtained

WP5.3 contains 2 deliverables D57 "draft design guidelines" & D59 "Final design guidelines".

None of the deliverables are completed.

Deviations from the work plan or / and time schedule and their impact to the project (if any please explain)

It was not possible to deliver a complete draft of the guidelines according to the time schedule (within the third year). The problem has been that other work packages and deliverables have been delayed, which has caused delay of the inputs to the guidelines. The work for completing the guidelines is expected to go on for a couple of months after the last year.

Comment on activities carried out within RT5 (AAU)

Activities are delayed.

At the Santander meeting in February 2003 the outline of the guidelines was discussed in detail.

At the meeting a list of partners responsible for delivery of the different chapters were established.

A detailed list of deadlines for draft versions of the guidelines were established, such it would be possible to discuss an almost complete draft of the guidelines at the Thessalonica meeting (October 2003). Many inputs to the draft version of the outline were collected from all partners in the following months. Several draft versions of the outline of the guidelines circulated among partners, and contributions, comments and suggestions were incorporated into one document containing the guidelines. However it was not possible to follow the deadlines established at the Santander meeting.

At the DELOS meeting in Thessalonica, October 2003 a new outline of the guidelines proposed by AAU was discussed in detail. Partners agreed on this new outline. Subsequent chapters were updated to follow the new structure, and the list of partners responsible for the different chapters in the guidelines was updated.

A list of deadlines for draft versions of the guidelines were established, such it would be possible to present a complete draft of the guidelines at the final meeting. Many inputs to the draft version of the guidelines have been collected from all partners. Several draft versions of the guidelines has circulated among partners, and contributions, comments and suggestions have been incorporated into one document containing the guidelines. However, it was not possible to respect the very strict deadlines and finish the chapters according to the time schedule.

In the end of the sixth semester (31 January 2004) the complete draft was still not finished. A preliminary draft version of the complete guidelines including several draft chapters was completed, but the whole document was not reviewed and some chapters/contributions were still not completed.

RT 6 MEETING, REPORTING & DISSEMINATION

WP 6.1 Meetings, workshop and reporting

Participants: **UB**, all others

Objectives of the reporting period

Objectives were to deliver the results presented at the 30th month meeting and the final meeting; the 5th Management Report and the Final Report. Moreover the final meeting with exploitation of project results to end users was organised and announced through an apposite leaflet.

Milestones and Deliverables obtained

D 55:Proceedings of workshop 3 and Proceedings of the Final Meeting.

WP 6.2 Dissemination

Participants: UB, FF, AAU, UCA, CSIC, UGOT, UTW, **UoS**, MBA

Objectives of the reporting period

Project web site has been regularly updated with project results, presentation and meeting information. End users were informed of the final project meeting by announcing the event on the web site and sending them the leaflet.

Scientific / Technical Progress made in different work packages according to the planned time schedule

Potential end users in the UK were informed about the course of the project and especially the development of the guidelines. Especially the Arun District Council, which is responsible for part of the Elmer scheme was informed about the finding of the scientific investigation in their area of responsibility.

Milestones and Deliverables obtained

Deliverable 7: project web page (regular updates till month 36)

Comment on activities carried out within RT6 (UB)

All meeting were carried out with a proportional participation. Dissemination tools are functioning. Deliverables are all available on the web site.

SECTION 4

Technological Implementation Plan (T.I.P.)

A Framework for the further development, dissemination and use of the results of EC RTD Projects (including also thematic networks and concerted actions)

(Project 3 years)

Contract No : **EVK3-CT-2000-00041**	Reporting period: **1.2.2001 – 29.2.2004**
Title: **Environmental Design of Low-Crested Coastal Defence Structures (DELOS)**	

Description of project

EC PROGRAMME:	**EESD**
PROJECT TITLE:	Environmental design of low crested coastal defence structures
ACRONYM:	**DELOS**
PROGRAMME TYPE:	
CONTRACT NUMBER:	EVK3-CT-2000-00041
PROJECT WEB SITE (if any):	http://www.delos.unibo.it
START DATE:	
END DATE:	
COORDINATOR DETAILS:	**Name:** Alberto Lamberti (Professor) **Organisation:** University of Bologna- DISTART Idraulica **Address:** Viale del Risorgimento 2, 40136 Bologna, Italy **Telephone:** 0039 051 2093749 **E-mail:** alberto.lamberti@mail.ing.unibo.it

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Commission Officer Name:	Hartmut Barth

Executive summary

Original research objectives

DELOS aims to promote effective and environmentally compatible design of LCS to defend European shores against coastal erosion and preserve the littoral environment as well as the coast economic development. DELOS objectives are: -to provide an inventory of existing LCS and a literature based description of their effects; -to analyse LCS hydrodynamics and stability as well as their effects on beach morphology by observation on sites, by laboratory experiments and numerical modelling; -to investigate the impacts of LCS on biodiversity and functioning of coastal assemblages by observations and field experiments at a range of spatial and temporal and in relation to different environmental conditions; -to develop a general methodology to quantify benefits for "Integrated Coastal Zone Management" based on

Contingent Valuation monetary values obtained in different European countries; -to provide validated operational guidelines for the design of LCS.

Expected deliverables

The principal expected achievements were: -to provide a reduced set of parameters describing synthetically the effects of defence structures from the different points of view; -to provide validated and calibrated models able to foresee effects of low crested defence structures on the littoral environment; -to provide a predictive model for expected ecological scenarios in consequences of different breakwater configurations and local/regional environmental conditions; -to provide tools able to foresee effects of social and economic relevance, including the public reaction to defence structures and benefits to tourism; -to provide clear guidelines for the design of low-crested structures to local authorities planning shore defence measures.

Project's actual outcome

Project results are summarised in the following. Ecology Ecological effects of LCSs are site-specific reflecting the complexity and variability of natural systems. LCSs always produce an increase in biodiversity and generate inshore sedimentation that negatively affects the landward soft bottom habitat. LCSs design criteria must be addressed to: - promote the development of salubrious areas in the protected zone by increasing the water flow through the structures; - reduce to the minimum LCSs length to avoid large-scale effects of habitat loss, fragmentation and community changes; - increase structure stability, minimise maintenance works and manage human usage, to facilitate settlement/persistence of algae and marine invertebrates and reduce ephemeral green algae; - avoid siltation and scouring that are felt as disturbances for abundance and composition of epibiotic assebmblages, for instance by increasing berm width; - increase armour geometry complexity and heterogeneity that promote settlement of organisms and enhance diversity; - assure structure submergence in low-tide to avoid consequent exsiccation of colonising organisms. Defence Value The construction of LCSs for beach protection is 'justified' from an economic point of view by the CVM surveys carried out within DELOS. The value of enjoyment of a beach visit is in average 25 € per person per day. Beach erosion produces a loss of value of about 50%; moreover, the 20% of interviewed declared that would have never visited the beach after the foreseen erosion. LCS design criteria shall account for the preferences that people expressed: - submerged structures for aesthetic reasons; - groynes for water quality and recreational activities. A Benefit Transfer Function was prepared with coefficients that should be calibrated on the site under analysis. The engineering results can be summarised by methodology. - Site-monitoring improved the knowledge of morpho-dynamic evolution in presence of different intervention type. Periodic bathymetry surveys were carried out in selected study sites. Currents at gaps appear to have a strong influence on local scour, LCS stability and swimming safety. - Laboratory experiments allowed to cover the lack of information on wave and current interaction with LCS both in 2D and 3D conditions. Stability, overtopping, filtration, transmission were examined and parametrised after having identified the most relevant process parameters. - Numerical modelling produced new validated 2D and 3D tools and calibrated existent models. Models are able to accurately predict most important processes as overtopping and transmission. The representation of morpho-dynamic effects at local scale is still uncertain because of scale-effects.

Broad dissemination and use intentions for the expected outputs

Dissemination & exploitation of results are achieved at 4 levels: 1) the consortium, through Project meetings and website; 2) the scientific community, through publications in peer-reviewed scientific journals and presentations at European and international conferences; 3) primary end-users, through meetings and Workshops; 4) secondary end-users and public, through Project leaflet and web-site. The most significant project results are summarised in: - a set of operational guidelines (to be printed tentatively by Elsevier) that, integrating engineering, ecological and economic knowledge, promotes effective and environmentally compatible design of low crested structures; - scientific papers in press on a Special Issue of Coastal Engineering (the highest impact-factor journal on the subject).

Overview of all your main project results

No.	Self-descriptive title of the result	Category A, B or C*	Partner(s) owning the result(s) (referring in

			particular to specific patents, copyrights, etc.) & involved in their further use
1	D5 WP1.1 Inventory of engineering properties for LCS and a related data bank	A	Aalborg University Universita' degli Studi di Roma Tre MODIMAR S.R.L. University of Bologna- DISTART Idraulica Aristoteleio Panepistimio Thessalonikis UNIVERSIDAD DE CANTABRIA DHI WATER & ENVIRONMENT INFRAM UNIVERSITAT POLITECNICA DE CATALUNYA UNIVERSITY OF SOUTHAMPTON
2	D11 WP4.1 A Benefit Transfer Function of environmental values: developing criteria to build in and to transfer CV monetary values of changes in environmental quality from other case studies in Europe	B	Universiteit Twente
3	D19 WP2.1 Calibrated 2DV near-field flow model: COBRAS provides near field kinematics over and inside LCS and will be used to assess velocities over the surface of the stones and to calibrate wave propagation models	A	UNIVERSIDAD DE CANTABRIA
4	D21 WP 2.2 A one line morphodynamic model is calibrated and adapted for the special LCS conditions: the one line model used is composed of a wave module calibrated with the results of the Boussinesq model, a long shore transport equation and mass conservationequation to represent the shoreline displacement	B	DHI WATER & ENVIRONMENT Universita' degli Studi di Roma Tre MODIMAR S.R.L. UNIVERSITAT POLITECNICA DE CATALUNYA
5	D20 WP 2.2 Quasi 3D morphodynamic model: this model is composed of a wave module, a phase averaged hydrodynamic model and a sediment transport model, which are coupled to form a morphological model. In the far field, the hydrodynamic part of these models will be calibrated by comparison with the calibrated Boussinesq model and the 3D experimental data	B	DHI WATER & ENVIRONMENT
6	D28 WP 4.2 CV study reports for 2 cases in Italy (Lido di Dante, Barcola-Trieste) and 1 in the Netherlands (Normerven)-objectives: to determine the implications for Benefit Transfer across countries in the European Union for specific empirical situation	B	University of Bologna- DISTART Idraulica Universiteit Twente
7	D58 WP 2.5 Study sites reports: description of 3 European sites (Elmer-UK; Lido di Dante_ Italy and Skagen-Denmark)	A	UNIVERSITY OF SOUTHAMPTON University of Bologna- DISTART Idraulica Aalborg University

8	D31 WP2.4 Report on wave basin experiments including experiment Data base: experimental information on several flow characteristics peculiar of fully 3D conditions (short crested and oblique waves and complete 3D structure) are provided.	A	Aalborg University University of Bologna- DISTART Idraulica Danmarks Tekniske Universitet INFRAM
9	D32 WP2.4 Report on wave channel experiments including experiment Data Base:Main objective of these experiments are: flow characterisation and stability	A	Aalborg University UNIVERSIDAD DE CANTABRIA
10	D37 WP2.2 Calibrated morphological models for beach evolution due to LCS implemented in a numerical tool kit	A	Universita' degli Studi di Roma Tre DHI WATER & ENVIRONMENT UNIVERSITAT POLITECNICA DE CATALUNYA
11	(D35) D46 WP3.2 Design features to mantain biodiversityt of epibiota and enhance biological resources:	A	Marine Biological Association of the United Kingdom Fondazione Flaminia Consejo Superior de Investigaciones Científicas (Centro de Estudios Avanzados de Blanes) Goeteborg University UNIVERSITY OF AARHUS
12	D38 WP3.2 Identification of design features to minimise bioerosion of LCS	A	Marine Biological Association of the United Kingdom Fondazione Flaminia Consejo Superior de Investigaciones Científicas (Centro de Estudios Avanzados de Blanes)
13	(D39) D40 WP3.4 Established contribution of breakwaters to regional biodiversity	A	Fondazione Flaminia Consejo Superior de Investigaciones Científicas (Centro de Estudios Avanzados de Blanes)
14	D41 WP2.1 Calibrated 3D near field flow: final model	A	DHI WATER & ENVIRONMENT
15	D42 WP2.1 Calibrated 2DH far field wave flow: final model	A	Universita' degli Studi di Roma Tre Aristoteleio Panepistimio Thessalonikis
16	D43 WP2.3 STRUCTURAL DESIGN: design formula for calculation of quarry rock armour stability in trunk and heads; well controlled closure relations for wave transmission and reflection	A	UNIVERSIDAD DE CANTABRIA University of Bologna- DISTART Idraulica Universita' degli Studi di Roma Tre Aalborg University
17	D44 WP2.3 FLOW VELOCITIES IN THE SURFACE REGION OF LCS: describes tools to evaluate wave load on attached life forms	A	UNIVERSIDAD DE CANTABRIA
18	(D33+D34) D45 WP3.1 Key data on breakwater design features for the	A	Consejo Superior de Investigaciones Científicas

	maintenance and enhancement of biodiversity and functional organisation of soft-bottom assemblages		(Centro de Estudios Avanzados de Blanes) Fondazione Flaminia Marine Biological Association of the United Kingdom
19	D47 WP3.4 Evaluation of overall potential of breakwater as a tool to aid conservation of coastal assemblages	A	Fondazione Flaminia Consejo Superior de Investigaciones Científicas (Centro de Estudios Avanzados de Blanes) Goeteborg University Marine Biological Association of the United Kingdom
20	D48 WP3.5 Report on model of suitable habitats for key species on breakwaters as a function of local hydrodynamics	A	Marine Biological Association of the United Kingdom STICHTING WATERLOOPKUNDIG LABORATORIUM
21	D49 WP3.5 Report on habitat Evaluation Procedure of sediments around different types of breakwaters	A	STICHTING WATERLOOPKUNDIG LABORATORIUM
22	D50 WP3.5 Report on meta-population model as a function of the large -scale distribution of breakwaters	A	Goeteborg University
23	D52 WP2.5 Report on scale effects for LCS	A	University of Bologna- DISTART Idraulica Aalborg University UNIVERSIDAD DE CANTABRIA Marine Biological Association of the United Kingdom UNIVERSITAT POLITECNICA DE CATALUNYA UNIVERSITY OF SOUTHAMPTON
24	D53 WP5.1 Engineering, ecological and socio-economical input to design guidelines	B	Goeteborg University University of Bologna- DISTART Idraulica Fondazione Flaminia Aalborg University DHI WATER & ENVIRONMENT UNIVERSIDAD DE CANTABRIA UNIVERSITAT POLITECNICA DE CATALUNYA Universiteit Twente STICHTING WATERLOOPKUNDIG LABORATORIUM Marine Biological Association of the United Kingdom
25	D54+D56 WP5.2 Verified partial inputs to design guidelines (Application to the project study sites and selected case studies)	B	University of Bologna- DISTART Idraulica Marine Biological Association of the United Kingdom
26	D59 WP5.3 DESIGN GUIDELINES FOR LCS INCLUDING EXAMPLE APPLICATIONS: cross-disciplinary design guidelines reflecting consideration of both structural, coastal protection, ecological and socio-economical performances	A	Aalborg University University of Bologna- DISTART Idraulica MODIMAR S.R.L. STICHTING WATERLOOPKUNDIG LABORATORIUM

			UNIVERSIDAD DE CANTABRIA UNIVERSITAT POLITECNICA DE CATALUNYA Universiteit Twente INFRAM UNIVERSITY OF SOUTHAMPTON Aristoteleio Panepistimio Thessalonikis Danmarks Tekniske Universitet Fondazione Flaminia Universita' degli Studi di Roma Tre

*A: results usable outside the consortium / B: results usable within the consortium / C: non usable results

Quantified Data on the dissemination and use of the project results

Items about the dissemination and use of the project results (consolidated numbers)	**Currently achieved quantity**	**Estimated future* quantity**
Product innovations	4	3
Process innovations	1	0
New services (commercial)	4	4
New services (public)	1	1
New methods	4	2
Scientific breakthrought	3	7
Technical standards to which this project has contributed	1	1
EU regulations/directives to which this project has contributed	1	1
International regulations to which this project has contributed	1	1
PhDs generated by the project	3	2
Grantees/trainees including transnational exchange of personnel	17	2

** "Future" means expectations within the next 3 years following the end of the project*

Comment on European Interest

Community added value and contribution to EU policies

European dimension of the problem

Identifying optimal design of coastal defence systems to maximise coastal protection and ecological benefit requires research initiatives at a scale that cannot be encompassed by any single country or loose consortium of countries, and needs to take into account the variability of economic, social, and cultural conditions that occur in different areas. DELOS addresses research issues required to support the management and sustainable use of coastal defence structures through a directed and concerted effort on the European scale, and prepares the necessary steps to provide forecast of local and global impacts scenarios. To achieve this aim, assessment of breakwater engineering and ecological performance are replicated at a range of spatial (local, regional and European) and temporal scales, and under the variety of environmental and socio-economic conditions that occur in different parts of Europe.

Contribution to developing S&T co-operation at international level. European added value

DELOS is a very applied project. Its aim is to lead to advance scientific and technological knowledge of the interactions between engineering and ecological performance of low crested structures and to develop integrated design guidelines, which take into account the littoral environment and the coast economic development. The expected outcome of DELOS is the development of a set of operational design guidelines that can be used by civil engineers and

local and national authorities to plan and execute the construction of safe, effective and environmentally friend low-crested coastal defence structures across European coasts.
Contribution to policy design or implementation At national, European and global level there is a strong public demand for improved management of the quality of coastal areas. EU has allocated important resources to Integrated Coastal Zone Management (ICZM) that is a very important Community Research Task. However, many tools necessary for optimum ICZM are missing. One of them is the identification, quantification and forecast of ecological and socio-economic impacts of coastal structures and coastal protection schemes. DELOS has contributed by delivering an operation tool (design guidelines) in this area. Moreover DELOS has contributed to EU policies on the conservation of natural habitats and biodiversity, by developing ecologically sensitive design of coastal defence structures. Design guidelines have taken into account as a priority the value of low-crested offshore structure as additional reef habitat and the possibility to exploit these structures to preserve and rehabilitate threatened habitats and species.

Contribution to Community social objectives

Improving the quality of life in the Community: DELOS aims to achieve an effective protection of sandy coasts (preferred habitats for recreation, safety and tourism), which would give secure benefits in terms of maintenance and improvement of suitable areas for tourism. Knowledge and amelioration of hydrodynamic conditions around the structures have positive effects on swimming safety. The structures also provide a focus for recreational and food gathering activities, in some areas benefiting artisanal fisheries for littoral gastropod molluscs. Development of design guidelines for LCS will result in more frequent choice of this type of structures instead of higher and more visible ones, so that, the negative visual impact will be reduced. Design guidelines also take into account the effects of breakwater morphology and location on colonising epibiota, in order to limit colonisation by species that are seen as a nuisance when turn off the structures and transported to the sandy beaches.
Provision of appropriate incentives for monitoring and creating jobs in the Community (including use and development of skills): The DELOS multidisciplinary partnership includes managers, end-users and scientists dedicated to a variety of natural and artificial systems in north, mid, south-Europe. As a result a considerable transfer of know-how among partners is foreseen, this will contributes to the development of skills in the EU. The pioneering DELOS studies will strengthen the competitive edge of European consultants and institutes in advising International environmental authority. Short to medium term employment benefits are also expected from DELOS as a consequence of economic benefits accruing to industries and services connected to tourism and other commercial activities at sea. European beaches are a major financial asset, which is strictly related to the quality and integrity of the beaches themselves. Through the identification of secure and environmentally friendly design guidelines for coastal defence systems, DELOS aims to guarantee the protection and sustainable use of European coastlines.
Supporting sustainable development, preserving and/or enhancing the environment (including use/conservation of resources): Many sandy coastlines across Europe are threatened by erosion. The knowledge, methodology and guidelines developed by DELOS are aimed to defend European shores against coastal erosion and at the same time preserve the littoral environment and the economic development within the coastal zone. Validated and calibrated models able to forecast effects of low crested defence structures on the littoral environment and associated assemblages of animals and plants are developed, with the primary aim to enhance the sustainable development and natural value of these systems. The study generates insights into ways to use artificial structures to restore or enhance local productivity and biodiversity. Future regulations linked to human interference and activities in the coastal zone will be influenced by the new knowledge created in the project.

Expected project impact (to be filled in by the project coordinator)

EU Policy Goals	I SCALE OF EXPECTED IMPACT OVER THE NEXT 10 YEARS -1 0 1 2 3	II other Not applicable to project	 Project Impacttoo difficult to estimate
1. Improved sustainable economic development and growth, competitiveness	0		√
2. Improved employment	1		
3. Improved quality of life and health and safety	2		
4. Improved education	1		
5. Improved preservation and enhancement of the environment	3		
6. Improved scientific and technological quality	2		
7. Regulatory and legislative environment	0		√
8. Other	0	√	

1. Economic development and growth, competitiveness	Scale of Expected Impacts over the next 10 years (2) By Project End -1 0 1 2 3	 After Project End -1 0 1 2 3
a) Increased Turnover for project participants - national markets	0	0
b) Increased Turnover for project participants - international markets	0	0
c) Increased Productivity for project participants	1	2
d) Reduced costs for project participants	0	0
e) Improved output quality/high technology content	2	2

2. Employment	Scale of Expected Impacts over the next 10 years (2) By Project End -1 0 1 2 3	 After Project End -1 0 1 2 3
a) Safeguarding of jobs	0	2
b) Net employment growth in projects participants staff	1	1
c) Net employment growth in customer and supply chains	0	0
d) Net employment growth in the European economy at large	1	1

3. Quality of Life and health and safety	Scale of Expected Impacts over the next 10 years (2)

	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Improved health care	0	0
b) Improved food, nutrition	0	1
c) Improved safety (incl. consumers and workers safety)	0	2
d) Improved quality of life for the elderly and disabled	0	0
e) Improved life expectancy	0	1
f) Improved working conditions	0	1
g) Improved child care	0	2
h) Improved mobility of persons	0	0

4. Improved education	**Scale of Expected Impacts over the next 10 years (2)**	
	By Project End -1 0 1 2 3	**After Project End** -1 0 1 2 3
a) Improved learning processes including lifelong learning	1	1
b) Development of new university curricula	0	0

5. Preservation and enhancement of the environment	**Scale of Expected Impacts over the next 10 years (2)**	
	By Project End -1 0 1 2 3	**After Project End** -1 0 1 2 3
a) Improved prevention of emissions	0	1
b) Improved treatment of emissions	0	0
c) Improved preservation of natural resources and cultural heritage	1	3
d) Reduced energy consumption	0	0

6. S&T quality	**Scale of Expected Impacts over the next 10 years (2)**	
	By Project End -1 0 1 2 3	**After Project End** -1 0 1 2 3
a) Production of new knowledge	2	2
b) Safeguarding or development of expertise in a research area	2	2
c) Acceleration of RTD, transfer or uptake	1	1
d) Enhance skills of RTD staff	2	1
e) Transfer expertise/know-how/technology	2	1

f) Improved access to knowledge-based networks	1	1
g) Identifying appropriate partners and expertise	2	2
h) Develop international S&T co-operation	1	1
i) Increased gender equality	2	0

7. Regulatory and legislative environment	**Scale of Expected Impacts over the next 10 years (2)**	
	By Project End -1 0 1 2 3	**After Project End** -1 0 1 2 3
a) Contribution to EU policy formulation		
Contribution to EU policy implementation		

8. Other (please specify)	**Scale of Expected Impacts over the next 10 years (2)**	
	By Project End -1 0 1 2 3	**After Project End** -1 0 1 2 3

Description of Results

No.	**Title**
1	D5 WP1.1 Inventory of engineering properties for LCS and a related data bank

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	www.delos.unibo.it

SUMMARY

An inventory data bank containing structural data on LCS's and their morphological effects and performances is formulated. 175 sites mainly within EU are identified and brief information regarding the following subjects is available: LCS locations, main objective, impacts on bio-

environment, socio-economic impacts, layout and cross-section geometry, and water level variations. The information is categorized in a databank and statistical information about the geometry of LCS's throughout Europe is derived. In addition 14 sites in Europe were chosen for further inspection and detailed information regarding the following subjects are available; geometry and construction materials, local meteomarine conditions, sea bed and beach characteristics, structural and coastal protection performances, socio-economic aspects, and ecological aspects.

SUBJECT DESCRIPTORS CODES
110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 210 ENVIRONMENTAL IMPACTS/INTERACTIONS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public
"Prototype experience regarding low crested structures" by A. Lamberti, R. Archetti, M. Kramer, D. Paphitis, C. Mosso, M. Di Risio	This paper will be included in the DELOS' special issue of Coastal Engineering	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP1)**	**NoI2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
2	D11 WP4.1 A Benefit Transfer Function of environmental values: developing criteria to build in and to transfer CV monetary values of changes in environmental quality from other case studies in Europe

CONTACT PERSON FOR THIS RESULT

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URL	
Specific Result URL	

SUMMARY

Benefit transfer is a series of techniques with the aim of inferring the benefits of a given policy at some new site (called policy site) from the benefits of similar policies already estimated for sites (called study sites) similar to the policy site. Benefit transfer is faster and cheaper than actually estimating the benefits for the policy site (that is, doing an original study), but its reliability is questionnable. The objective on this WP was to complete an exercise in benefit transfer for coastal defence at large and for low crested defence in particular. Enough data to attempt a transfer exercise were available only for informal beach recreation (and not for any other category of benefit of coastal defence). Using regression models, we estimate a transfer function of the value associated with informal beach recreation. We also inform the user of the risk of transferring, for example, the probability of an error no larger than 40% in transferring a value is about 70%, no larger than 50%, it is about 75%.

SUBJECT DESCRIPTORS CODES
110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 208 ENVIRONMENTAL ECONOMICS/NATURAL RESOURCES ECONOMICS 220 EVALUATION

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							

Patent granted						
Patent search carried out						
Registered design						
Trademark applications						
Copyrights	√			√		
Secret know-how						
Other - please specify:						

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				

Details:	The results are made available to an unrestricted although specialised public of coastal managers or other interested parties. Any further research opportunities on related topics will be considered.

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
3	D19 WP2.1 Calibrated 2DV near-field flow model: COBRAS provides near field kinematics over and inside LCS and will be used to assess velocities over the surface of the stones and to calibrate wave propagation models

CONTACT PERSON FOR THIS RESULT

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URL	http://www.unican.es
Specific Result URL	

SUMMARY

The model provides and excellent tool to design coastal defense structures. It solves the two dimensional Reynolds Average Navier Stokes equations on a finite difference scheme tracking the free surface using a volume of fluid approach. Therefore, it is able to overcome most of the limitations of most of the available numerical models for water wave and structure interaction. It is able to simulate the two dimensional interaction of transient nonlinear waves with any kind of structure including porous media flow and turbulence outside and inside the structure. The porous media flow is simulated using the Volume Average Reynolds Average Navier Stokes equations. The model can be used to evaluate velocities, pressure, forces, turbulent intensity, free surface evolution, wave breaking, etc. when waves interact with structures. The model is able to consider any kind of geometry and number of layers and therefore it can be used not only for low crested structures but also for conventional rubble mound breakwaters, vertical structures or composite breakwaters. Furthermore, other potential applications for the model are the design of non-conventional structures such as Jarlan type structures; vertical barriers, etc. for which the existing design methodology is very limite. Therefore, it can be said that the model can be used by the coastal and harbour engineering community and more specifically by consultants and administrations involved in the design, construction and conservation of coastal defence structures to provide a more realiable design. There is a very limited number of such kind of models in the world due to the ability of the model to simulate most of the 2-D processes involved in the interaction of wave and structure interaction. The model works as a numerical wave flume and therefore is a perfect tool to complement other traditional techniques to design structures such as empirical formulations or numerical models. At its current stage it requires some additional work to validate further applications since most of the validation has been carried out for LCS and to provide a user's friendly interface to make it available for engineering consultants and public administrations.After this additional work has

been completed the model is expected to have many differente commercial success factors.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 129 COMPUTER SCIENCE/ENGINEERING, NUMERICAL ANALYSIS, SYSTEMS, CONTROL

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Garcia, N., Lara J.L. and Losada, I.J. (2003) 2-D Experimental and numerical analysis of wave interaction with low-crested breakwaters including breaking and flow recirculation. Coastal Engineering (ELSEVIER), submitted.	Describes the validation of the numerical model	Public
Losada, I.J., Lara, J.L., E.D. Christensen and Garcia, N (2004) . Breaking process, velocities and turbulence intensity around low-crested structures. Coastal Engineering (ELSEVIER), DELOS special issue, submitted.	Shows potential applications of the model to evaluate velocity and turbulence fields around LCS	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP 1)**	**NoI 2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design					√	√	
Trademark applications							
Copyrights					√	√	
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 61.1 Sea and coastal water transport 80 Education

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Software code
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	6	24
Number of (public or private) entities potentially involved in the implementation of the result:	1	20
of which: number of SMEs:	0	14
of which: number of entities in third countries (outside EU):	0	2
Targeted user audience: of reachable people	50	200
S&T publications (referenced publications only)	3	5
publications addressing general public (e.g. CD-ROMs, WEB sites)	0	1
publications addressing decision takers / public authorities / etc.	2	5
Visibility for the general public	NO	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	√
MKT	Marketing agreement	√	**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership	√	**CONS**	Available for consultancy	√
Other	(please specify)				
Details:	We are looking for interested end-user who might collaborate providing funding to test the model with protype cases and to carry out further developtments for application in the engineering profession.				

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

The potential benefit is that in the future the model can be further developed for commercial use to be sold worldwide.

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
4	D21 WP 2.2 A one line morphodynamic model is calibrated and adapted for the special LCS conditions: the one line model used is composed of a wave module calibrated with the results of the Boussinesq model, a long shore transport equation and mass conservationequation to represent the shoreline displacement

CONTACT PERSON FOR THIS RESULT

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URL	
Specific Result URL	

SUMMARY

Two one-line models capable of simulating shoreline evolution under the presence of LCS were developed in WP 2.2 during the course of the DELOS projects. Activities carried out by the partners involved in this development (MOD and UPC) were closely co-ordinated, e.g. by selecting a number of common test cases for which both models were applied. Common to both models was also the fact that development focused on the description of wave transmission behind LCS, which is the main parameter used for the computation of longshore transport rates behind the structures. The first one-line model (ARIES) was developed by MOD. Predictions of shoreline response were compared to empirical relationships available in literature and to the UPC model in order to point out the sensibility of the prediction to different approaches and to achieve a common optimised approach. One-line shoreline evolution models have been developed, calibrated, validated and applied during the DELOS project. At the present stage of development, where coastal area morphological modelling is still too demanding from a computational point of view, one-line models are the best tool available for an initial estimate of the long-term impact of LCS on coastal morphology. As with any modelling tool, it is important to keep the model's limitations in mind when interpreting the results It should also be remembered that combination of different types of models usually is the best approach for collecting as much design information as possible.

SUBJECT DESCRIPTORS CODES

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Contini P., Mita M., Codispoti N., Briganti R., Franco L.(2003): Shoreline evolution in presence of detached	Proceedings of Medcoast 03 Conference.	Public

breakwaters. Analysis by means of one-line model.		

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP**[1)]	**NoI**[2)]	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		

S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	NO	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
5	D20 WP 2.2 Quasi 3D morphodynamic model: this model is composed of a wave module, a phase averaged hydrodynamic model and a sediment transport model, which are coupled to form a morphological model. In the far field, the hydrodynamic part of these models will be calibrated by comparison with the calibrated Boussinesq model and the 3D experimental data

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	

SUMMARY

Predicting the morphological imapct of low-crested structures (LCS) on the neighbouring coasts is an important elemnt of the design of these structures. Morphological impact can be limited or minimised through an adequate design of the dimensions of the structure, placement of nourishment in critical areas prone to erosion, etc. With the development of numerical models capable of describing hydrodynamic and morphological processes in coastal areas and in the vicinity of LCS, coastal area morphological modelling has become a viable

alternative for the analysis of morphological impact. MIKE 21 CAMS, developed by DHI Water & Environment, is such a numerical modelling tool. The development and application of the Coastal Area Morphological modelling System MIKE 21 CAMS was initiated at DHI Water & Environment (DHI) more than 20 years ago. MIKE 21 CAMS had been earlier applied in a systematic manner to investigate the morphological response induced by a single shore-parallel surface-piercing breakwater. Simple design curves derived on the basis of results obtained from the application of the model complex to obtain the desired morphological response induced by the surface-piercing structures were presented in Zyserman and Johnson (2002), see the reference under Documents. While significant effort has been used to investigate emerged breakwaters, limited experience exists at DHI with regards to the application of MIKE 21 CAMS or its individual modules to modelling low-crested structures (LCS). Some preliminar tests have been performed, however, no special treatment was given to effects such as wave overtopping and mass flux over the crest of the submerged breakwater. As part of its involvement in the DELOS project, it is the intention to systematically apply MIKE 21 CAMS to extend the knowledge already gained for shore-parallel surface-piercing breakwaters to LCS. The aim of this result is to provide guidance on the selection of model parameters to adequately simulate the hydrodynamics in the vicinity of low-crested structures using the standard wave and flow components of the morphological modelling complex. To this aim, measurements performed during the physical model tests in the wave basin of Aalborg University (AAU) were used. The present result includes a brief description of the morphodynamic model complex MIKE 21 CAMS, a summary of the tests conducted at AAU that are of interest for the present analysis (for more details, reference is made to DELOS D24 and D31). The set-up and validation of the wave module using laboratory data is described afterwards, followed by a similar analysis for the flow module.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 129 COMPUTER SCIENCE/ENGINEERING, NUMERICAL ANALYSIS, SYSTEMS, CONTROL

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Zyserman, J.A. and Johnson, H.K. Deliverable D20: Quasi 3D Morphodynamic Model Complex	The document describes the calibration and validation of the wave and current modules of the coastal area morphological modelling system MIKE 21 CAMS against data collected during the 3D hydrodynamic tests at the wave basin of Aalborg University	Public
Zyserman, J.A. and Johnson H.K. (2002): Modelling morphological processes in the vicinity of shore-parallel breakwaters. Coastal Engineering 45 (3-4) , pp. 261-284	The coastal area morphological modelling system MIKE 21 CAMS is applied to systematically investigate the morphological response to surface-piercing breakwaters of different dimensions	Public

INTELLECTUAL PROPERTY RIGHTS

<table>
<tr><td rowspan="3"><u>Type of IPR</u></td><td colspan="5"><u>KNOWLEDGE:</u>
Tick a box and give the corresponding details(reference numbers, etc) if appropriate</td><td colspan="2"><u>Pre-existing know-how</u>
Tick a box and give the corresponding details(reference numbers, etc) if appropriate</td></tr>
<tr><td colspan="4">Current</td><td>Foreseen</td><td>Tick</td><td>Details</td></tr>
<tr><td>Tick</td><td>NoP1)</td><td>NoI2)</td><td>Details</td><td>Tick</td><td></td><td></td></tr>
<tr><td>Patent applied for</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Patent granted</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Patent search carried out</td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Registered design</td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Trademark applications</td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Copyrights</td><td>√</td><td colspan="2"></td><td></td><td>√</td><td></td><td></td></tr>
<tr><td>Secret know-how</td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Other - please specify:</td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td></tr>
</table>

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 61.1 Sea and coastal water transport 73 Research and development 92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Software code
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	1	1
Number of (public or private) entities potentially involved in the implementation of the result:	1	1
of which: number of SMEs:	0	0
of which: number of entities in third countries (outside EU):	0	0
Targeted user audience: of reachable people		
S&T publications (referenced publications only)	1	4
publications addressing general public (e.g. CD-ROMs, WEB sites)		

publications addressing decision takers / public authorities / etc.			
Visibility for the general public	NO		

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
6	D28 WP 4.2 CV study reports for 2 cases in Italy (Lido di Dante, Barcola-Trieste) and 1 in the Netherlands (Normerven)- objectives: to determine the implications for Benefit Transfer across countries in the European Union for specific empirical situation

CONTACT PERSON FOR THIS RESULT

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URL	
Specific Result URL	

SUMMARY

Silva Marzetti. This research provides data about non-marketable use value and non-use value of the Italian coast, and also about visitors' preferences on different kinds of beach defence structures. As regards use value, the daily value of informal recreational activities of four Italian beaches was estimated: Lido di Dante (RA), Trieste, Pellestrina island (VE) and Ostia. The method used is the Contingent Valuation (CVM) in the value of enjoyment version. Since each of the four sites considered has distinctive characteristics, different questionnaires were used. The value of the beach recreational use changes according to the site characteristics, seasons, scenarios and population groups. In particular, as regards different scenarios, mean daily use values of the current state range from 5.24 to 27.67 €, erosion condition from 2.05 to 13.26 €, and protection scenario from 6.45 to 28.37 €. The great majority of respondents

are in favour of the protection of beaches from erosion, and composite intervention (groynes, nourishment and submerged breakwaters) and pure nourishment are the most preferred kinds of defence structures. As regards option and non-use values, the willingness to pay (WTP) for the defence of Venice (as a cultural and historical heritage) from sea flooding was estimated by means of a CVM survey. The mean WTP for the defence of Venice per year is 4.85 €, and it differs widely according to nationality. Only 64.4% of the people claiming to be willing to pay are 100% sure that they would pay the amount declared if actually asked to pay. As regards donation motives, the majority of respondents would pay for preserving Venice for the future generations. Philippe polomèUniversity of Twente. Several case studies about the socio-economic benefits and costs of low crested defence schemes were developed. The Dutch case study at Normerven focused on the non-use value generated by the restoration of seabird breeding area. The two main results are first, that although the original restoration had a rather hign value, replications of the area were not necessarily positively valued. Second, that value is sensitive to the social context in which the coastal defence is provided.

SUBJECT DESCRIPTORS CODES
110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 220 EVALUATION 208 ENVIRONMENTAL ECONOMICS/NATURAL RESOURCES ECONOMICS 176 ECONOMIC AND ENVIRONMENT IMPACTS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Marzetti S. and Lamberti A.(2003), Economic and Social Evaluation of the Defence System of Venice and its Lagoon (Italy), Proceeding of the Sixth International Conference on the Coastal Environment, MEDCOAST 03, E. Ozham (Editor), 7-11 October 2003, Ravenna, Italy, pp. 306-318.	Abstract This paper presents results of two surveys by questionnaire. The former is a Contingent Valuation Method (CVM) survey in the willingness to pay version applied in order to evaluate the option price and non-use values of Venice's cultural heritage by tourists and day-visitors in Venice. The latter is an experimental survey carried out for Pellestrina Island in the Lagoon of Venice for estimating the use value of Pellestrina beach, and for finding out the preferences about different defence structures. The research shows that more than 70% of respondents are willing to pay for the defence of Venice, and that the great majority of interviewees elicited positive values for the Pellestrina beach use. Amongst defence structures, the composite intervention (nourishment, groynes and submerged breakwaters) is preferred.	Public
Marzetti S. and Zanuttigh B.(2003),	Abstract This paper presents	Public

Economic and Social Valuation of Beach Protection in Lido di Dante (Italy), Proceeding of the Sixth International Coastal Environment, MEDCOAST 03, E. Ozhan (Editor), 7-11 October 2003, Ravenna, Italy, pp. 319-30.	findings about a survey by questionnaire on the Lido di Dante beach.The survey has two parts. In the first part the Contingent Valuation Method is applied for assessing the non-marketable recreational use of the Lido di Dante beach in the hypothetical scenarios of erosion and protection. The second part aims to find out preferences about different kinds of coastal defence structures. The research shos that the daily use value in Euros of the Lido di Dante beach considerably changes in the situation of erosion in respect to the status quo use value, and that the majority of respondents think that the beach should be protected. In addition, amongst the different beach defence techniques, respondents prefer composite intervention (submerged breakwaters, groynes and nourishment), and aesthetic reasons mainly justifies this preference.	
Marzetti Silva (2003), 'Economic Valuation of the Recreational Beach Use - The Italian Case-Studies of Lido Di Dante, Trieste, Ostia and Pellestrina Island', DELOS Report, D28/A	In the four Italian case-studies of DELOS the basic CVM structure of the Yellow Manual questionnaires were adapted to the site situation.The results show that the unusual evaluation question of the daily beach use was properly understood by interviewees.Comparisons of results show that the beach value changes according to different scenarios (current state,erosion and protection), relevant population, seasons and beach characteristics.	Confidential
Marzetti Silva, Leopoldo Franco, Alberto Lamberti e Barbara Zanuttigh (2003), Preferences about Different Kinds of Low Crested Structures and Beach Materials – The Italian Case-Studies of Lido di Dante, Ostia and Pellestrina Island, D28/C	In order to design defence projects which also satisfy beach visitors' preferences, some specific questions about respondents' opinion on four different defence projects were included in the CV questionnaires about Lido di Dante, Ostia and Pellestrina. Interviewed visitors expressed their preference on four coastal	Confidential

	defence structures: parallel breakwaters, nourishment, groynes, and composite intervention (nourishment, groynes and submerged breakwaters). Amongst these defence techniques, composite intervention is the most preferred in Lido di Dante and Pellestrina, while nourishment in Ostia. The main motive of preference generally is aesthetic reasons.	
Marzetti Silva (2003), Willingness to Pay for the Defence of Venice (Italy) as World Heritage Site, DELOS Report, D28/B-I .	This paper presents results of one survey by questionnaire in Venice. A CVM survey in the willingness to pay version was applied in order to evaluate the non-marketable option price and non-use values of Venice's cultural heritage by tourists and day-visitors in Venice. It is shown that more than 70% of respondents are willing to pay for the defence of Venice, and that 64% of these respondents are sure that they would pay the amount elicited if asked.	Confidential
Marzetti S. (2003),'Valuation of the benefits from the coastal defence systems of some Italian sites: Venice and its lagoon, Lido di Dante, Ostia and Trieste' , ELOISE Conference, Poster, Gdansk,	This poster shows the main aims and some results of five Italian CVM surveys carried out in 2002. The main aim were: a)to assess the beach use value of recreational benefits from the coastal defence systems of Pellestrina Island (Lagoon of Venice), Lido di Dante (Ravenna), Ostia (Rome) and Trieste; b)to estimate the willingness to pay for the defence system of Venice as cultural heritage site. As regards the Lido di Dante, Pellestrina and Ostia beaches the individual mean daily use values are presented, and also the preferences for different kind of defence structures. As regards Venice, the mean willingness to pay per year is shown.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP 1)**	**NoI 2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√			Results about the Italian case-studies.			
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Results of demonstration trials available
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	18	18
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)	2	2
publications addressing general public (e.g. CD-ROMs, WEB sites)	3	

publications addressing decision takers / public authorities / etc.	1	
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:	The results are made available to an unrestricted although specialised public of coastal managers or other interested parties. Any further research opportunities on related topics will be considered.				

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

Experience has been acquired about the organization and management of Contingent Valuation (CV) surveys (by questionnaire)in order to estimate the economic value (recreational use value; option, existence and bequest values)of coastal sites visited by tourists and day-visitors. These data must be used for the Cost-benefit Analysis applied to the Coastal protection project. In addition, in order to design defence projects which also satisfy beach visitors’ preferences, DELOS experience has shown that a CV survey is also a good opportunity to collect data about visitors' opinion on different defence structures and beach materials. In particular, experience has been acquired about the creation of a CV questionnaire for coastal sites;this is the core of a CV survey, and has to be created according to the different characteristics of the site and relevant population.

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
7	D58 WP 2.5 Study sites reports: description of 3 European sites (Elmer- UK; Lido di Dante_ Italy and Skagen- Denmark)

CONTACT PERSON FOR THIS RESULT

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URL	http://www.soes.soton.ac.uk
Specific Result URL	

SUMMARY

Field measurements in the area of interest were used for the calibration of the hydrodynamic model. The resultant tidal currents, in the area of the scheme, flow in a counter-clockwise direction reaching peak magnitude during high water. The associated net bed-load sediment

transport over a spring-neap tidal cycle in the area has the same direction as the peak currents in the area. Tidal currents are entering the area behind the structures, through the gaps at the east of the scheme, flowing over the salient features accelerating, during high water conditions. This accelerated flow over a restricted depth area causes the mobility of the sediment and it is probably a controlling factor of the salient growth. The bay area between the breakwaters has low sediment mobility under tidal currents. Wave diffraction at the gap of the breakwaters was observed during all of weather conditions, as confirmed by the field measurements. Diffraction is the main process decreasing the incident energy on the coast. Wave induces sediment mobility, estimated using a Stokes 2nd order waves, demonstrate the ability of even mild waves to transport the sediment in the direction of propagation of the diffracted wave. The presence of the salient feature is an evidence of the above sediment transport. The sediment trends established for the area within the project (D30) are in good agreement with the estimated wave-induced sediment transport. For the case of mild energy conditions in the bay area both methods estimate the direction of sediment transport, to be in the onshore with sediment directed towards the salients in the lee of the structures. Results obtained here are applicable to other offshore breakwater schemes in the Eu and especially in the UK were the environmental conditions are similar to the present site.

SUBJECT DESCRIPTORS CODES
110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 173 EARTH SCIENCE, EARTH OBSERVATION/STRATIGRAPHY/SEDIMENTARY PROCESSES 210 ENVIRONMENTAL IMPACTS/INTERACTIONS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Archetti R. Tirindelli M., Gamberini, G., Lamberti A. (2003). Analysis of currents around a low crested barrier: comparison between field and numerical results.	Proc. of the VI MEDCOAST International Conference on the Mediterranean Coastal Environment, 7 – 10 October 2003. Ravenna. Italy. Ed E. Ozhan (Ed.) pp 1731 – 1740.	Public
M. Di Risio, R. Archetti , G. Bellotti, M. Soldati. (2003). Nearshore waves and currents at Pellestrina.	Proc. of the VI MEDCOAST International Conference on the Mediterranean Coastal Environment, 7 – 10 October 2003. Ravenna. Italy. Ed E. Ozhan (Ed.) pp 2145 – 2154.	Public
Archetti R., Tirindelli M., Lamberti A. (2003). Field measurements of hydrodynamics around a beach defense system	Proc. Coastal Structures 2003 ASCE.	Public
A. Lamberti, R. Archetti, M.	DELOS' Special Issue, Coastal Engineering.	Public

Kramer, D. Paphitis, C. Mosso, M. DiRisio (2004) Prototype experience regarding low-crested structures.		

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE:** Tick a box and give the corresponding details(reference numbers, etc) if appropriate					**Pre-existing know-how** Tick a box and give the corresponding details(reference numbers, etc) if appropriate	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		

Number of (public or private) entities potentially involved in the implementation of the result:	2	
of which: number of SMEs:	0	
of which: number of entities in third countries (outside EU):	0	
Targeted user audience: of reachable people		5
S&T publications (referenced publications only)		2
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.	2	
Visibility for the general public	NO	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

Extrapolation of approaches used/developed into other areas of coastal sediment dynamics research and/or application. Utilasation in relation to other EU offshore breakwaters schemes, for coastal protection and/or beach development.

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

Additional partners for the dissemination of the results can be construction companies operating in the area of coastal engineering, local authorities interested in the coastal protection and/or the sustainable development on their coastal area and companies offering consultancy on the environmental impact of the coastal structures.

No.	Title
8	D31 WP2.4 Report on wave basin experiments including experiment Data base: experimental information on several flow characteristics peculiar of fully 3D conditions (short crested and oblique waves and complete 3D structure) are provided.

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	www.delos.unibo.it

SUMMARY

New unique laboratory experiments on low-crested structures (LCS's) were performed within the DELOS project. The experiments were aiming at extending and completing existing available information with respect to a wide range of engineering design properties. 12 different structural set-ups in 3D were built in a wave basin at the laboratory at Aalborg University (AAU), and 325 tests were performed. In order to make ideal set-ups in the laboratory with respect to each subject it was necessary to separate testing with different purposes. In this way the wave basin experiments at AAU were grouped in stability tests, hydrodynamic tests and wave transmission tests. Tests were not performed at any specific scale, but a scale of 1:20 represent an approximate scale with respect to typical full scale configurations. Structure freeboard, wave height and wave period/steepness were varied in all tests. • 69 stability tests were performed to investigate structural damage to heads and trunks subject to 3D waves. Influence of wave obliquity was tested on 2 structural set-ups with different crest widths. • 88 hydrodynamic tests were completed to analyze wave and current flows near the structures, and to provide data for calibration of numerical models. 2 structural set-ups with a gap between the roundheads and 2 set-ups with oblique structures were tested in 2D and 3D waves. • 168 wave transmission tests were performed with the objective of studying influences of wave obliquities on transmitted wave energy, wave directions and spectral changes. 3 structural set-ups with rubble structures and 3 set-ups with smooth plywood structures were tested in 2D and 3D waves. The wave obliquity was one of the main parameters, which were studied in the wave basin experiments. The experiments provide unique information about the influences of this parameter where almost no research has been done before. The DELOS experiments have filled some gaps within existing knowledge providing valuable information for establishing design guidelines for low-crested structures.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	Details (Title, ref. number, general description, language)	Status: PU=Public CO=Confidential
Laboratory experiments on low-crested breakwaters	The paper gives an overview of all the experiments performed within DELOS. Reference: M. Kramer, B. Zanuttigh, J.W. van der Meer, C. Vidal and F.X. Gironella, DELOS' special issue of Coastal Engineering.	Public
Stability of Low-Crested Breakwaters in Shallow Water Short Crested Waves	The paper presents results of 3D laboratory experiments on low-crested breakwaters. Two typical structural layouts were tested at model scale in a wave basin at Aalborg University, Denmark, to identify and quantify the influence of various hydrodynamic conditions (obliquity of short crested waves, wave height and wave steepness) and structural geometries (crest width and freeboard) on the stability of low-crested breakwaters. Results are given in terms of recommendations for design guidelines for structure stability. Reference: Kramer, M. and Burcharth, H.F. (2003). Proc. Coastal Structures 2003 Conference, Portland, Oregon, USA.	Public
Oblique wave transmission over low-crested structures	The paper describes the oblique wave transmission tests and proposes recommendations for prediction formulae for wave transmission in case of oblique wave attack. Reference: Jentsje W. van der Meer, Baoxing Wang, Ard Wolters, Barbara Zanuttigh and Morten Kramer (2003). Proc. Coastal Structures 2003 Conference, Portland,	Public

	Oregon, USA.	
Wave and current flows around low-crested structures	The paper deals with the experiments aiming on analysing waves and current around low-crested structures. The paper focusses on describing results on overtopping. Reference: Alberto Lamberti, Barbara Zanuttigh, Morten Kramer (2003). Proc. Coastal Structures 2003 Conference, Portland, Oregon, USA.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP1)**	**NoI2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		

of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
9	D32 WP2.4 Report on wave channel experiments including experiment Data Base:Main objective of these experiments are: flow characterisation and stability

CONTACT PERSON FOR THIS RESULT

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URL	www.civil.auc.dk
Specific Result URL	www.delos.unibo.it

SUMMARY

New unique laboratory experiments on low-crested structures (LCS's) were performed within the DELOS project. The 2D experiments were carried out in two European laboratories aiming at extending and completing existing available information with respect to a wide range of engineering design properties. 174 wave channel tests in total were performed on two structural set-ups at small scale and two set-ups in a large scale facility. The small scale wave

channel tests were performed at the University of Cantabria (UCA) in Santander, and large scale wave channel tests were completed at the Polytechnic University of Catalonia (UPC) in Barcelona. The near and far field 2D hydrodynamics were studied at small scale at UCA, and large scale 2D tests on wave transmission and reflection were performed at UPC. Tests were not performed at any specific scale, but the following scales represent an approximate scale with respect to typical full scale configurations. Structure freeboard, wave height and wave period/steepness were varied in all tests. 66 wave transmission and reflection tests were performed at UPC (large scale, about 1:4) to investigate the influence of crest width, structure slope, and scale effects on wave transmission and reflection coefficients for LCS's. 2 structural set-ups with different crest widths were tested in regular and irregular waves. 108 2D near and far field hydrodynamic tests were performed at UCA (small scale, about 1:10) to describe in detail the flow inside and over the structure. Wave transmission and run-up on the beach was also monitored. 2 structural set-ups with different crest widths were tested in regular and irregular waves. Flow velocities inside and close to the surface of structures was some of the parameters studied in the small scale wave flume tests. This subject is not only interesting with respect to engineering design properties but it provides also important ecological information on living conditions for lifeforms attached to the structure surface, because the flow velocities causes exposure to the lifeforms due to drag forces. The DELOS experiments have filled some gaps within existing knowledge providing valuable information for establishing design guidelines for low-crested structures.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Wave channel experiments	The report describes the DELOS wave channel tests in detail with respect to layout, set-up, materials, wave conditions and results. Reference: Vidal, C., Gironella, X. (2003). Internal report, DELOS deliverable D32, available from the Internet www.delos.unibo.it.	Public
Laboratory Experiments on Low-crested Breakwaters	The paper gives an overview of all the experiments performed within DELOS. Reference: M. Kramer, B. Zanuttigh, J.W. van der Meer, C. Vidal and F.X. Gironella, DELOS' special issue of Coastal Engineering (2004).	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if**	**Pre-existing know-how Tick a box and give the**

	appropriate					corresponding details(reference numbers, etc) if appropriate	
	Current				Foreseen	Tick	Details
	Tick	NoP[1)]	NoI[2)]	Details	Tick		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
10	D37 WP2.2 Calibrated morphological models for beach evolution due to LCS implemented in a numerical tool kit

CONTACT PERSON FOR THIS RESULT

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URL	
Specific Result URL	

SUMMARY

The one-line model (ARIES), developed by MOD and improved within the DELOS project (see result D21) has been applied to study shoreline evolution behind a single detached breakwater by means of parametric tests. A number of these tests aimed to compare the predicted shoreline response with the one estimated with simple design rules largely used in engineering practice. Also the study case of Le Morge (Italy) has been simulated to test the model performance in predicting shoreline evolution in presence of multiple breakwaters. Also a procedure to obtain a description of the wave climate from directional wave recorder buoys has been proposed. It has been also shown how sensitive is the beach response to wave transmission which is the leading phenomenon for submerged breakwaters. This means that it is necessary to look critically to empirical design rules which are derived considering only wave diffraction. The approach has been tested quite successfully to a real case of shore protection works by means of detached breakwaters together with a procedure for extracting from a wave climate a limited series of waves that can be considered equivalent to the complete time series in term of wave energy. The application of ARIES model with such improvements permits also to evaluate the efficiency of beach protection layouts. The example of Le Morge multiple breakwaters is significative in this sense.

SUBJECT DESCRIPTORS CODES

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	Details (Title, ref. number, general description, language)	Status: PU=Public CO=Confidential
Contini P., Mita M., Codispoti N., Briganti R., Franco L.(2003): Shoreline evolution in presence of detached breakwaters. Analysis by means of one-line model.	Proceedings of Medcoast 03 Conference.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate					Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate	
	Current				Foreseen	Tick	Details
	Tick	NoP[1)]	NoI[2)]	Details	Tick		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	Actual current quantity	Estimated (or future) quantity
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
11	(D35) D46 WP3.2 Design features to mantain biodiversityt of epibiota and enhance biological resources:

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	

SUMMARY

Epibiotic assemblages colonising LCS are subject, similarly to assemblages on natural rocky shores, to a variety of physical and biological factors including spatial and temporal variability; wave exposure, tidal level, larval supply and biological interactions. These factors influence the epibiotic communities in every coastal environment and cannot be modified. For example the abundance and composition of assemblages vary between locations and also in relation to season, independently of the type of design used for the LCS. However, the studies undertaken showed that design features of LCS might significantly affect the epibiota. The introduction/modification of selected design features of LCS could therefore minimise impacts and enhance effects that can be seen as positive. For example, the integration of more complex units structures such as textured or pitted blocks or cavities in the LCS design might increase the diversity of habitats and species. This might enhance living resources such as presence of shellfish and crustaceans but also can have positive effects on the recreational and amenity use of these structures by public. Results showed that the structures and the surrounding area represent an ideal place for several recreational activities such as food harvesting, sport fishing and observation of marine life. Several studies and experiments carried out across Europe guarantee the generality of the findings and provide useful information that can be disseminated in form of guidelines and recommendations for an environmentally sensitive design of coastal and sea defence structures. Several end users could benefit from the application of this result: 1) the private sector, such as engineering companies involved in the design and construction of LCS and surveyors involved in the Environmental Impact Assessment and monitoring; 2) the public sector, such as Environment Agencies and local councils involved in the decision making process and coastal management; 3) the scientific community, especially those in the research field of anthropogenic impacts on coasts and pollution. Taking into account the variety of target potential users dissemination of this result will be through conference and seminars for scientific and wider audience, briefing of conservation agencies, distribution of technical reports to local councils and coastal managers, and peer reviewed international publications. Coastal and sea defences are increasing exponentially along most European coasts, as a consequence of erosion and flooding. However, the ecological aspects and consequences associated with the design and construction of LCS and other coastal defence have been considerably neglected, despite the acknowledgement of the need for a more sustainable coastal development which must take into account the status, protection and preservation of the ecosystem. This result can help involved stakeholders towards a more environmentally sound coastal management, as also required by the Habitat and Water Framework Directive.

SUBJECT DESCRIPTORS CODES
70 BIOLOGICAL SCIENCES, BIOLOGY 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 175 ECOLOGY, ECOSYSTEMS, ECOLOGICAL EVOLUTION/DYNAMICS 210 ENVIRONMENTAL IMPACTS/INTERACTIONS 207 ENVIRONMENT, ENVIRONMENTAL SCIENCE

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Moschella P.S. 2002. Ecological effects of coastal defence structures in UK. Science for Water Policy (SWAP). The implications of the Water Framework Directive. Norwich, 2-4 September 2002.	Oral presentation and proceedings.	Public
Bacchiocchi F., L. Airoldi. 2003. Distribution and dynamics of epibiota on hard structures for coastal protection.	Estuar. Coast. Shelf. Sci.56 1157-1166.	Public

P. Moschella, L. Airoldi, F. Bacchiocchi , M. Abbiati, R.Thompson, S.Hawkins. 2003. Ecological implications of coastal defence structures in a macro- and microtidal system.	38th European Biological Symposium, Aveiro, Portugal, 8-12 September 2003. Oral presentation and proceedings.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 61.1 Sea and coastal water transport 73 Research and development 92 Recreational, cultural and sporting activities d2 Others

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Guidelines, methodologies, technical drawings
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		24
Number of (public or private) entities potentially involved in the implementation of the result:		3
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		10
S&T publications (referenced publications only)		6
publications addressing general public (e.g. CD-ROMs, WEB sites)		1
publications addressing decision takers / public authorities / etc.		1
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:	At the end of the project a financial and technical collaboration with potential end users involved in the planning and construction phase of LCS is sought to allow the application of our results and therefore provide a real example of environmentally sensitive coastal defence structure which can be used as a model for a sound coastal management across Europe.				

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
12	D38 WP3.2 Identification of design features to minimise bioerosion of LCS

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	

SUMMARY

Bioerosion is the erosion of hard substrata such as wood or rock by marine organisms. These are able to penetrate the substratum making holes by means of mechanical and chemical processes. Bioerosion in the sea occurs worldwide and can have detrimental consequences on natural ecosystems such as coral reefs but also endanger the stability of marine wooden structures. LCS however appear not to be particularly affected by bioerosion in Europe. This is because most of the structures are built in granite, concrete, i.e. a type of rock which cannot be penetrated by boring organisms. Only structures made of carbonate rocks such as limestone are liable to erosion by borers. In addition, in temperate waters the presence of boring species seems limited only to certain geographical locations. No bioerosion was observed on several LCS and other coastal defence structures in the UK and Italy (Adriatic coast), although presence of various boring organisms (mainly date mussels) was recorded on LCS consisting of limestone blocks in the Gulf of La Spezia. However, also in this case of the effect of bioerosion on stability was negligible, as holes made by bivalves were limited to the surface layer and not deeper than 10 cm. This result shows that bioerosion can be easily avoided by using granite and concrete instead of limestone rock as material for construction of LCS. The deployment of large building blocks would however overcome any potential problems caused by bioerosion in carbonate rocks. Despite bioerosion has a minimal effect on stability of LCS, diversity of epibiota colonising the structures can be positively enhanced, especially if softer carbonate rocks are used as building material. Bioerosion and weathering increase the surface complexity of these rocks by creating crevices, pits and holes which provide more suitable habitats for a higher number of species.

SUBJECT DESCRIPTORS CODES
64 BIODIVERSITY 105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 216 EROSION 373 MATERIALS TECHNOLOGY/ENGINEERING

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Moschella P.S. 2002. Ecological effects of coastal defence structures in UK. Science for Water Policy (SWAP). The implications of the Water Framework Directive.	Norwich, 2-4 September 2002. Oral presentation and Proceedings.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE:** Tick a box and give the corresponding details(reference numbers, etc) if appropriate	**Pre-existing know-how** Tick a box and give the corresponding details(reference numbers, etc) if

						appropriate	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:	1	5
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people	10	100
S&T publications (referenced publications only)	0	1
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	

LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
13	(D39) D40 WP3.4 Established contribution of breakwaters to regional biodiversity

CONTACT PERSON FOR THIS RESULT

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URL	www.ambra.unibo.it/
Specific Result URL	

SUMMARY

The present result may be used to draw conclusions about the potential effects of coastal defence structures over large spatial scales. In particular, it has been shown that major alterations to coastal environments may result from the introduction of LCSs over large stretches of coast as a consequence of the increased availability of hard-bottom and sheltered habitats in areas where they do not occur naturally. Results suggest that, although defence structures become colonised by rocky-bottom species, their assemblages seem to differ from those occurring on nearby natural reefs. Further, LCSs seem to act by changing the patterns of distribution of locally abundant species rather than by increasing species diversity. This raises concern that LCSs may cause considerable change to the identity and/or abundance of epibiotic species within an area. The possible consequences of these changes to coastal assemblages should be taken into account when establishing coastal zone management plans covering large stretches of coastlines. The present results have been incorporated into the desing guidelines. The potential end users will be mainly practitioners of coastal management. On a short term, the present original results are also expected to form the basis of some relevant publications on international scientific journals. In this case the end-user will be mainly the scientific community although some results could be dissaminated to the general public. A first manuscript will be prepared within the end of the project to be submitted to a special issue of the International journal "Coastal Engineering". On a longer term, further collaboration will be carried on between the members of the consortium, to further develope some of the original ideas emerged from the project.

SUBJECT DESCRIPTORS CODES
64 BIODIVERSITY 69 BIOLOGICAL MONITORING/RISK FACTORS AND ASSESSMENT 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 175 ECOLOGY, ECOSYSTEMS, ECOLOGICAL EVOLUTION/DYNAMICS 210 ENVIRONMENTAL IMPACTS/INTERACTIONS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Bacchiocchi, F. and Airoldi, L., 2003. Distribution and dynamics of epibiota on coastal defence works hard-bottom structures for coastal protection.	Est. Coast. Shelf. Sci., 56: 1157-1166.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP 1)**	**NoI 2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
73 Research and development 75 Public administration and defence; compulsory social security 80 Education

92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	Actual current quantity	Estimated (or future) quantity
Time to application / market (in months from the end of the research project)		36
Number of (public or private) entities potentially involved in the implementation of the result:		4
of which: number of SMEs:		1
of which: number of entities in third countries (outside EU):		0
Targeted user audience: of reachable people	50	300
S&T publications (referenced publications only)	1	2
publications addressing general public (e.g. CD-ROMs, WEB sites)		1
publications addressing decision takers / public authorities / etc.		1
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:	Further collaboration with and finantial support from potential end users involved in the construction of LCS is sought to allow the application of results and to establish sound strategies of coastal management along Italian and other European sandy coasts				

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
14	D41 WP2.1 Calibrated 3D near field flow: final model

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	

SUMMARY

Over the past several years significant efforts have devoted at DHI to develop advanced computational fluid dynamics (CFD) tools. The development has been centred around a so-called three-dimensional Navier-Stokes solver, NS3. The model has been developed with the aim of making it applicable to the analysis and investigation of as many flow and sediment transport problems as possible. Thus, the model includes a description of the instantaneous free surface in order to make it applicable to e.g. simulation of breaking waves in the surf zone. Since a reliable and ample description of the three dimensional flow around low-crested structures is nowadays only possible using physical models or field data, in the frame of DELOS the intention has been to apply NS3 to the simulation of flow over and around LCS. The term flow referring both to wave motion (e.g. wave breaking and overtopping) and to the wave-induced currents and over and around the structure. In order to simulate the vertical structure of the flow adequately, the NS3 model has to include a suitable description of the spatial and temporal structure of the turbulence under breaking and broken waves. Main scientific/technological objective has been to analyse the capability of the NS3 model to simulate the near-field flow around impermeable low-crested structures, especially three dimensional processes such as wave breaking under oblique incident waves or wave propagation around the head to the LCS. The Navier Stokes solver solves the instantaneous Navier-Stokes equations in three dimensions using a finite-volume approach on a multi-block grid. The spatial discretisation is based on the finite-volume approach on a multi-block grid. The time integration of the Navier-Stokes equations is performed by application of the fractional step method. The free surface is resolved using a Volume-of-Fluid (VOF) description. The waves are generated at an inlet boundary where Stokes waves up to 5th order, cnoidal waves up to 5th order or to use a stream function waves can be specified. At the beach, the remaining wave energy is absorbed by means of a sponge layer.The 3D Navier-Stokes solver includes several turbulence models: RANS (Reynolds Averaged Navier-Stokes equations) models such as k-e, k-w or LES models (Large-Eddy Simulation) with a Smagorinsky sub-grid scale model or a k-equation for the sub-grid scale turbulence. The model application for LCS has been validated with a limited set of cases provided by the DELOS experimental work carried out in the Aalborg wave basin, since the model is computationally expensive. Comparisons between numerical and free surface records show a very reasonable agreement especially in front and above the structure. Even if the model is still under development and not ready for standard engineering applications, results have shown that the potential applications of the model to analyse the three-dimensional flow around the structure are very high. In a few years, considering the increasing computer power capabilities, this kind of model will be a unique tool for LCS design. It is extremely relevant to consider that the number of physical model tests to be carried out will be considerably reduced. Furthermore, most of the limitations due to physical models will be overcome.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 129 COMPUTER SCIENCE/ENGINEERING, NUMERICAL ANALYSIS, SYSTEMS, CONTROL 204 ENGINEERING, CONCURRENT ENGINEERING

369 MARINE: OCEANOGRAPHY (PHYSICAL AND OPERATIONAL)

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Christensen, E.D. and Zyserman, J.A. Deliverables D17 and D41: Calibrated 3D Near-Field Flow Final Model. DELOS Project	The documents describe the three-dimensional Navier-Stokes solver, the data used for its validation and the results obtained from the validation exercise.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP 1)**	**NoI 2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Software code

Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	6	6
Number of (public or private) entities potentially involved in the implementation of the result:	1	1
of which: number of SMEs:	0	0
of which: number of entities in third countries (outside EU):	0	0
Targeted user audience: of reachable people		
S&T publications (referenced publications only)	1	2
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
15	D42 WP2.1 Calibrated 2DH far field wave flow: final model

CONTACT PERSON FOR THIS RESULT

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URL	

Specific Result URL	

SUMMARY

The design of structures to be built in the nearshore region generally involves the evaluation of different possible layouts, under the effects of local wave and current conditions, with the aim of minimizing costs and maximizing the desired results. In particular the design of low-crested structures involves optimisation of several parameters, which influence both the position and the shape of the structures. An alternative to physical models and attractive procedure is to employ suitable numerical and mathematical models. In principle, a very advanced numerical model, able to correctly simulate all the nearshore phenomena (turbulence, waves, currents, sediment transport, etc.) could be equivalent or even superior to a physical model. In practice, the numerical models currently employed in engineering activities, use several assumptions and simplifications: the phenomena that can be simulated strictly depend on the governing equations solved by the model. The objectives have been to improve our modelling capabilities of the hydrodynamics in nearshore areas including the presence of LCS. The two dimensional models are supposed to give a reliable prediction of wave and currents in areas adjacent to the LCS and to provide an improved description of the surf and swash zones. This hydrodynamic modelling should be extremely relevant for the analysis of the morphodynamics around LCS schemes. The results of this work are mainly due to contributions form the Universities of Rome and Thessalonika. The work carried out in Thessalonika has been mostly the development of a a 2DH-Boussinesq-type model combined with a depth-averaged Darcy-Forchheimer equation for simulating wave propagation over submerged porous breakwaters. The model was tested against experimental measurements. Several data sets corresponding to different regular and irregular wave conditions were used for model verification. Scale effects assessment has been carried out with different experimental setups.The comparisons indicate that the model simulates quite well wave evolution at the regions before and over the breakwater. Present model behaviour is enhanced, compared with the behaviour of weakly non-linear Boussinesq-type models applied in the simulation of wave evolution over impermeable and permeable submerged bars. The work carried out by the University of Rome has been mostly devoted to the enhancement of 2DH models based on the extended Boussinesq equations in order to analyse consider improved applications in the surf and swash zones nearby LCS.Among the most relevant achievements are: a new shoreline boundary conditions for use in wave-resolving Boussinesq-type model; a new method for incorporating the swash zone into wave-averaged circulation models and a new method for simulating wave breaking effects into Boussinesq-type models. The technique developed for the new shoreline boundary conditions allows imposition of the appropriate value of water depth and velocity at the shoreward limit of the computational domain. Validation of the method against analytical solutions suggests good performance of the new boundary conditions. The new method for incorporating the swash zone into wave-averaged circulation models is based on an integral model. The technique has been validated against both numerical solution of the nonlinear shallow water equations and available experimental data.The new method for simulating wave breaking has been implemented in a numerical solver and tested with success. Comparison with available experimental data suggests very good performances of the new method.In order to improve wave breaking simulation, a new criterion for determining weather waves are breaking or not (breaking criterion) is being developed. The great advantage of numerical and mathematical models is that their application is usually much less expensive than physical ones: it is certainly more economic to modify computer files describing the bathymetry of the area under investigation than to rebuild a physical model layout. Therefore, a first economic implication is that the development of this kind of modelling may result in a lower a more reliable design costs for LCS. From the strategic point of view, the use of this kind of modelling should be considered as part of any guidelines for the design of LCS schemes.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT

129 COMPUTER SCIENCE/ENGINEERING, NUMERICAL ANALYSIS, SYSTEMS, CONTROL 369 MARINE: OCEANOGRAPHY (PHYSICAL AND OPERATIONAL)

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
D42: 2DH Final Boussinesq-type model	This document is a detailed report on the work carried out in the frame of DELOS to develop and improve numerical models based on the Boussinesq equations for application to the design of LCS systems.	Public
H. Johnson DHI; Th. Karambas, J. Avgeris AUTh; B. Zanuttigh UB; I. Caceres UPC; G. Bellotti, M. Brocchini (2004) Modelling of wave and currents around submerged breakwaters. Coastal Engineering (ELSEVIER), DELOS special issue, submitted	Scientific paper including all the information regarding the modelling of waves and currents around LCS generated in DELOS	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP 1)**	**NoI 2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development 80 Education

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	0	0
Number of (public or private) entities potentially involved in the implementation of the result:	5	50
of which: number of SMEs:	1	30
of which: number of entities in third countries (outside EU):	0	
Targeted user audience: of reachable people		
S&T publications (referenced publications only)	5	
publications addressing general public (e.g. CD-ROMs, WEB sites)	0	0
publications addressing decision takers / public authorities / etc.	1	0
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	√
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
16	D43 WP2.3 STRUCTURAL DESIGN: design formula for calculation of quarry rock armour stability in trunk and heads; well controlled closure relations for wave transmission and reflection

CONTACT PERSON FOR THIS RESULT

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URL	http://www.unican.es
Specific Result URL	http://www.gioc.unican.es

SUMMARY

When waves reach LCSs, they suffer transformation due to the processes of reflection, dissipation and transmission over the structure as well as diffraction around the heads. These changes modify the direction and magnitude of the energy flux reaching the beach, producing changes both in plan form and profile. To design functional LCS's schemes, the designers need formulas for prediction of variables as wave reflection and transmission. Besides functional design, low crested structures should withstand the wave action during their usable life with damage below a determined level. The main damage mode of low crested rubble mound structures is related to the movement of armour units, so stability formulas for this damage mode should be provided for the design. The objective this result was to produce well controlled closure relations for armour stability, wave transmission and reflection to be used in the functional design of LCS.Applied methodology, scientific achievements and main deliverablesDeliverable D 43 complements DELOS deliverable D22 "Structural design preliminary report" oriented towards a revision of available formulae for the design of Low-crested rubble mound structures. Deliverable D 22 presents a brief summary of the most used formulae for wave transmission and armour stability of LCS's. Deliverable D 43 includes the achievements of DELOS in these fields, specifically on wave reflection, transmission and LCS stability.As far as wave transformation over LCS's is concerned, the DELOS project was focused on wave transmission. Wave reflection was not considered to be an important aspect and was only treated at the end of the project and some preliminary results obtained with DELOS data sets were presented in D43.For wave transmission, all previous data sets on wave transmission and results from DELOS laboratory experiments carried out at the University Cantabria and the Polytechnic University of Catalonia were gathered together (2337 tests). The full analysis was carried out by Briganti et al (2003). As a result two new formulae were proposed for narrow and wide -crest LCS's, respectively. These formulas used three non-dimensional parameters to describe wave transmission. Besides this result, the DELOS database on wave transmission was used by Panizo et al (2003) to build a neural network. Using this network, the influence of additional non-dimensional parameters was analysed. The resulting neural network added three new parameters not included in the Briganti et al. (2003) proposed formulae.The shape of the transmitted spectra was analysed by Van der Meer (2003) who proposed a new methodology to define the shape of the transmitted spectrum. Using data from 3D basin experiments carried out within the DELOS project at Aalborg University, the oblique transmission was analysed, van der Meer et al. (2003).In relation to 3D LCS armour stability, two existing data sets Vidal et al (1992) and Burger (1995) were gathered together with data obtained in wave basin experiments within DELOS to develop a simplified stability formula for initiation of damage, Kramer and Burcharth (2003) based on the fact that most of LCS's are built in shallow waters where wave height is depth-limited.Finally, based on the analysis of scour around LCS's carried out within DELOS, new formulae were proposed for the width of the toe berm protection, for both the front slope and the head sections. New empirical formulae have been obtained for wave transmission, reflection and stability of LCS's. These formulae improve or complement existing formulations, thus providing a way for a more

reliable and cost-efficient design of the structure and the complete (beach – structure) LCS scheme.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Briganti, R., J.W. van der Meer, M. Buccino and M. Calíbrese, 2003. "Wave transmission behind low crested structures". ASCE, Coastal Structures 2003 Conference, Portland, Oregon, USA	Description of new formulae for wave trasnmission in low-crested structures	Public
Kramer, M. and Burcharth, H.F. 2003. "Stability of low-crested breakwaters in shallow water short crested waves. ASCE, Coastal Structures 2003 Conference Portland, Oregon, USA.	Information on stability of LCS under short-crested waves, based on experimental work in a wave basin	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP**[1)]	**NoI**[2)]	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents

2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	0	
Number of (public or private) entities potentially involved in the implementation of the result:	5	50
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):	0	20
Targeted user audience: of reachable people		
S&T publications (referenced publications only)	3	1
publications addressing general public (e.g. CD-ROMs, WEB sites)	0	0
publications addressing decision takers / public authorities / etc.	1	1
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
17	D44 WP2.3 FLOW VELOCITIES IN THE SURFACE REGION OF LCS: describes tools to evaluate wave load on attached life forms

CONTACT PERSON FOR THIS RESULT

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Telephone	+34-94-2201029
Fax	+34-94-2201092
E-mail	desirejm@gestion.unican.es
URL	http://www.unican.es
Specific Result URL	

SUMMARY

The breaking process over the overtopped structure enhances the pumping of wave-induced mass fluxes over the low-crested detached structure. This results in an enhanced nearshore circulation and consequently the presence of the LCS modifies the sediment fluxes and morphodynamic evolution. Furthermore, the fluxes through the permeable structure may also contribute to additional modifications. Consequently circulation and morphodynamic models assessing morphodynamic evolution in the presence of LCS should include additional information regarding the fluxes on the top and through the structure. It is well established that hydrodynamic forces due to breaking waves are among the most important sources of shore organism distribution and mortality. Therefore, in order to interpret the biomechanical characteristics of the epibiota on a low-crested structure; stress levels resulting in tissue damages or complete dislodgement; average flow conditions to predict larval settlement and delivery of nutrients or critical periods of very low flow speed causing hypoxia; a feasible description of the flow is required. These is only possible based on an appropriate modelling of the velocity field and breaking processes in the near field of the structure and how those are affected by incident wave parameters, structure geometry and permeable material characteristics. However, it has to be pointed out that the different applications do not really require the knowledge of the turbulence fluctuations velocity components. The knowledge of the instantaneous mean flow, the seepage velocity, the maximum or minimum mean velocities is sufficient to fullfill most of the questions raised with regard to stability, functionality or ecological issues.Therefore, as part of the work carried out within WP2.1. a detailed analysis of the flow velocities in the surface region of LCS has been considered to be relevant. The main scientific and technological objective has been to provide reliable information on the velocity distribution around and inside LCS and how the velocity distribution is affected by the incident wave conditions, structure geometry and porous material characteristics. Furthermore, a second goal is to provide reliable tools to evaluate the magnitudes of the velocity fields under design conditions. This information is extremely important to evaluate LCS stability since some of the stability formulations are based on the evaluation of the velocity at the surface of the structure. The applied methodology consists of the combination of the analysis of the experimental data gathered in the frame of the project and the generation of numerical data using the 2DV numerical model based on the VARANS equations (deliverable D19). Based on both the numerical and experimental results the velocity distribution is studied. The influence of relevant magnitudes such as berm width, freeboard, incident wave conditions, model scale and structure material on the velocity distribution is considered. Comparison between measured and numerical velocities show a very good agreement, showing only small deviations very close to the surface of the structure where local effects are affecting the measurements.The main deliverable has been a document on flow velocities in the velocity of the surface of LCS. In this document the application of deliverable D19: Calibrated 2DV near-field flow model, to evaluate the velocity field around, on and inside LCS is explained. Several examples for the validation of the results are shown, comparing numerical and experimental data. The model is proven to reproduce with a high degree of agreement the velocity field around, on the surface and within the structure for different geometries, incident wave conditions and construction material. The shoaling and breaking effects in the seaward and

crest zones, as well as the higher harmonics generation phenomenon in the transmission zone, are well simulated, whether the structure freeboard is positive, zero or negative.

SUBJECT DESCRIPTORS CODES
68 BIOLOGICAL ENGINEERING 105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 129 COMPUTER SCIENCE/ENGINEERING, NUMERICAL ANALYSIS, SYSTEMS, CONTROL

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Losada, I.J., Garcia, N. and Lara, J.L. Deliverables D23 and D44: Report on turbulent flow velocities in the surface region of LCS. DELOS project.	This documents includes the experimental and numerical work carried out in order to analyse velocity distributions around LCS.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	0	0
Number of (public or private) entities potentially involved in the implementation of the result:	2	
of which: number of SMEs:	0	0
of which: number of entities in third countries (outside EU):	0	0
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)	2	1
publications addressing decision takers / public authorities / etc.	0	1
Visibility for the general public	NO	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
18	(D33+D34) D45 WP3.1 Key data on breakwater design features for the maintenance and enhancement of biodiversity and functional organisation of soft-bottom assemblages

CONTACT PERSON FOR THIS RESULT

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E-mail	dani@ceab.csic.es
URL	http://www.ceab.csic.es
Specific Result URL	http://www.delos.unibo.it

SUMMARY

The effect of Low Crested Structures (LCS) on habitat complexity of the surrounding soft-bottoms is sometimes very low. However, different LCS designs and hydrodynamic conditions (e.g. tidal ranges) tend to give rise to different levels of response. The sediment descriptors (granulometry, organic matter content, chlorophyll-a content) usually do not show significant differences around the LCS because of the high within-treatment variability (nested Analysis of Variance "ANOVA" design). A multivariate analysis (Principal Component Analysis) usually provides better indications of recognizable between-treatments patterns of distinctiveness. The soft-bottom infaunal assemblages around the LCS also shows high within-treatment variability. Conversely, it is possible to demonstrate marked differences between the assemblages around the LCS and between them and the controls, independently of the tidal range (nested ANOVA design). The use of biological (number of species, abundance, biomass, diversity), as well as functional (trophic groups), descriptors are a better tool to record the impact caused by the LCS than the sedimentary characteristics. Multivariate analyses (such as Multi-Dimensional Scaling or Analysis of Similarity) show differences among treatments independent of the distinctiveness of the raw data. However, it is necessary to explore the results on the basis of either abundance or biomass and on the basis of either species or trophic groups, as the resolution may vary depending on the studied situation. The analyses confirmed the patterns obtained with the ANOVA approach, highlighting the fact that the largest dissimilarity always occurred between landward and control areas. The analyses of samples collected at successive distances from LCS (always designed according to the particular characteristics of each target site) are able to produce an integrated picture of the systems, that could be linked (easily) both to environmental trend and to dynamic models in order to assess the influence of hydro- and sediment dynamics on the soft-bottom assemblages. The effect of LCS on both sediment descriptors and infaunal communities was localised mainly in the proximity of the structures. The degree of exposition and the hydrodynamic regime at landward seem to be key features influencing the diversity of the infauna around the LCS, particularly stronger in the presence of additional structures (such as parallel groins) or after beach nourishment. As the presence of the LCS induces a disruption in the normal succession from shoreline to deep waters, changes in sediment characteristics and infaunal assemblages seem to be an inevitable consequence of the LCS construction, which always depend on the response of the peculiar assemblages inhabiting a given area. Thus, it is strictly necessary to know the composition of these assemblages before the construction, in order to be able to assess their possible subsequent evolution (e.g. species disappearance-from and/or colonization-of the new environment). Local and wide geographical areas should be studied to determine the possible sources of species able to respond to the new artificial conditions. The overall habitat diversity of the stretch of coast where the LCS are built usually tends to increase and, as a consequence, the biodiversity also tends to increase. To some extent, this could be regarded as a positive result. However, the ecological relevance strongly depends on the species responsible of the changes. Whether they are species accidentally coming from the newly added hard bottoms or species more or less associated to increasing disturbances, the increase in infaunal biodiversity must be considered as a negative transformation. Despite the join studies were carried out in very different coastal systems, the results obtained are consistent. This strengthens the findings on

the effect of LCS on soft-bottoms and will allow the formulation of LCS design guidelines to be applied to different coastal systems in Europe. It seems feasible to introduce design criteria to facilitate a positive evolution of the assemblages (once the artificial situation tends to become stable) addressed, for instance, to try to avoid the development of insalubrious areas in the protected zone (e.g., by increasing the water flow through the LCS). Coastal managers from local and regional authorities, as well as private companies with interests in deployment of infrastructures affecting the littoral should take the above considerations into account. However, it must be pointed out that the effects of LCS on soft-bottoms should always be minimised, independently of any increase in biodiversity, as the principle is to maintain the most natural ecosystem conditions, protecting them from human interventions. For example, the number of LCS should be reduced to the minimum necessary to protect the coast, to avoid large-scale effects of habitat loss, fragmentation and community changes.

SUBJECT DESCRIPTORS CODES
37 ANTHROPOGENIC IMPACT ON ECOSYSTEMS 64 BIODIVERSITY 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 343 INVERTEBRATES 175 ECOLOGY, ECOSYSTEMS, ECOLOGICAL EVOLUTION/DYNAMICS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Martin Daniel., Fabio Bertasi, Marina A. Colangelo, Matthew Frost, Stephen J. Hawkins, Enrique Macpherson, Paula S. Moschella, Maria Paola Satta, Richard C. Thompson, Mindert deVries, Victor U. Ceccherelli. 2004.- Ecological impacts of low crested structures on soft bottoms and mobile infauna: how to evaluate and forecast the consequences of an unavoidable modification of the native habitats.	Coastal Engineering.	Public
Airoldi L., Abbiati M., Hawkins, Jonsson P.R., Martin D., Moschella P., Thompson R., Åberg P. 2004.- An ecological perspective on deployment and design of low crested structures.	Coastal Engineering.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE:** Tick a box and give the corresponding details(reference numbers, etc) if appropriate		**Pre-existing know-how** Tick a box and give the corresponding details(reference numbers, etc) if appropriate	
	Current	**Foreseen**	**Tick**	**Details**

	Tick	NoP 1)	NoI 2)	Details	Tick		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
73 Research and development 92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Guidelines, methodologies, technical drawings
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		36
Number of (public or private) entities potentially involved in the implementation of the result:		4
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		6
publications addressing general public (e.g. CD-ROMs, WEB sites)		1
publications addressing decision takers / public authorities / etc.		1
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	√
MAN	Manufacturing agreement		**PPP**	Private-public partnership	

MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:	At the end of the project a financial and technical collaboration with potential end users involved in the planning and construction phase of LCS is sought to allow the application of our results and therefore provide a real example of environmentally sensitive coastal defence structure which can be used as a model for a sound coastal management across Europe.				

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
19	D47 WP3.4 Evaluation of overall potential of breakwater as a tool to aid conservation of coastal assemblages

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	

SUMMARY

The present results may facilitate informed decisions about the construction of coastal defence structures and the management of coastal areas. In particular, results have shown that: 1)local environmental impacts can scale up in a non-linear manner. Both local and broad scales need to be considered in the design process; 2) major alterations to the species identity and composition may result from the introduction of LCSs over large stretches of coast; 3) there is a risk that the LCSs may promote the expansion of introduced species, or of species that are a nuisance to beach tourism. For example, along the coasts of Emilia Romagna, the introduced species Codium has taken advantage of the availability of hard substrata along an exposed sandy coast, and in particular of sheltered habitats that seem to provide better conditions for its growth; 4) the spatial arrangement (i.e. location, relative proximity to natural reefs and other artificial structures) of LCSs is of great importance in influencing the type of hard-bottom species that will colonise any novel structure. The present results have been incorporated into the desing guidelines. The potential end users will be mainly practitioners of coastal management. On a short term, the present original results are also expected to form the basis of some relevant publications on international scientific journals. In this case the end-user will be mainly the scientific community although some results could be dissaminated to the general public. A first manuscript will be prepared within the end of the project to be submitted to a special issue of the International journal "Coastal Engineering". On a longer term, further

collaboration will be carried on between the members of the consortium, to further develope some of the original ideas emerged from the project.

SUBJECT DESCRIPTORS CODES
22 ALGAE 37 ANTHROPOGENIC IMPACT ON ECOSYSTEMS 122 COMMUNITY DEVELOPMENT, COMMUNITY STUDIES 154 DEMOGRAPHY 366 MARINE ECOSYSTEMS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Bacchiocchi, F. and Airoldi, L., 2003. Distribution and dynamics of epibiota on coastal defence works hard-bottom structures for coastal protection.	Est. Coast. Shelf. Sci., 56: 1157-1166.	Public
Bulleri F., M. Abbiati, L. Airoldi, 2004 - The colonisation of human-made structures by the invasive alga Codium fragile ssp. tomentosoides in the north Adriatic Sea (NE Mediterranean).	Hydrobiologia, in press	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP1)**	**NoI2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development 75 Public administration and defence; compulsory social security 80 Education 92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		36
Number of (public or private) entities potentially involved in the implementation of the result:		4
of which: number of SMEs:		1
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people	50	300
S&T publications (referenced publications only)	1	5
publications addressing general public (e.g. CD-ROMs, WEB sites)		1
publications addressing decision takers / public authorities / etc.		1
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:	Further collaboration with and finantial support from potential end users involved in the construction of LCS is sought to allow the application of results and to establish sound strategies of coastal management along Italian sandy coasts				

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	Title
20	D48 WP3.5 Report on model of suitable habitats for key species on breakwaters as a function of local hydrodynamics

CONTACT PERSON FOR THIS RESULT

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URL	http://www.gu.se
Specific Result URL	

SUMMARY

It is well established that the distribution of intertidal organisms is correlated to wave exposure. Exposure is rarely well defined and a number of measures have been used to quantify exposure. Most measures involve different aspects of fetch and dominating wind directions. Rarely has the effect of waves been directly measured and often exposure is classified in terms of the biological community, introducing logical circularity. Surprisingly little effort has been focused on cause-effect relationships behind the observed correlations between wave exposure and the distribution of organisms. A few successful attempts to unravel the effects of wave action on the survival of shore organisms show that some organisms are indeed limited in their distribution by the hydrodynamic forces imposed by, in particular, breaking waves. A low-crested breakwater (LCS) introduces a strong gradient in wave exposure, mainly between the seaward and the landward side. This result focuses on detecting and predicting patterns of epibiota on LCS in relation to the hydrodynamic environment. Fieldstudies in UK (Elmer) and Italy (Ravenna) was conducted together with theoretical analyses. In field studies organism commonly found on the breakwaters were used, including barnacles, algae: long-lived (Fucus sp.) and ephemerals (Enteromorpha sp.) and the grazing molluscs Patella vulgata and Littorina littorea. Average flow speed was measured using the weight loss of discs cast in gypsum. Maximum force acting on an object in breaking waves was estimated using spring-loaded balls (Bell and Denny 1994). Studies were conducted to look at effects of topography (on larger and smaller scale) and scour on breakwater epibiota Theoretical models used were the mechanistic model of wave-induced detachment of epibiota, model of LCS interior flow and biological oxygen demand and model of LCS interior flow and nutrient depletion CONCLUSIONS From field work together with statistical and theoretical analyses the following conclusions about identified relations between epibiotic patterns and hydrodynamic regime can be made: 1. The survival of epibiotic organisms may depend on rare events of maximum wave-induced forces. The maximum force acting on epibiota, and thus probability of detachment, is expected to be approximately linearly related to maximum breaking wave height. 2. Hydrodynamic forces, modelled and observed, acting on the epibiota on LCS can be sufficiently large to detach organisms or inflict tissue damages. 3. Topography on scales larger than epibiota will offer refuges increasing survival and biodiversity 4. Topography on scales smaller than epibiota may be important during recruitment and for adhesion strength. Very smooth surfaces, in particular in combination with high flow speeds, can be used to reduce the diversity and abundance of epibiota. 5. Scour on the observed LCS seems to be a problem for epibiota only in a zone close to the toe. 6. A model of flow within LCS indicates that the supply of oxygen is sufficient to support macro-fauna for pore sizes

exceeding 0.2 m.

SUBJECT DESCRIPTORS CODES
22 ALGAE 64 BIODIVERSITY 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 175 ECOLOGY, ECOSYSTEMS, ECOLOGICAL EVOLUTION/DYNAMICS 366 MARINE ECOSYSTEMS

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Granhag L M, Finlay J A, Jonsson P R, Callow J A and M E Callow. Roughness-dependent removal of settled spores of the green alga Ulva (Enteromorpha) exposed to hydrodynamic forces from a water jet.	Biofouling (accepted)	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors

45 Construction 73 Research and development 75 Public administration and defence; compulsory social security 80 Education 92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	0	36
Number of (public or private) entities potentially involved in the implementation of the result:	4	4
of which: number of SMEs:	0	0
of which: number of entities in third countries (outside EU):	0	0
Targeted user audience: of reachable people	50	300
S&T publications (referenced publications only)	0	2
publications addressing general public (e.g. CD-ROMs, WEB sites)	0	0
publications addressing decision takers / public authorities / etc.	0	1
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
21	D49 WP3.5 Report on habitat Evaluation Procedure of sediments around different types of breakwaters

CONTACT PERSON FOR THIS RESULT

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URL	www.wldelft.nl
Specific Result URL	

SUMMARY

Delft Hydraulics has provided for a link between the morphodynamic environment of the area surrounding a LCS and the prediction of the impact on local species communities. This link is based on application of Delft3D-FLOW and MOR (Lesser, 2002) and work done in the EU life BIOMAR project (Picton, 1998). Results indicate that a sensitive and realistic prediction of biotope changes caused by impacts of coastal infrastructure can be derived from this approach. The approach could prove valuable for utilisation in imapct assessment related to the application of the EU bird and habitat directives. Developed modelling techniques are standard and directly available. Applicability is limited by the scope of the BioMar biotops system. LESSER, G.R., KESTER, J. VAN, ROELVINK, J.A., STELLING, G.S., 2002. Development and validation of a three-dimensional morphological model. WL/Delft Hydraulics, Delft University of Technology. PICTON, B.E. AND COSTELLO M. J. 1998. The BioMar biotope viewer: a guide to marine habitats, fauna and flora in Britain and Ireland, Environmental Sciences Unit, Trinity College, Dublin. Published by: Environmental Sciences Unit, Trinity College, Dublin. ISBN 0 9526 735 4 1

SUBJECT DESCRIPTORS CODES
110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 176 ECONOMIC AND ENVIRONMENT IMPACTS 210 ENVIRONMENTAL IMPACTS/INTERACTIONS 400 MODELLING/MODELLING TOOLS, 3-D MODELLING

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Model description	LESSER, G.R., KESTER, J. VAN, ROELVINK, J.A., STELLING, G.S., 2002. Development and validation of a three-dimensional morphological model. WL/Delft Hydraulics, Delft University of Technology.	Public
Method description	Frost, M., M. de Vries, 2004. Prediction of the impact of LCS on biotopes in the coastal zone. In press.	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE:** Tick a box and give the corresponding details(reference numbers, etc) if appropriate					**Pre-existing know-how** Tick a box and give the corresponding details(reference numbers, etc) if appropriate	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP**[1)]	**NoI**[2)]	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:						√	Mathematical Model system is propoerty of Delft Hydraulics

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
40 Electricity, gas, steam and hot water supply 45 Construction 73 Research and development 90 Sewage and refuse disposal, sanitation and similar activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Results of demonstration trials available
Other:	more validation cases are sought

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	0	0
Number of (public or private) entities potentially involved in the implementation of the result:	2	3
of which: number of SMEs:	1	1

of which: number of entities in third countries (outside EU):	0	0
Targeted user audience: of reachable people	0	0
S&T publications (referenced publications only)	0	2
publications addressing general public (e.g. CD-ROMs, WEB sites)	0	0
publications addressing decision takers / public authorities / etc.	0	1
Visibility for the general public	NO	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement	√	**INFO**	Information exchange/training	
JV	Establish a joint enterprise or partnership	√	**CONS**	Available for consultancy	
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

We can provide expertise on (quantitative) prediction of impacts assessment of coastal infrastructure on ecology and back this up using modelling tools.

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

We need people with a good knowledge of local coastal ecosystems and access to (local) authorities to market our joint capabilities

No.	**Title**
22	D50 WP3.5 Report on meta-population model as a function of the large -scale distribution of breakwaters

CONTACT PERSON FOR THIS RESULT

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URL	www.gu.se
Specific Result URL	

SUMMARY

The construction of artificial rocky reefs (e.g. low crested defence structures, LCS) in a sandy beach environment creates virgin habitat for rocky shore organisms. Earlier isolated patches of natural habitat may become connected via a chain of “stepping-stones” such that gene flow is permitted and also the dynamics of some or all species is shifted from the original situation. Such a situation may promote the invasion of introduced or alien species. Depending on the

actual positions of new artificial substrate the dispersal speeds, i.e., km/generation or similar, may differ. In this result we are assessing the large-scale effects of breakwaters on the distribution and abundance of species. For this result we have used Patella caerulea as a model organism. P. caerulea is a long lived prosobranch gastropod living in the intertidal. This marine snail grazes on the rock surface consuming the microfilm as well as recruits of barnacles and macroalgae. It has the potential of structuring its environment. Spatial ecology and spatial population dynamics are wide fields of research. However, it is still unknown what the general effect on originally isolated natural communities is when gene flow is established. This result tries to answer some questions about the effect of the positioning of LCS's on the regional population dynamics of P. caerulea in the Ravenna region, Italy. A metapopulation is a population of populations. In effect this means that there exist several local populations that interact, via migration or dispersal. This interaction causes regional dynamics. Many people have helped in developing metapopulation models, and models exist for several different organisms, environments etc. Metapopulation models are used to calculate extinction risks for endangered species in fragmented landscapes, the design of nature reserves etc. We have constructed a metapopulation model that encompasses local dynamics. This is important for long-lived organisms such as P. caerulea. Conclusions We have modelled the maximum distance of dispersal to 89 km. However, depending on variations in flow and behaviour of larvae dispersal may range between 10 and 89 km. This means that the probability of gene flow between the natural rocky reefs in the area was extremely low before the construction of breakwaters and harbours began. There are no longer any stretches of beaches without structures of 89 km or longer. We conclude that although we cannot at present quantify the probability of gene flow, or migrants per generation, between the natural rocky reefs in the studied area, there exists a substantial transport of larvae along the Ravenna shoreline. Through the action of the structures as "stepping-stones" the natural reefs will undoubtedly experience gene flow. The position of a LCS has a great effect on the population dynamics following removal of structures in the model. Also, the removal of LCSs in the model will have different effects depending on flow regime, e.g., year-to-year variations. We have identified a number of key structures that with a high probability contribute to a substantial part of the regional population dynamics. That is, if new LCSs are added to this area their effect will be different depending on where they are placed. These clear large scale effects of LCSs on biota demands that planning of building new LCSs must be done on a regional or a country-wide scale.

SUBJECT DESCRIPTORS CODES
175 ECOLOGY, ECOSYSTEMS, ECOLOGICAL EVOLUTION/DYNAMICS 211 ENVIRONMENTAL INDICATORS/MONITORING/RISK ASSESSMENT 366 MARINE ECOSYSTEMS 400 MODELLING/MODELLING TOOLS, 3-D MODELLING 154 DEMOGRAPHY

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Airoldi L, Abbiati M, Hawkins S J, Jonsson P R, Martin D, Moschella P S, Sundelöf A, Thompson R C, Åberg P. An ecological perspective on the deployment and design of low- crested and other hard coastal defence structures.	Submitted to Coastal Engineering	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP 1)**	**NoI 2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development 75 Public administration and defence; compulsory social security 80 Education 92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	0	36
Number of (public or private) entities potentially involved in the implementation of the result:	3	3
of which: number of SMEs:	0	0
of which: number of entities in third countries (outside EU):	0	0

Targeted user audience: of reachable people	50	300
S&T publications (referenced publications only)	0	3
publications addressing general public (e.g. CD-ROMs, WEB sites)	0	0
publications addressing decision takers / public authorities / etc.	0	1
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
23	D52 WP2.5 Report on scale effects for LCS

CONTACT PERSON FOR THIS RESULT

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Specific Result URL	

SUMMARY

Scale effects in physical models of rubble mound breakwaters appear because the ratios between the forces of interest, as present in prototype, cannot be maintained in a scaled model. None of the standard scaling laws for hydraulic models (Froude, Cauchy, Reynolds, Weber) provides accurate scaling for all processes of wave-related breakwater models. Scale effects are due to properties of breakers, wave impacts on armour blocks; run-up and overtopping; structure deformation; wave generated flow in the porous structure; flow forces on plants and organisms attached to the structure. Wave loads on breakwaters are compounded of impulsive and pulsating loads. No major scale effects are evident for pulsating loads. In this case Froude scaling is accurate to transfer model results to prototype scale.

Impulsive loads induced by breaking waves involve compressibility of air during a very short time. The fluid becomes a mixture air/water and cannot be treated as incompressible. Froude law is not adequate for scaling model results of impulsive events. Cauchy law has proved to be inaccurate too. Surface tension can alter the deformation of the crest shape as the approaching waves break. Surface tension effects become increasingly important as wavelength and intensity of breakers decrease. Without surface tension the crest deforms to generate a jet at the crest that plunges into the wave face to start the turbulent spilling process. When surface tension becomes dominant, this jet is replaced by a bulge-capillary structure at the crest and turbulence is produced by separation at the point of high-upward surface curvature at the leading edge of the bulge. During the turbulent processwhen surface tension is unimportant, splashing motions occur: air bubbles are produced. When surface tension is dominant, surface fluctuations and turbulence are reduced, and a single continuous bumpy surface makes up the boundary between air and water. The different compressibility of water is due to the different process of bubble formation from fresh to sea water. Air bubbles are smaller in sea than in fresh water and are entrained in a breaking wave. Their size distribution is different from fresh to sea water. These differences are caused by: salt concentration, ionic structure, exudates of marine organisms, surface tension, temperature and viscosity. The effects of different compressibility of water from model to prototype is overestimation of pressure magnitude and underestimation of pressure rise time for impulsive loading, if Froude or Cauchy laws are used. In aerated sea water, the presence of air produces a cushioning effect, reducing the magnitude of the impact and extending its duration. As inertia forces scale as u^2, even a use of Weber law would lead to errors: surface tension does not scale from model to prototype. It is suggested to analyse wave loading by use of the impulse (integral of load over time during impulsive events). Scaling model impulses to prototype dimensions by use of Froude law gives accurate results even for impulsive events. Another parameter which can be used for impulsive events analysis is the integral of the ratio dp (pressure) to water density. This parameter is a function of percentage void ratio. Use of this parameter involves the need for measurements of air content in model and prototype. When comparing model tests with sea water to full scale field results, differences can be noted in maximum impulsive pressures. The different ambients (laboratory and field) play a decisive role and affect the ambient conditions of the experiment. Run-up seems to be influenced by scale effects. Overtopping scales down with Froude, even if for small values of discharge some scale effects might cause underestimation in small scale models. Porous flow in model is almost entirely laminar, whereas in field condition the motion is turbulent. Empirical methods exist for scale corrections. Forces on plants and organisms should be measured in the field. The transport mode in prototype should be maintained in sediment model. Dean parameter is used to asses which transport is dominating. In situations where both modes of transport (suspension ? no suspension) occur, only qualitative results can be obtained as it is not possible to scale them simultaneously. A correct scaling for sediment preserves Dean parameter, uses an undistorted geometrical scale and scales hydrodynamics with Froude. Such a model preserves similarity in wave form, sediment fall path, wave-induced velocity, break point, breaker type, wave decay. Scale effects can arise when viscous domain becomes dominant and in presence of ripples. Marine organisms attached to breakwaters increase structure roughness, reduce water flow through the structure and trap large quantity of sediment. All these effects affects flow through the structure.

SUBJECT DESCRIPTORS CODES
110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 210 ENVIRONMENTAL IMPACTS/INTERACTIONS 207 ENVIRONMENT, ENVIRONMENTAL SCIENCE

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
Tirindelli M., Lamberti A., Paphitis, D., Collins, M.B., Vidal, C., Hawkins, S.,	Deliverable 52, DELOS EVK3-CT-2000-00041, pp 36 +	Public

Moschella, P., Burchart, H., Sanchez-Arcccilla, A. (2004) "Wave Action on Rubble Mound Breakwaters: the Problem of Scale Effects"	Appendices.	
Tirindelli M. & Lamberti A. (2004) "Evaluation of Wave-Induced Loads on Low-Crested Structure Elements"	ICCE 2004, Lisbon, Portugal (Accepted Abstract).	Public
Tirindelli M. & Lamberti A. (2004) "Impulsive forces induced by breaking waves on biotic elements attached to low crested structures"	Hydraulic National Conference 2004, Trento, Italy (Accepted Abstract).	Public
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development 80 Education

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)

Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

Application of the principles and issues identified in the report can provide a strong background upon which future construction of Low Crested Structures can be based. It can be utilised as a guide for modelling the potential impacts of a proposed scheme.

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

Additional partners for the dissemination and use of this report can be local authorities investigating the impacts of a proposed scheme, construction companies that will be commissioned to carry out the necessary works and consultancy groups funded to produce environmental impact assessments of the proposed structures.

No.	**Title**
24	D53 WP5.1 Engineering, ecological and socio-economical input to design guidelines

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Specific Result URL	

SUMMARY

The objective of this result was to provide input to the design guidelines from engineering, ecological and socio-economical perspective of design of low crested structures. The result is thus the transfer of knowledge from other results in this project to the production of guidelines. D59 WP5.3 DESIGN GUIDELINES FOR LCS INCLUDING EXAMPLE APPLICATIONS: cross-disciplinary design guidelines reflecting consideration of both structural, coastal protection, ecological and socio-economical performances. All major conclusions that were transferred to WP3.5 are summarised in deliverable D53.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 176 ECONOMIC AND ENVIRONMENT IMPACTS 175 ECOLOGY, ECOSYSTEMS, ECOLOGICAL EVOLUTION/DYNAMICS 400 MODELLING/MODELLING TOOLS, 3-D MODELLING

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status:** **PU=Public** **CO=Confidential**

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE:** **Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how** **Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP[1)]**	**NoI[2)]**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development 92 Recreational, cultural and sporting activities

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Guidelines, methodologies, technical drawings
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)	0	36
Number of (public or private) entities potentially involved in the implementation of the result:	0	3
of which: number of SMEs:	0	0
of which: number of entities in third countries (outside EU):	0	0
Targeted user audience: of reachable people	50	300
S&T publications (referenced publications only)	0	0
publications addressing general public (e.g. CD-ROMs, WEB sites)	0	0
publications addressing decision takers / public authorities / etc.	0	1
Visibility for the general public	NO	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
25	D54+D56 WP5.2 Verified partial inputs to design guidelines (Application to the

	project study sites and selected case studies)

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URL	
Specific Result URL	

SUMMARY

The activity for this WP is documented by Chapter 12 of the Guidelines. Due to the difficulty of building-up a reliable new case to which guidelines could be applied, an existent study site was chosen for this exercise. Thanks to the many multidisciplinary collected information, it was decided to analyse Lido di Dante before the construction of the submerged structures, as it appeared in 1994: three groynes and a high tendency to beach erosion. Five different design alternatives were proposed: a pure nourishment with sand, a submerged barrier, some emergent barriers, an extension of the two external groynes, a submerged barrier connected to the two external groynes by submerged structures. These alternatives were first sketched accounting for formulae and tools presented in the guidelines. Then, numerical simulations were carried out with Mike 21 software on all alternatives and hydrodynamics and predicted sedimentary budget were derived and compared. Comments from an ecological point of view were asked for. Finally, accounting also for social needs and desires obtained from the CVM survey carried out in summer 2002, the final choice was done and the detailed design alternative was performed.

SUBJECT DESCRIPTORS CODES
110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status:** **PU=Public** **CO=Confidential**

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE:** **Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how** **Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP**[1)]	**NoI**[2)]	**Details**	**Tick**		
Patent applied							

for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 73 Research and development

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Scientific and/or Technical knowledge (Basic research)
Other:	

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		
Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	NO	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or		**CONS**	Available for consultancy	√

	partnership				
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

No.	**Title**
26	D59 WP5.3 DESIGN GUIDELINES FOR LCS INCLUDING EXAMPLE APPLICATIONS: cross-disciplinary design guidelines reflecting consideration of both structural, coastal protection, ecological and socio-economical performances

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Specific Result URL	www.delos.unibo.it

SUMMARY

The effect of manmade activities is primarily local but can extend far away from the location of intervention. This underlines the importance of establishing coastal zone management plans covering large stretches of coastlines. The present guidelines on Low Crested Structures (LCS's) attempts to provide methodological tools both for the engineering design of the structures and for the prediction of performance and environmental impacts of such structures. It is believed that the guidelines will provide valuable inputs to coastal zone management plans. The target audience for this set of guidelines is consulting engineers or engineering officers and officials of local authorities dealing with coastal protection schemes. The guidelines are also of relevance in providing a briefing of current best practice for local and national planning authorities, statutory agencies and other stakeholders in the coastal zone. The guidelines have been drafted in a generic way to be appropriate throughout the European Union taking into regard current European Commission policy and directives to promote sustainable development and integrated coastal zone management.

SUBJECT DESCRIPTORS CODES
105 CIVIL ENGINEERING (INCL PAVEMENTS AND STRUCTURES) 110 COASTAL MORPHOLOGICAL CHANGES AND COASTAL DEFENSE MECHANISMS 111 COASTAL ZONE ECOSYSTEMS AND MANAGEMENT 176 ECONOMIC AND ENVIRONMENT IMPACTS 175 ECOLOGY, ECOSYSTEMS, ECOLOGICAL EVOLUTION/DYNAMICS 400 MODELLING/MODELLING TOOLS, 3-D MODELLING

DOCUMENTATION AND INFORMATION ON THE RESULT

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: PU=Public CO=Confidential**
http://www.delos.unibo.it/Deliverables.html	The pdf document will be downloadable from DELOS website as soon as the EC will approve the Project closure.	Public

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE: Tick a box and give the corresponding details(reference numbers, etc) if appropriate**					**Pre-existing know-how Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP 1)**	**NoI 2)**	**Details**	**Tick**		
Patent applied for							
Patent granted							
Patent search carried out							
Registered design							
Trademark applications							
Copyrights	√				√		
Secret know-how							
Other - please specify:							

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Market application sectors
45 Construction 75 Public administration and defence; compulsory social security

CURRENT STAGE OF DEVELOPMENT

Current stage of development	Guidelines, methodologies, technical drawings
Other:	In preparation

Quantified data about the result

Items (about the results)	**Actual current quantity**	**Estimated (or future) quantity**
Time to application / market (in months from the end of the research project)		

Number of (public or private) entities potentially involved in the implementation of the result:		
of which: number of SMEs:		
of which: number of entities in third countries (outside EU):		
Targeted user audience: of reachable people		
S&T publications (referenced publications only)		
publications addressing general public (e.g. CD-ROMs, WEB sites)		
publications addressing decision takers / public authorities / etc.		
Visibility for the general public	YES	

Further collaboration, dissemination and use of the result

COLLABORATIONS SOUGHT

R&D	Further research or development	√	**FIN**	Financial support	
LIC	Licence agreement		**VC**	Venture capital/spin-off funding	
MAN	Manufacturing agreement		**PPP**	Private-public partnership	
MKT	Marketing agreement		**INFO**	Information exchange/training	√
JV	Establish a joint enterprise or partnership		**CONS**	Available for consultancy	√
Other	(please specify)				
Details:					

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

Exploitation plans

CONFIDENTIAL

I am the Co-ordinator of the above project, and confirm on behalf of the contracted Partners the information contained in this Technological Implementation Plan, and I authorise its public dissemination.

Signature: **Name:**

Date: **Organisation:**

SECTION 5

Executive publishable summary, related to the overall project duration

(Project 3 years)

Contract No : **EVK3-CT-2000-00041**	Reporting period: **1.2.2001 – 29.2.2004**
Title: **Environmental Design of Low-Crested Coastal Defence Structures (DELOS)**	

Contract n°	**EVK3-CT-2000-00041**	Reporting period:	**1.2.2001-29.2.2004**
Title	**Environmental Design of Low Crested Coastal Defence Structures – DELOS**		

Objectives:

DELOS aimed at promoting effective and environmentally compatible design of low crested structures (LCS) to defend European shores against erosion and to preserve the littoral environment and the coast economic development. Specific objectives and methods were:

- to provide an inventory of existing LCS and a literature based description of their effects;
- to analyse LCS hydrodynamics, stability and effects on beach morphology by surveys on sites, laboratory experiments and numerical modelling;
- to investigate the impacts of LCS on biodiversity and functioning of coastal assemblages by observations and field experiments;
- to develop a general methodology to quantify benefits for "Integrated Coastal Zone Management" based on Contingent Valuation monetary values in different European countries;
- to provide local authorities with validated operational guidelines for the design of LCS.

Scientific achievements:

DELOS achievements are summarised considering separately the three main disciplinary tasks/expertises inside the Project.

Ecology

Ecological effects of LCS are site-specific reflecting the complexity and variability of natural systems. LCS always produces an increase in biodiversity and generates inshore sedimentation that negatively affects the landward soft bottom habitat.

LCS design criteria must be addressed to:

- promote the development of salubrious areas in the protected zone by increasing the water flow through the structures;
- reduce to the minimum LCSs length to avoid large-scale effects of habitat loss, fragmentation and community changes;
- increase structure stability, minimise maintenance works and manage human usage, to facilitate settlement/persistence of algae and marine invertebrates and reduce ephemeral green algae;
- avoid siltation and scouring that are felt as disturbances for abundance and composition of epibiotic assebmblages, for instance by increasing the berm width;
- increase armour geometry complexity and heterogeneity that promote settlement of organisms and enhance diversity;
- assure structure submergence in low-tide to avoid consequent exsiccation of colonising organisms.

Economics

The construction of LCSs for beach protection is 'justified' from an economic point of view by the CVM surveys carried out within DELOS.

LCS design criteria shall account for the preferences that people expressed:

- submerged structures for aesthetic reasons;
- groynes for water quality and recreational activities.

A Benefit Transfer Function was prepared with coefficients that should be calibrated on the site under analysis.

Engineering

Site-monitoring improved the knowledge of morpho-dynamic evolution in presence of different intervention type. Currents at gaps appear to have a strong influence on local scour, LCS stability and swimming safety.

Laboratory experiments allowed to cover the lack of information on waves and currents interaction with LCS both in 2D and 3D conditions. Stability, breaking, overtopping, filtration, transmission were examined and parametrised after having identified the most relevant process parameters.

Numerical modelling produced new validated 2D and 3D tools and calibrated existent models. Models are able to accurately predict most important processes as overtopping and transmission; the representation of morpho-dynamic effects at local scale is still uncertain because of scale-effects.

Global results

The most significant Project global result consists of *Design Guidelines* for LCS construction that will be generally applicable across European coastlines and cover economic, social, ecological and engineering aspects. Selected conclusive articles are going to be printed in a Special Issue of Coastal Engineering Journal. A web-site was regularly updated with project advances and will remain active to disseminate main Project results.

Socio-economic relevance and policy implications:

The societal impact of DELOS will be felt in many sectors, including the civil engineering community, tourist industries and recreational activities, coastal environmental authorities and consultancy organisations advising the management of the coastal area and its living resources, and local political, regulatory and enforcement authorities.

DELOS addressed these primary contributions to Community social objectives:

Preservation, protection and improvement of coastal environments

Analysis to forecast effects of low crested defence structures on the littoral environment and associated assemblages of animals and plants was performed to enhance the sustainable development and natural value of these systems.

The study generated insights into ways to use artificial structures to restore or enhance local productivity and biodiversity.

Improving the quality of life, health and safety

The knowledge and guidelines developed within DELOS may guarantee an effective protection of European sandy coasts, which would give secure benefits in terms of maintenance and improvement of suitable areas for tourism.

Knowledge and amelioration of hydrodynamic conditions around the structures can give positive effects on swimming safety.

The structures may also provide a focus for recreational and food gathering activities, in some areas benefiting fisheries for littoral gastropod molluscs.

The development of *Design Guidelines* for LCS will result in more frequent choice of this type of structures instead of higher and more visible ones. The negative visual impact can thus be reduced, which is generally perceived as equating with higher habitat quality by the public.

Design guidelines take into account also the effects of breakwater morphology and location on colonising epibiota, in order to limit colonisation by species that are seen as a nuisance when torn off the structures and transported to the sandy beaches (e.g. green algae and kelp detritus) while promoting assemblages that are similar to those on natural hard sea-beds and rocky shores.

In order to guarantee the up-take of information by potential users and the implementation of developed design guidelines, DELOS involved representatives end-user from the very beginning of the project

Conclusions:

The Project met all the initial objectives. Further research is however felt necessary on several topics, e.g.: biological effects forecasting, morpho-dynamic modelling, extension of benefit valuation function beyond touristic use. The cooperation of researchers of different scientific background requires time and patience before becoming effective.

Keywords:

Low crest, Coastal structures, Hydrodynamics, Erosion, Ecology, Functioning, Design, Valuation.

SECTION 6

Detailed report, related to the overall project duration

(Project 3 years)

Contract No : **EVK3-CT-2000-00041**	Reporting period: **1.2.2001 – 29.2.2004**
Title: **Environmental Design of Low-Crested Coastal Defence Structures (DELOS)**	

DETAILED DESCRIPTION OF THE SCIENTIFIC RESULTS

RESULT N°1

WP 1.1 AAU

D 5 Inventory of engineering properties for LCS and a related data bank

Background (description of the problems to be solved)

No databanks or reports describing physical properties of existing LCS's in Europe exist. No guidelines on design of LCS's exist and structures in the different countries are mainly designed on the basis of experiences.

Scientific/technological and socio-economic objectives

The structural layout and cross-sections used in existing LCS's are important for the structural and coastal protection performance. Information regarding existing structures is directly useful in design of new structures. Further when developing new design tools, e.g. parametric formulae, it is necessary to know the range of parameters for the validity of the new formulae.

Applied methodology, scientific achievements and main deliverables

Initially study sites were identified and brief information about a large number of sites was provided. The information was collected by many European partners in the DELOS project and presented on the Internet www.delos.dk. This site served as a common place for sharing documents and information during the collection of the inventory data. Further a limited number of sites of special interest were selected for detailed study. The main deliverable D5 consist of the brief descriptions, the detailed descriptions, a document summarizing all information, a document with statistics on LCS’s geometry, and a data bank with categorized selected properties and statistics for LCS's.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The results provided a base of knowledge for the subsequent work packages in the DELOS project. The knowledge was directly used in the guidelines (explained subsequent in result no. 26, WP5.3, D59, e-tip 2040).

Dissemination and exploitation of the results

The results including raw-data are available to the public on the Internet for download. The results are distributed to all project partners and are used in several internal reports. The most recent publication containing some of the findings is the paper on Prototype Experiences, which is a part of the DELOS Special Issue of Coastal Engineering. No further steps are planned to disseminate the results.

Main literature produced

1) The paper "Prototype experience regarding low crested structures" by A. Lamberti, R. Archetti, M. Kramer, D. Paphitis, C. Mosso, M. Di Risio, which will be included in the DELOS’ special issue of Coastal Engineering is under preparation.
2) Documents including raw-data available on the Internet www.delos.unibo.it:

- "Inventory Summary" about available information
- "Inventory Statistics" summarizes statistics on LCS’s geometry
- Excel sheet with summarized selected properties and statistics for LCS's
- Excel sheet with additional inventory data
- Brief questionnaires completed in DK, NL, IT, GR, ES, and UK

- Detailed questionnaire completed in IT (Lido di Dante, Punta Marina, Cesenatico, Bellaria-Igea, Bisceglie 1 & 2, Castel Volturno, Ostia, Pellestrina, and Amendolara), GR (Lakopetra and Paphos), and ES (Altafulla and La Laja-Canary Islands)
- Inventory of existing structures on the French coast
- Inventory of LCS in USA and Japan

RESULT N°2

WP 4.1 UTW

D 11 A Benefit Transfer Function of environmental values: developing criteria to build in and to transfer CV monetary values of changes in environmental quality from other case studies in Europe

Background (description of the problems to be solved)

Using bibliographical references collected in WP 1.3, the first task of WP 4.1 consisted in extracting data from those references. The second step was to assess the possibilities of transferring the reported benefits.

Scientific/technological and socio-economic objectives

WP 4.1 is a contribution towards the improvement of the cost-benefit analysis (CBA) methodology, as applied to LCS defence. The policy implications should be whether each LCS CBA should be based on data collected specifically for that LCS site, or whether the CBA could reliably use existing data on other sites and defence schemes.

Applied methodology, scientific achievements and main deliverables

A benefit transfer function is essentially a regression line through a set of reported benefits. The statistical specification of the benefit transfer function is still evolving but, for illustrative purpose the general form of such function is represented as:

$$Benefit_i = \alpha + \beta X_i + \gamma Y_i + \delta Z_i + \varepsilon_i ,$$

where □□□□ are the parameters to estimate, X is a vector of site characteristics, Y is a vector of socio-economic characteristics (often, the sample means), Z is a vector of study characteristics (among others, the valuation techniques that have been used, if more than one; or the year of the study), and i indexes the studies.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The transfer of benefits has shown to be reliable in certain cases, such as landscape preservation benefits. When this is the case, it is a technique that is both cheaper and faster than a site-specific CBA with proper data.

However, the literature reveals that many seafront assets can be valued, but there are few studies per type of asset. The comparability of the values found in the literature on any one such asset is difficult because: The scheme characteristics are nearly never explicit, The study variables (indicating the valuation that has been used in the case study) are well documented but the estimates are not always comparable, The site characteristics and flooding patterns are often not very clear, And the socio-economic variables are not always reported. Therefore, in general, benefit transfer is not reliable for any seafront asset, with the possible exception of the asset “informal beach recreation” that is discussed below.

Informal Beach Recreation has been estimated on 26 sites (there is also 2 references in the literature that are not site-specific), of those 7 value the access to the site, while 19 measure the Value Of Enjoyment (VOE) of the site. All the VOE estimates are from the UK, several of which only appear in review studies. The VOE rarely coincides with the defence scheme value (because the defence scheme never preserves the site exactly as it was, and because the VOE refers to whole site, while the beach erosion threat would in general not imply the disappearance of the whole site). In conclusion, even with informal beach recreation, transfer is at best doubtful, and we do not recommend its use. Instead, we recommend that any project of coastal defence do its own valuation. The decision to undertake such a valuation could in turn be based on WP 4.1 report in the sense that this report indicates for which assets the largest values may be expected.

Dissemination and exploitation of the results
Internal reports of the DELOS project.
Presentation of the Dutch results on benefit transfer and the case study at:

- Sixth International Conference of the Russian Society for Ecological Economics RSEE'2003 "Economic Development and the Environment: information, modelling and management", Lake Baikal, Russian Federation.

Seminar series of the ECRU unit, Faculty of Agronomy, Université Catholique de Louvain, Belgium and at seminar series of the Faculty of Public Policy and Public Administration, University of Twente.

RESULT N°3

WP 2.1 UCA

D 19 Calibrated 2DV near-field flow model: COBRAS provides near field kinematics over and inside LCS and will be used to assess velocities over the surface of the stones and to calibrate wave propagation models

Background (description of the problems to be solved)
Near field hydrodynamics models are essential to describe the flow around and inside LCS. Reflection, transmission, overtopping and other complex phenomena such as wave breaking, turbulence generation and porous flow inside the structure are some of the processes that have to be modelled and predicted in order to provide relevant information for LCS design. A correct assessment of these processes has implications on structure functionality and stability, on the morphodynamics and scour associated with the presence of LCS as well as on the biomechanics of marine organisms attached to the structure.

Scientific/technological and socio-economic objectives
The main scientific and technological objective was to develop a numerical tool able to reproduce most of the processes involved in the interaction of wave and LCS including, wave reflection, transmission, wave overtopping, wave breaking, turbulence generation, transport and dissipation and porous flow through the structure. The second objective was to prove the capability of the model to be applied to real cases and to obtain numerical data as an input for far field hydrodynamic and morphodynamic models.

From the socio-economic point of view, the model should provide a technical tool to design more efficient, environmental friendly LCS with a lower cost.

Applied methodology, scientific achievements and main deliverables
In the last few years a new generation of models based on the Navier-Stokes equations have become available for the coastal engineering community. However, even if this kind of modelling is relatively extended in other fields such as mechanical and aerospace engineering, it is in its initial stage in the coastal engineering field. This is probably due to our large domains of interest and the ample range of Reynolds numbers of our interest flows.

In the frame of DELOS the numerical work to analyse the near-field flow in LCS has been based on a 2DV numerical model originating from the Navier-Stokes equations. This two-dimensional model based on the Volume-Averaged Reynolds Averaged Navier-Stokes (VARANS) equations is named COBRAS.

The most important limitation is considering only two-dimensional flows and the problems associated with the possible shortcomings of using $k-\varepsilon$ equations for turbulence modelling. However, it has several advantages. It is able to simulate porous flow including turbulence in the permeable region and it requires less computational resources which allows the evaluation of the functional performance of LCS under several wave incident conditions, structure geometry and porous material characteristics.

The model has been validated against small scale and large scale experimental data, showing excellent results for all the different physical magnitudes considered, i.e., free surface, pressure, velocity, TKE, shear stresses, etc. Furthermore, the model has been used to consider several structure geometries, construction material and incident wave conditions, even for prototype conditions showing a very high application potential.

The main deliverable has been a numerical code ready for application to LCS and a user's manual.

Conclusions including socio-economic relevance, strategic aspects and policy implications

At this stage of development the two-dimensional model presented combined with some 3-D specific applications is probably the most suitable way to carry out the analysis of the flow for wave interaction with LCS. Therefore, from the strategic point of view, this model should be considered to complement the standard empirical formulations for the design of LCS, since it provides a way to consider several different geometry and incident conditions scenarios. From a socio-economic point of view, its regular application for the design of coastal structures should help to provide a more reliable, cost-efficient and environmental design of LCS.

Dissemination and exploitation of the results

The model, results and applications has been presented in several conferences: Spanish and French Coastal Engineering conferences, Coastal Structures 03, ASCE and will be presented in the International Coastal Engineering Conference, to be held in Lisbon in 2004. The results have been also presented to the end-users in the DELOS end-user meeting as well as in different seminars in Portuguese and Spanish administrations and Universities.

Main literature produced

Garcia, N., Lara J.L. and Losada, I.J. (2003) 2-D Experimental and numerical analysis of wave interaction with low-crested breakwaters including breaking and flow recirculation. Coastal Engineering (ELSEVIER), submitted.

Losada, I.J., Lara, J.L., E.D. Christensen and Garcia, N (2004) . Breaking process, velocities and turbulence intensity around low-crested structures. Coastal Engineering (ELSEVIER), DELOS special issue, submitted.

Losada, I.J., Lara J.L. and Garcia, N. (2003). 2-D Experimental and numerical analysis of wave interaction with low-crested breakwaters including breaking and flow recirculation. Proceedings Coastal Structure 03, ASCE. (in press).

RESULT N°4

WP 2.2 DHI

D 21 A one line morphodynamic model is calibrated and adapted for the special LCS conditions: the one line model used is composed of a wave module calibrated with the results of the Boussinesq model, a long shore transport equation and mass conservation equation to represent the shoreline displacement

Background (description of the problems to be solved)
LCS interact with the incident waves and have thus a significant impact on the hydrodynamics, the sediment transport and the nearshore morphology in the vicinity of LCS. In order to investigate the impact of LCS on the shoreline response at a medium- to long-term time scale, it is important to count with calibrated one-line models capable of representing shoreline evolution in the vicinity of these structures. In particular wave transmission should be predicted with reliable empirical formulae.

Scientific/technological and socio-economic objectives
Low crested structures (LCS) are frequently built as part of coastal protection schemes, either to protect an exposed coastline, to support a perched beach, or to keep nourishment in place. In connection with the design of LCS, it is important to keep in mind that placement of these structures may have undesired negative impact on the morphology of the adjacent coasts. In order to investigate the medium- to long-term response of the shoreline in terms of changes in coastline position, numerical modelling tools including the effect of LCS on waves, currents and longshore transport need to be developed.

From the socio-economic point of view, these models should provide a technical tool to assist in the design of more efficient LCS at a lower cost, while keeping their impact on coastal morphology within acceptable limits.

Applied methodology, scientific achievements and main deliverables
Two one-line models capable of simulating shoreline evolution under the presence of LCS were developed in WP 2.2 during the course of the DELOS projects. Activities carried out by the partners involved in this development (MOD and UPC) were closely co-ordinated, e.g. by selecting a number of common test cases for which both models were applied. Common to both models was also the fact that development focused on the description of wave transmission behind LCS, which is the main parameter used for the computation of longshore transport rates behind the structures.

The first one-line model (ARIES) was developed by MOD. Predictions of shoreline response were compared to empirical relationships available in literature and to the UPC model in order to point out the sensibility of the prediction to different approaches and to achieve a common optimised approach.

The second model (Beach1L) was developed by UPC, and included several formulas for wave transmission coefficient. UPC’s approach was specifically aimed at simulating the medium-term shoreline response under the influence of detached breakwaters of varying crest height.

Conclusions including socio-economic relevance, strategic aspects and policy implications
One-line shoreline evolution models have been developed, calibrated, validated and applied during the DELOS project. At the present stage of development, where coastal area morphological modelling is still too demanding from a computational point of view, one-line models are the best tool available for an initial estimate of the long-term impact of LCS on coastal morphology.

As with any modelling tool, it is important to keep the model’s limitations in mind when interpreting the results It should also be remembered that combination of different types of models usually is the best approach for collecting as much design information as posisble.

Dissemination and exploitation of the results
The results obtained have been published in internal reports of the DELOS project (Deliverable 21), have been presented at several international conferences and included in the conference proceedings, and also published in peer-reviewed literature, as described in the list below.

Main literature produced

R. Briganti, J. Van der Meer, M. Buccino & M. Calabrese (2003): Wave transmission behind low crested structures. Coastal Structures 2003, 26-29.August, 2003, Portland, Oregon, U.S.A.(in print)

Contini P., Mita M., Codispoti N., Briganti R., Franco L.(2003): Shoreline evolution in presence of detached breakwaters. Analysis by means of one-line model. Proceedings of Medcoast 03 Conference.

RESULT N°5

WP 2.2 DHI

D 20 Quasi 3D morphodynamic model: this model is composed of a wave module, a phase averaged hydrodynamic model and a sediment transport model, which are coupled to form a morphological model. In the far field, the hydrodynamic part of these models will be calibrated by comparison with the calibrated Boussinesq model and the 3D experimental data

Background (description of the problems to be solved)

The presence of LCS in coastal areas drastically change the wave, flow and sediment transport conditions in their vicinity compared to the situation along the neighbouring, open coastal areas. This is a result of the (partial) blocking of the incident waves by the structures. The impact of LCS on the hydrodynamic and sediment transport conditions is also reflected in changes in coastal morphology in the vicinity of the structures. In order to investigate the far-field bathymetry changes induced by LCS (scour is not included within the morphological changes discussed here), it is important to count with coastal area models capable of simulating the main processes that take place in their vicinity.

Scientific/technological and socio-economic objectives

Low crested structures (LCS) are frequently built as part of coastal protection schemes, either to protect an exposed coastline, to support a perched beach, or to keep nourishment in place. However, placement of these structures may have a negative impact on the morphology of the adjacent coastal areas. In order to investigate the short- to medium-term impact on the nearshore bathymetry, numerical modelling tools specifically aimed at describing the peculiarities of the hydrodynamics, sediment transport and morphology around and in the immediate vicinity of LCS need to be applied.

From the socio-economic point of view, the morphodynamic model should provide a technical tool to assist in the design of more efficient LCS at a lower cost, while keeping their impact on coastal morphology within acceptable limits.

Applied methodology, scientific achievements and main deliverables

Coastal area morphological models have now been available for a number of years. However, the wave and flow modules that are used to investigate the response of the bathymetry to e.g. emerged structures cannot be directly applied to simulation of conditions around LCS. For example, wave modules typically include a description of wave breaking which is applicable to the relatively smooth slopes of sandy beaches, while the process of wave breaking on the steep slopes of LCS may be quite different. Nor is the process of transmission of wave energy through overtopping included in most available wave models. Something similar can be said about simulation of the flow over the submerged structure by the flow model of the coastal area morphological modelling system.

Within the framework of DELOS the coastal area morphological model MIKE 21 CAMS will be applied to investigate the response of the bathymetry in the nearshore region to the presence of LCS. The model includes a quasi-3D description of the flow and the sediment transport, which allows e.g. simultaneous computation of longshore and cross-shore transport within the surf zone. Focus was mainly placed in calibrating/validating the wave and flow modules of CAMS against data collected in the wave basin of AAU during the 3D hydrodynamic tests carried out as part of the DELOS project. As a result of the analysis, the wave breaking formulation in the wave module MIKE 21 PMS was changed. No clear conclusion regarding the ability of the flow module MIKE 21 HD to reproduce the water levels and current velocities recorded in the experiment could be achieved, due to differences in the set-up of the physical and the numerical models. This applies mainly to porosity of the structures and the side walls of the wave basin.

The main deliverable is a coastal area morphological modelling system applicable to schemes that include LCS.

Conclusions including socio-economic relevance, strategic aspects and policy implications

At the present stage of development of coastal area morphological modelling tools, the system presented here constitutes one of the most advanced possibilities that are available today for the detailed analysis of the evolution of the bathymetry in response to the far-field impact of LCS. Since this analysis is limited to short- to medium-terms temporal scales, most comprehensive results will be obtained by combining the coastal area morphological model with one-line models specifically aimed at simulating shoreline response behind LCS.

From a socio-economic point of view, regular application of this type of tools for the design of coastal structures should assist in obtaining more reliable, cost-efficient and more friendly (from the point of view of morphological impact) low-crested structures.

Dissemination and exploitation of the results

The results obtained have been published in internal reports of the DELOS project (Deliverable 20), have been presented at several international conferences and included in the conference proceedings, and also published in peer-reviewed literature, as described in the list below.

Main literature produced

Zyserman, J.A. and Johnson H. K.(2002): Modelling morphological processes in the vicinity of shore-parallel breakwaters. Coastal Engineering 45 (3-4), pp. 261-284.

Johnson, H. K. (2003): Wave modelling in the vicinity of submerged breakwaters. Submitted for review and possible publication in Coastal Engineering.

Christensen, E.D., Zanuttigh, B. and Zyserman, J.A. (2003): Validation of numerical models against laboratory measurements of waves and currents around low-crested structures. Coastal Structures 2003, 26-29.August, 2003, Portland, Oregon, U.S.A. (in print)

Johnson, H. K., Karambas, T.V., Avgeris, I., Zanuttigh, B, Gonzáles, D. and Cáceres, I. (2004): Modelling of waves and currents around submerged structures. Coastal Engineering (ELSEVIER), DELOS special issue, submitted

RESULT N°6

WP 4.2 UB

D 28 CV study reports for 2 cases in Italy (Lido di Dante, Barcola-Trieste) and 1 in the Netherlands (Normerven)- objectives: to determine the implications for Benefit Transfer across countries in the European Union for specific empirical situation

Background (description of the problems to be solved)

The value of the coastal projects of Lido di Dante and Trieste is made up of the sum of the values of the consequences of these projects. In the Cost-benefit Analysis (CBA) all the values of the consequences must be considered. Some of them are not established by the market. As regards the case-studies of Lido di Dante and Trieste, in the DELOS research study the focus is on the beach use value, which is a non-marketable value. It must be estimated in monetary term for the CBA. In addition, informal beach recreation has been studied more than any other type of coastal asset, therefore a benefit transfer (a technique for estimating the value of one site given the value of similar sites) can be estimated.

Finally, as regards different defence techniques, beach visitors have different preferences that must be known in order to design new defence projects.

Scientific/technological and socio-economic objectives

The main aims of the DELOS research study are: i) to estimate the beach use value in different conditions (status quo, erosion and protection) and different seasons (spring/summer and autumn/winter); ii) to see whether the British Penning-Rowsell method is suitable for estimating the beach use value of Italian beaches; iii) to see whether this method needs adaptation and innovation in order to be applied in Italy; iv) to present an example of benefit transfer for coastal defence; vi) to obtain information on visitors' preferences about different kinds of coastal defence structures useful for project researchers about the design of different defence structures.

Applied methodology, scientific achievements and main deliverables

Beach use value requires a specific valuation method to be estimated. The chosen methodology is a version of the CV method known as value of enjoyment (VOE) as described in the Yellow Manual. The willingness to pay version of the CVM requires the specification of a *payment vehicle* (such as tax, entry fee or voluntary donation), while this is not required for the VOE version. As regards Italian beaches, at the time of survey any form of payment would have been unpopular; therefore, the CVM in the VOE version was preferred for beach visitors and residents.

CV surveys in the VOE version ask each user to estimate the value he/she attributes to the enjoyment obtained from a visit to the beach in different scenarios. At the heart of the CV approach is the questionnaire, which attempts to develop plausible scenarios in which evaluations can be made. The basic VOE questionnaires used for the Italian case-studies are those published in the well-known Yellow Manual, Appendices 4.2 (a) and (b) - the Standard site user questionnaire and the Standard resident questionnaire. The questionnaires were adapted to the Italian case-studies by asking the beach use value not only in spring/summer but also in autumn/winter.

As regards the transfer function, a Brouwer's equation is estimated by OLS.

Finally, as regards defence structures, some questions have been included in the survey questionnaire of Lido di Dante to find out respondents' preferences about different kinds of coastal defence structures and the main reason for their preference.

Conclusions including socio-economic relevance, strategic aspects and policy implications

These Italian surveys gave mean values for informal recreation on a beach in its current state from 5.2 Euros to 27.7 Euros per visit. This is therefore of the same order of magnitude as the US and UK beaches, though there are large variations across beaches, and some respondents sometimes express very large values. These surveys have also shown that coastal visitors are sensitive to the protection of coastal sites from erosion and flooding and that they are generally in favour of defence projects.

As regards the transfer function, the reader should be cautious when predicting the use value of one site given the existing values of other sites. In addition, there are many sources of value at the coast and it does not seem possible to estimate a function that would provide the total value of a coastal defence scheme for any single site. Finally in Lido di Dante, of the different beach defence techniques, respondents prefer composite intervention (submerged breakwaters, groynes and nourishment), and this preference is mainly justified by aesthetic reasons.

Main literature produced

Marzetti Dall'Aste Brandolini S. (2003), 'Valuation of the benefits from the coastal defence systems of some Italian sites: Venice and its Lagoon, Lido di Dante, Ostia and Trieste', Poster, ELOISE conference, Gdansk, March 2003.

Marzetti dall'Aste Brandolini S. and Lamberti A. (2003), 'Economic and social valuation of the defence system of Venice and its lagoon (Italy)', Prooceedings of the sixth international conference on the Mediterranean coastal environment, MEDCOAST 03, E. Ozhan (editor), 7-11 October 2003, pp. 307-318.

Marzetti dall'Aste Brandolini S. and Zanuttigh B. (2003), 'Economic and social valuation of beach protection in Lido di Dante (Italy), Prooceedings of the sixth international conference on the Mediterranean coastal environment, MEDCOAST 03, E. Ozhan (editor), 7-11 October 2003, pp. 319-330.

Marzetti Dall'Aste Brandolini S. (2003), 'Economic Valuation of the Recreational Beach Use - The Italian Case-Studies of Lido Di Dante, Trieste, Ostia and Pellestrina Island', D28/A, DELOS Report.

Marzetti Dall'Aste Brandolini S. (2003), Willingness to Pay for the Defence of Venice (Italy) as World Heritage Site, DELOS Report, D28/B-I, DELOS Report.

Marzetti Silva, Leopoldo Franco, Alberto Lamberti and Barbara Zanuttigh (2003), Preferences about Different Kinds of Low Crested Structures and Beach Materials – The Italian Case-Studies of Lido di Dante, Ostia and Pellestrina Island, D28/C, DELOS Report.

Marzetti Dall'Aste Brandolini S. and Lamberti A. (2004), Evaluation of the recreational use of Barcola beach in Trieste (Italy), Sustainable Tourism 2004, 7-9 July 2004, Segovia, Spain.

Polomé, P. (2002), DELOS WP 4.1 Final Report (Benefit Transfer). Available on the DELOS webpage www.delos.unibo.it/.

Polomé, P., van der Veen, A. and Geurts, P.A.T.M. (2003), "Contingent Valuation of a Restored Coastal Natural Area", in *Assessment of Option Value and Non-Use Values – The Case-Studies of Venice (Italy) and Normerven (The Netherlands)*, Report D28/B-II of the DELOS project.

RESULT N°7

2.5 UoS

D 58 Study sites reports: description of 4 European sites (Elmer- UK; Lido di Dante, Pellestrina- Italy and Skagen- Denmark)

Background (description of the problems to be solved)

Field observations are a key component in understanding the processes governing the hydrodynamic and sediment transport regime in the environmnet. This prototype scale information (unaffected by any scale effect) can be utilised both in the calibration of numerical and physical models, but also will be analysed individually in order to provide information on the overall regime under different conditions.

Furthermore, this information helped in developing an understanding of the functioning of the system, through collection of visual observation and feedback from the local community and socio-economic environment. The study sites reports summarise the information collected, analysed in the field, developing a progressive understanding of the physical processes governing the evolution of the environment.

Four sites were selected as the main study sites of the project: one was macro-tidal (Elmer, UK); the meso-tidal sites of Denmark; and two micro-tidal sites (LidodiDante and Pellestrina, Italy).

Scientific/technological and socio-economic objectives

Acquisition of data at prototype scale regarding the hydrodynamic conditions (i.e. wind, waves, currents, tidal elevation), governing the coastal environment and the acquisition of scour and beach morphology information, was the primary objective of the WP. Historical information on the evolution of the protected areas was collected, as background information; this assisted in the identification of the prevailing conditions and the detailed investigation of the sites. Finally, field measurements obtained in the area of interest were used for the calibration of the hydrodynamic model. Data were obtained on armour stability and the resistance of life form on the structures. An evaluation of the scale effects on sediment transport was undertaken.

Applied methodology, scientific achievements and main deliverables

A number of methods were used in the field campaigns. Waves and currents were collected using different kind of instruments and approaches and bedload trap measurements were undertaken sporadically. Morphology information, concerning both the beach on a wider scale and at the local scour near the breakwaters, was obtained regularly and surface sediment samples were collected on a dense grid. This information was used for the estimation of grain size trends.

A comprehensive overview of the selected study sites was obtained under WP 2.5. The detailed investigation of the sites helped in the understanding of the principal physical processes that govern the hydrodynamic and sediment regime.

Main deliverables for these WP were the study site reports and the report on scale effects, for the LCS.

Conclusions including socio-economic relevance, strategic aspects and policy implications

Similarities in the study sites were identified due mainly to the presence of the LCS. Waves diffraction, significantly milder wave condition in relation with the unprotected areas; and a predominant sediment accretion patterns where observed. However, differences in environmental conditions (nontidal – macrotidal) and engineering decisions (i.e. a wide range of geometric characteristics including deeply-, semi-submerged and emerged structures) have revealed the importance of different processes in the various sites.

In the macro-tidal environment of Elmer (U.K), the existence of relatively strong tidal currents in the nearshore area influences the evolution of the area. The tidal currents are entering the area behind the structures, through the gaps at the east of the scheme, flowing over the salient features, accelerating during high water conditions. This accelerated flow over a restricted depth area causes mobility of the sediment and it is probably a controlling factor for the salient growth. At the same time, the bay area between the breakwaters has low sediment mobility under tidal currents.

Wave induced sediment mobility, estimated using Stokes 2^{nd}-order waves, demonstrate the ability of even moderate wave conditions to transport the sediment in the direction of propagation of the diffracted wave. Sediment trends established for the area within the project (D30) are in good agreement with the estimated wave-induced sediment transport. For the case of mild energy conditions in the bay area, both methods estimate the direction of sediment transport; this is onshore with sediment directed towards the salients in the lee of the structures.

For the case of Denmark, winds and waves are often very mild during the summer months and the water behind the breakwaters can, be of poor environmental quality. The limited water exchange traps seaweed behind the breakwaters smelling unpleasantly (a similar observation was made even in areas with stronger tidal currents and high water exchange (Elmer)). Since the construction of the breakwaters, the annual nourishment volume has been established on the basis of maintaining the beach. The breakwaters and the nourishment have stopped the ongoing erosion of the cliff at the site, securing the village and leaving the beach for recreational activities.

At Lido di Dante, the currents are driven mainly by the prevailing wind-wave pattern. Interaction of the main current system with the LCS and groins over the area leads to the formation of eddy circulation at both heads of the LCS, and rip-currents towards the gap in the middle of the LCS.

During the surveys with drifters it was observed that currents strongly increase from the Northern cell to the Southern cell for waves coming from NE. Current intensity reaches the maximum values at the roundheads, where intensities as high as 1.8 m/s were simulated, and at the central gap, whereas is less intense along the barrier where it reached intensity 1.0 m/s offshore but only 0.4 m /s leeward, where, the submerged connectors produce a calm area. Wave intensity is obviously higher seaward than leeward the barrier. These currents are responsible of a strong erosion at the southern roundhead of the LCS. Velocities trough the gap are due to tide oscillation and during severe storms to wind and waves: measured currents can reach up to 0.5 m/s, confirming the simulation results. These currents are responsible of the strong erosion at the gaps, therefore special maintenance is requested at the gap and at the roundheads.

From the comparison between wave height inside and outside the LCS a wave transmission coefficient ranging from 0.35 – 0.65 was estimated. As expected, k_t increases with swl. Comparing the swl in and outside the structures we can see a strong set up during intensive storms ranging between 0 to 0.4 m, for very high wave height.

A deep eroded area are created at about 70m from the two roundheads, due to the strong vortices that are induced at the roundheads during storms. Another deep erosion area at the gap was observed. It is also interesting to note the sand accumulation at the seaward side of the LCS. The periodical ecological surveys undertaken over the area and on the structures provide information on the biological composition. The epibiota reveals that mussels (*Mytilus galloprovincialis,*) and green algae (*Enteromorpha intestinalis)* are present, both to seaward and leeward the structures, but are more abundant to seaward. Oysters (*Ostrea edulis* and *Crassostrea gigas*) and microfilm are more abundant to leeward of the barrier. Oysters, in particular, are practically absent to seaward (around 5%). In relation to the hydrodynamics and ecological data, some conclusions can be drawn; these show that both mean and extreme values of hydrodynamic fluxes strongly affect the barrier colonisation (Bacchiocchi et al., 2003).

At Pellestrina, the main currents occur: along the shoreline; the submerged barriers; and the roundheads of the emerged groins, where the highest waves form rip-current or vortex. Current intensity can reach maximum velocity of 1.5 – 2 m/s in the above mentioned zones, but the average velocity is about 0.5 m/s. Sediment transport is correlated strictly to the hydrodynamic conditions, so it is blocked partially by the submerged cross-shore connectors; likewise, by the submerged long-shore barrier. Sediment budget analysis has revealed an equilibrium trend, with low annual erosion of about 2.8% of the nourished sand.

Dissemination and exploitation of the results

The results obtained here are applicable to other offshore breakwater schemes in the EU and, especially, in the UK where the use of LCS is increasing presently (Elmer is amongst the first of the large projects). The data can be utilised in other EU offshore breakwaters schemes, for coastal protection and/or beach development.

Additional partners for the dissemination of the results can be construction companies operating in the area of coastal engineering, Local Authorities interested in coastal protection and/or the sustainable development within the coastal area and companies offering consultancy on the environmental impact of the coastal structures.

Main literature produced

Archetti R. Tirindelli M., Gamberini, G., Lamberti A. (2003). *Analysis of currents around a low crested barrier: comparison between field and numerical results.* Proc. of the *VI* MEDCOAST International Conference on the Mediterranean Coastal Environment, 7 – 10 October 2003. Ravenna. Italy. Ed E. Ozhan (Ed.) pp 1731 – 1740.

M. Di Risio, R. Archetti , G. Bellotti, M. Soldati. (2003). N*earshore waves and currents at Pellestrina.* Proc. of the *VI* MEDCOAST International Conference on the Mediterranean Coastal Environment, 7 – 10 October 2003. Ravenna. Italy. Ed E. Ozhan (Ed.) pp 2145 – 2154.

Archetti R., Tirindelli M., Lamberti A. (2003). *Field measurements of hydrodynamics around a beach defense system.* Proc. Coastal Structures 2003 ASCE.

Plomaritis, T. Paphitis, D. Collins, M.B., Kramer, M., Dinesen, G., Archetti, R., Barbanti, C., Clementi, E., Zanuttigh, B., Lamberti, A. (2004), 3rd year Study Sites Report. Deliverable 58, DELOS EVK3-CT-2000-00041, pp 105.

A. Lamberti, R. Archetti, M. Kramer, D. Paphitis, C. Mosso, M. DiRisio (2004) Prototype experience regarding low-crested structures. DELOS' Special Issue, *Coastal Engineering*.

RESULT N°8

WP 2.4 AAU

D 31 Report on wave basin experiments including experiment Data base: experimental information on several flow characteristics peculiar of fully 3D conditions (short crested and oblique waves and complete 3D structure) are provided

Background (description of the problems to be solved)

New unique laboratory experiments on low-crested structures were performed within the DELOS project. Wave basin experiments with fixed bed were carried out in the laboratories at Aalborg University (AAU), Denmark, aiming at extending and completing existing available information with respect to a wide range of engineering design properties. 12 different structural set-ups in 3D were built in the wave basin and 325 tests were performed. Experiments with moving bed were carried out in the laboratories at the Technical University of Denmark (ISVA), Denmark, aiming at describing locations and magnitudes of scour around the roundhead of a submerged breakwater.

Scientific/technological and socio-economic objectives

In order to make ideal set-ups in the laboratory with respect to each subject it was necessary to separate testing with different purposes. In this way the wave basin experiments at AAU were grouped in stability tests, hydrodynamic tests and wave transmission tests:

- 69 **stability tests** were performed to investigate structural damage to heads and trunks subject to 3D waves. Influence of wave obliquity was tested on 2 structural set-ups with different crest widths.
- 88 **hydrodynamic tests** were completed to analyze wave and current flows near the structures, and to provide data for calibration of numerical models. 2 structural set-ups with a gap between the roundheads and 2 set-ups with oblique structures were tested in 2D and 3D waves.
- 168 **wave transmission tests** were performed with the objective of studying influences of wave obliquities on transmitted wave energy, wave directions and spectral changes. 3 structural set-ups with rubble structures and 3 set-ups with smooth plywood structures were tested in 2D and 3D waves.

The scour experiments at ISVA were performed in order to develop formulae for the width of the toe protection at the roundhead section.

Applied methodology, scientific achievements and main deliverables

The chosen set-ups were based on a survey of the geometry of 1248 existing low crested breakwaters in the EU, see the description of Result no. 1 (WP1.1, D5, E-tip 1984). Typical ranges of structural geometries were identified and scaled by 1:20 leading to appropriate sizes of the structures with respect to the size of the wave basin. The largest possible armour stone sizes were chosen based on existing knowledge about stability of LCS's and the obtainable wave conditions in the basin. Sufficiently large Reynolds numbers were ensured to avoid problems with viscous scale effects (the Reynolds numbers were typically about $3\text{-}5{\cdot}10^4$ in the tests).

Conclusions including socio-economic relevance, strategic aspects and policy implications

The wave obliquity was one of the main parameters, which were studied in the wave basin experiments at AAU. The experiments provide unique information about the influences of this parameter where almost no research has been done before. The DELOS experiments have filled some gaps within existing knowledge providing valuable information for establishing design guidelines for low-crested structures.

Dissemination and exploitation of the results

The results including raw-data are available to the public on the Internet for download. The results are distributed to all project partners and are used in several internal reports. The most recent publication is the paper on Laboratory Experiments, which is a part of the DELOS Special Issue of Coastal Engineering.

Main literature produced

D31 Wave basin experiments (2003). Kramer, M., Zanuttigh, B., Baoxing, W., Van der Meer, J.W., Lamberti, A., and Burcharth, H.F. Internal report, DELOS deliverable D31, available from the Internet www.delos.unibo.it.
The report describes the wave basin tests in detail with respect to layout, set-up, materials, wave conditions, results and comparisons to existing data.

Scour around the round head of a submerged rubble-mound breakwater (2003). Sumer, M., Fredsøe, J., Dixen, M., Jakobsen, F. Internal report, DELOS deliverable D31, available from the Internet www.delos.unibo.it.
The report describes locations and magnitudes of scour around the roundhead of a submerged breakwater.

Laboratory experiments on low-crested breakwaters (2004). Kramer, M., Zanuttigh, B., Van der Meer, J.W., Vidal, C. and Gironella, F.X., DELOS' special issue of Coastal Engineering.
The paper gives an overview of all the experiments performed within DELOS.

Local scour and erosion around low crested coastal defence structures (2004). Sumer, M., and Zyserman, J. DELOS' special issue of Coastal Engineering.
The paper describes scour around roundheads and trunks, as well as more distant morphological effects.

Stability of Low-Crested Breakwaters in Shallow Water Short Crested Waves (2003). Kramer, M. and Burcharth, H.F. Proc. Coastal Structures 2003 Conference, Portland, Oregon, USA.
The influence of various hydrodynamic conditions (obliquity of short crested waves, wave height and wave steepness) and structural geometries (crest width and freeboard) on the stability of low-crested breakwaters are identified and quantified. Results are given in terms of recommendations for design guidelines for structure stability

Oblique wave transmission over low-crested structures (2003). Van der Meer, J.W., Wang, B., Wolters, A., Zanuttigh, B. and Kramer, M.. Proc. Coastal Structures 2003 Conference, Portland, Oregon, USA.
The paper describes the oblique wave transmission tests and proposes recommendations for prediction formulae for wave transmission in case of oblique wave attack.

Wave and current flows around low-crested structures (2003). Lamberti, A., Zanuttigh, B. and Kramer, M. Proc. Coastal Structures 2003 Conference, Portland, Oregon, USA.
The paper deals with the experiments aiming on analysing waves and current around low-crested structures. The paper focusses on describing results on overtopping.

RESULT N°9

WP 2.4 AAU

D 32 Report on wave channel experiments including experiment Data Base: Main objective of these experiments are: flow characterization and stability

Background (description of the problems to be solved)

New unique laboratory experiments on low-crested structures (LCS's) were performed within the DELOS project. The 2D experiments were carried out in three European laboratories aiming at extending and completing existing available information with respect to a wide range of engineering design properties. Small scale fixed bed tests were performed at the University of Cantabria (UCA), Santander, Spain. Large scale fixed bed tests were performed at the Polytechnic University of Catalonia (UPC), Barcelona, Spain. Experiments with moving bed were carried out at the Technical University of Denmark (ISVA), Copenhagen, Denmark.

Scientific/technological and socio-economic objectives

In order to make ideal set-ups in the laboratory with respect to each subject it was necessary to separate testing with different purposes. Tests were not performed at any specific scale, but the following scales represent an approximate scale with respect to typical full scale configurations.

Wave channel tests at UCA (small scale, about 1:10):

- 108 **2D near and far field hydrodynamic tests** were performed to describe in detail the flow inside and over the structure. Wave transmission and run-up on the beach was also monitored. 2 structural set-ups with different crest widths were tested in regular and irregular waves.

Wave channel tests at UPC (large scale, about 1:4):

- 66 **wave transmission and reflection tests** were performed to investigate the influence of crest width, structure slope, and scale effects on wave transmission and reflection coefficients for LCS's. 2 structural set-ups with different crest widths were tested in regular and irregular waves.

Wave channel tests at ISVA (small scale, about 1:10):

- Tests were performed to describe flow and scour processes in the vicinity of the trunk section using regular waves. Permeable and impermeable structures were investigated. Influence of breaking waves were examined.

Flow velocities inside and close to the surface of structures was some of the parameters studied in the small scale wave flume tests. This subject is not only interesting with respect to engineering design properties but it provides also important ecological information on living conditions for lifeforms attached to the structure surface, because the flow velocities causes exposure to the lifeforms due to drag forces.

The new wave transmission and reflection experiments were carried out to supplement previous experiments. The new tests were performed with the following objectives:

- A new structure slope was tested to improve the Iribarren number influence in formulae for reflection and transmission coefficients.
- Different crest widths were tested to determine the effect of the parameters B/h, h/L, B/L on the following subjects (B is the crest width, L is the wave length and h is the water depth):
    1) reflection and transmission coefficients (Kr, Kt),
    2) the incident/reflected phase shift,
    3) the regeneration of Kt behind the LCS.
- To analyze scale effects by comparing with DELOS tests carried out at the University of Cantabria (UCA).The new data allowed comparison of different methods for obtaining the incident and reflected wave conditions.

The scour experiments at ISVA were performed in order to develop formulae for the width of the toe protection at the trunk section.

Applied methodology, scientific achievements and main deliverables

The physical models were designed to represent real situations. Damage to the structures were avoided by covering the structures with a metallic net. The net ensured that the armour stones stayed in fixed positions during the testing.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The DELOS experiments have filled some gaps within existing knowledge providing valuable information for establishing design guidelines for low-crested structures.

Dissemination and exploitation of the results

The results including raw-data are available to the public on the Internet for download. The results are distributed to all project partners and are used in several internal reports. The most recent publication is the paper on Laboratory Experiments, which is a part of the DELOS Special Issue of Coastal Engineering.

Main literature produced

D32 Wave channel experiments (2003). Vidal, C., Gironella, X. Internal report, DELOS deliverable D32, available from the Internet www.delos.unibo.it.

The report describes the DELOS wave channel tests in detail with respect to layout, set-up, materials, wave conditions and results.

Flow and scour at the trunk section of submerged breakwaters (2003). Fredsøe, J., Sumer, M., Di Panta, A., Gislason, K., and Jakobsen, F. Internal report, DELOS deliverable D32, available from the Internet www.delos.unibo.it.

The report describes flow patterns and locations and magnitudes of scour around the trunk of a submerged breakwater.

Laboratory experiments on low-crested breakwaters (2004). Kramer, M., Zanuttigh, B., Van der Meer, J.W., Vidal, C. and Gironella, F.X., DELOS' special issue of Coastal Engineering.

The paper gives an overview of all the experiments performed within DELOS.

Local scour and erosion around low crested coastal defence structures (2004). Sumer, M., and Zyserman, J. DELOS' special issue of Coastal Engineering.

The paper describes scour around roundheads and trunks, as well as more distant morphological effects.

RESULT N°10

WP 2.2 DHI

D 37 Calibrated morphological models for beach evolution due to LCS implemented in a numerical tool kit

Background (description of the problems to be solved)

The investigation of the impact of LCS on the shoreline response at a medium- to long-term time scale, covers an important role in design practice. The sensibility of the shoreline response to the wave transmission is an important factor in the choice of the characteristics of LCSs used in coastal defence.

Scientific/technological and socio-economic objectives

One line model may be an important tool in functional design of LCS. They can investigate from a qualitative and quantitative point of view the relationships between the LCS characteristics and the impact on the shoreline.

From the socio-economic point of view, these models should provide a technical tool to assist in the design of more efficient LCS at a lower cost, while keeping their impact on coastal morphology within acceptable limits.

Applied methodology, scientific achievements and main deliverables
The one-line model (ARIES), developed by MOD and improved within the DELOS project (see result n° 4) has been applied to study shoreline evolution behind a single detached breakwater by means of parametric tests. A number of these tests aimed to compare the predicted shoreline response with the one estimated with simple design rules largely used in engineering practice.
Also the study case of Le Morge (Italy) has been simulated to test the model performance in predicting shoreline evolution in presence of multiple breakwaters. Also a procedure to obtain a description of the wave climate from directional wave recorder buoys has been proposed.

Conclusions including socio-economic relevance, strategic aspects and policy implications
It has been also shown how sensitive is the beach response to wave transmission which is the leading phenomenon for submerged breakwaters. This means that it is necessary to look critically to empirical design rules which are derived considering only wave diffraction.

The approach has been tested quite successfully to a real case of shore protection works by means of detached breakwaters together with a procedure for extracting from a wave climate a limited series of waves that can be considered equivalent to the complete time series in term of wave energy.

The application of ARIES model with such improvements permits also to evaluate the efficiency of beach protection layouts. The example of Le Morge multiple breakwaters is significative in this sense.

Dissemination and exploitation of the results
The results obtained have been published in internal reports of the DELOS project (Deliverable 37), have been presented an international conference and included in the conference proceedings as described below.

Main literature produced
Contini P., Mita M., Codispoti N., Briganti R., Franco L.(2003): Shoreline evolution in presence of detached breakwaters. Analysis by means of one-line model. Proceedings of Medcoast 03 Conference.

RESULT N°11

WP 3.2 MBA

D 35+46 Design features to maintain biodiversity of epibiota and enhance biological resources

Background (description of the problems to be solved)
Sea level rise due to climate change and increased storminess represents a serious threat to many sedimentary coastlines which have become more vulnerable to erosion and flooding. As a consequence, sea defence structures are an increasingly common feature of sedimentary coastlines throughout Europe and it is anticipated that their occurrence will increase over the next few decades. The construction of coastal defences results in the loss and fragmentation of sandy habitats that are replaced by artificial rocky habitats in essentially sedimentary ecosystems. However, there has been little research to assess the ecology of epibenthic communities colonising such coastal defences and potential implications for coastal management. This work package aimed at characterising the abundance, diversity and distribution of epibiotic communities on low crested,

coastal defence structures in relation to their engineering design and environmental setting. First, natural processes that are likely to affect epibiotic communities on LCS and are unavoidable were investigated. Secondly, the influence of engineering design features on epibiota was considered at the design stage, to inform how these factors can be modified to allow targeted management of biodiversity or natural living resources.

Scientific/technological and socio-economic objectives

The overall aim of this work package was to study the ecology of epibiotic communities on LCS in order to identify engineering design features that minimize impacts on these communities and enhance biological or socio-economic resources.

Specific objectives addressed within this work package were:

1. Characterize the diversity and abundance and distribution of epibiota on LCS and identify common features and differences with natural rocky shores communities
2. Identify natural processes that affect epibiota such as geographical variability, colonization and succession and disturbance.
3. Identify engineering design features of LCS which influence the ecology of epibiota.
4. Examine potential effects of epibiota on engineering performance of LCS, such as bioerosion.
5. Combine existing knowledge on the ecology of natural rocky shores and results from DELOS to provide guidelines to engineers and coastal managers for construction of environmentally sensitive LCS and for managing desired outcomes such as enhancing diversity and living resources.
6.

Applied methodology, scientific achievements and main deliverables

METHODS

Investigations were carried out on LCS and other coastal defences located in four different countries (UK, Denmark, Spain, Italy) throughout the three years of the project. Different tidal systems (macro-, meso- and microtidal) were therefore investigated, allowing generalisation of results obtained. Descriptive studies were used to identify general patterns and processes; an experimental approach was then adopted to test specific hypotheses on effects of LCS on epibiota. Broad scale surveys were completed in UK and Italy whilst local scale studies were carried out in Denmark and Spain as a limited number of structures were available. In these studies, the influence of a variety of environmental variables (e.g. geographical location, temporal variability and tidal range.) was investigated. Also, the effects of LCS design features (e.g. design, height, building material etc.) on diversity and abundance of epibiota were also assessed. The abundance and composition of epibiota was sampled in the intertidal, at mid-tidal level on macrotidal shores and around 0m above the chart datum on microtidal shores. Additional sampling was carried out in the subtidal in Demark and the UK. Quantitative data on composition and abundance of epibiota were collected from LCS using standard methods for sampling rocky shore benthos. On each LCS, engineering design features were recorded and also experimentally manipulated to test the effect of specific features on epibiota. A variety of statistical tools were used, encompassing univariate, bivariate and multivariate analyses.

MAIN SCIENTIFIC RESULTS

1. Characterisation of epibiotic communities

In both microtidal and macrotidal systems, epibiota on LCS shares the same functional groups as on natural rocky shores such as ephemeral green algae, canopy forming fucoids, mussels and barnacles and gastropods. Epibiota on LCS is, however, characterised by fewer species than natural rocky shores. The most common species in a particular region were present on both breakwaters and natural shores and differences were mainly caused by the absence of rarer taxa on LCS. Several interacting factors might explain these differences, the lack of propagule sources nearby the LCS for species typical of hard substrata, the relatively recent age of LCS in respect of natural rocky shores, the higher disturbance by sand scours and maintenance works experienced by LCS and the lower surface and habitat complexity in comparison to rocky shores.

2. Natural processes affecting diversity, abundance and dynamics of epibiotic communities

As on natural rocky shores, LCS are strongly influenced by both physical factors, such as wave exposure and vertical gradients, and biological interactions, such as competition, grazing and predation. Epibiotic communities are also affected by natural processes such as, disturbance and recruitment fluctuations. All these influence in turn colonisation and succession processes and lead to natural variability of epibiotic communities at different spatial and temporal scales, for which control through engineering intervention is minimal.

2.1 Spatial variability - Comparisons of epibiota between countries indicated that the same functional groups of algae, filter feeders and grazers, were present on LCS throughout Europe. The relative proportions of these groups and of species within group, however, differed between countries. The relative abundance of functional groups and species composition varied also at regional level, within country. Geographical and regional variation in epibiotic communities are determined by various factors including differences in the species pool, larval supply, tidal range, wave and current regimes.

2.2 Wave exposure - Clear differences in the abundance and composition assemblages of epibiota were apparent between the landward and the seaward side of structures at all locations investigated. In general, suspension feeders (mussels, barnacles) dominated the exposed seaward side, whilst algae were more abundant on the more sheltered landward side. These differences were more evident within each functional group. The distribution of species on landward and seaward sides reflects that observed on natural exposed and sheltered shores respectively. This pattern is determined by a combination of wave exposure and biological interactions such as grazing.

2.3 Vertical gradients - As on natural rocky habitats, results showed that the abundance and diversity of epibiota on LCS varies with tidal elevation (on macrotidal coasts) or depth (on microtidal coast). On macrotidal shores LCS located lower on the shore the total number of species increases significantly and assemblages are therefore more diverse. This is because lower on the shore environmental stresses are reduced and conditions are sutibale to a larger number of species. On meso- and microtidal shores diversity increase with depth, with the number of species being already three times higher at –0.5m and further increasing at –2m. The higher diversity at increasing depths is probably related to less physically disturbed conditions than in the wave-swept zone (0m).

2.4 Temporal variability - Similarly to natural rocky shores, epibiotic communities also vary considerably over time. Results showed that colonisation and succession of epibiota on a new LCS follow similar trajectories to those on occurring on rocky shores. In the UK, LCS will develop a mature epibiotic community after 3 to 5 years from construction. The composition and abundance of epibiotic communities is also influenced by short-term fluctuations (within a season), seasonal changes (within a year) and long-term changes (between years and decades). These communities are therefore highly dynamic, nevertheless some temporal changes can be predicted with a certain level confidence.

2.5 Disturbance - Disturbance on LCS is generally higher than on natural rocky shores, as they are surrounded by sand which causes abrasion and scouring on the epibiota colonising the blocks, particularly at the sediment / LCS interface, particularly in the first 30-50cm zone above the sediment. Also, sediment level varies with time causing burial of organisms previously exposed. On LCS, disturbance can further increase due engineering maintenance works consisting of the addition of new blocks to the structure to compensate for storm damage or sinking. For mature biological communities to develop structures need to be stable and built in such a way that maintenance can be performed less frequently.

3. Design features influencing diversity and abundance of epibiota that can be modified through engineering intervention

Most of the above environmental factors and processes are pre-determined and cannot be modified through engineering intervention. Result from studies and experiments showed, however, the

introduction/modification of selected design features can minimise negative effects such as disturbance or achieve target effects such as enhancing species diversity.
3.1 Reducing disturbance - The design of LCS can significantly reduce physical disturbance. The construction of berms around the LCS can for example reduce scouring and abrasion of epibiota by sand. Also, more stable LCS will need less frequent maintenance work thus normal successional processes can occur on epibiota colonising the structures, resulting in more abundant and diverse assemblages.
3.2 Increasing surface and habitat complexity - Most LCS consist of very homogeneous, smooth building blocks, which lack therefore of any complex surface. Results showed that diversity can be significantly increased by enhancing surface and habitat complexity. At a scale of <1cm, species such as barnacles and small periwinkles settle preferentially in small crevices than on adjacent smooth areas. At a scale of < 10cm, the presence of small pits or holes on the blocks, significantly increases the number of species, particularly juveniles. In general crevices, small fractures as well as pits and holes can retain water during emersion time at low tide and so considerably reduce desiccation stresses experienced by organisms. These features of the surface also provide refuges from predation and shelter from wave action. At larger spatial scale (10-100cm) the presences of rock pools further increase habitat complexity and as a consequence species diversity. Many organisms living in the pools such as hydroids, ascidians, sponges are very sensitive to desiccation therefore could not survive on blocks during low tide. Water stands in rock pools during low tide, creating suitable conditions for a wider number of species. The rock type used as building material for LCS can also indirectly affect the epibiota primarily through their surface complexity, which depends on their intrinsic physical and chemical properties. For example, carbonate rocks are more easily weathered than igneous rocks, showing after few years of exposure to the sea very rough surfaces, with crevices, pits and deep fractures.
3.3 Increasing species diversity - Species diversity is enhanced by reducing disturbance and increasing surface and habitat complexity. On macrotidal systems, diversity can be further increased by locating structures lower on the shore, so that a larger portion of LCS can be colonized by lower shore species.
3.4 Reducing length of structure - The marked differences in the composition and abundance of epibiota between landward and seaward can be minimised by shortening the structures and reducing the crest height. In this way more frequent overtopping and currents surroundings currents will make the landward will have a more similar to the exposed, seaward side.

4. Influence of epibiota on performance of LCS

Epibiotic assemblages can, on the other hand, influence the performance of coastal defence structures. A descriptive study showed that porosity can be considerably reduced by marine growth. For example, LCS located in sites of high mussel recruitment pore size can decrease up to a maximum of 80%. The presence of sediment trapping species such as mussels (*Mytilus* spp.) and tube forming worms (*Sabellaria* pp.) can further reduced porosity, although they also stabilize the structure. Mussels could have also a filtering effect on the surrounding waters, as already suggested by the use of these bivalves to depurate docks.

CONTRIBUTIONS TO DELIVERABLES

This result contributed to the following deliverable (in bold are the main Deliverables produced):
D2, D3, D4, D9, D13, D26, **D35,** D36, D38, **D46**, D53, D54, D55, D57, D58, D59, D60.

Conclusions including socio-economic relevance, strategic aspects and policy implications

LCS provide new hard substrate available for colonisation by algae and benthic organisms typical of natural rocky shores. As on natural rocky shores, epibiota on LCS are subject to natural processes such as colonisation and succession and disturbance and is controlled by physical (wave exposure, vertical gradients) and biological (grazing, competition) factors. These similarities of LCS to rocky shores means that we can use our extensive knowledge on this natural system along with results from DELOS to better understand and predict effects on epibiota. LCS, however, differ from rocky shores in three major aspects: they have a limited horizontal and vertical extent, they are characterised by a lower surface and habitat complexity and finally they experience a higher disturbance. As a result, the epibiotic assemblages on LCS are much impoverished in species, and diversity is generally lower (D35). There are natural processes affecting epibiota on LCS that are pre-determined and cannot be modified. These include: 1) at large scale, geographical and regional variability in epibiotic assemblages (D35); 2) at local scale, wave exposure and biological interactions (D35); 3) vertical gradients according to tidal height, depth (D46); 4) temporal variability of epibiota (D35, D46); 5) Disturbance caused by sand scouring and siltation. These factors, although outside the control of engineers, need to be taken into consideration for the construction of LCS as they will have a certain effect on the development of epibiota. However, selected target effects on epibiota, can be achieved through engineering intervention. LCS design features can be modified to manage desired outcomes, for example to minimise disturbance or enhance biodiversity as previously described. For example, if increasing diversity is considered a desired outcome, then more complex surfaces and artificial rock pools should be integrated in the design of LCS.

In conclusion, the structure and dynamics of epibiotic assemblages are affected to a different extent by environmental factors and LCS design features. The environmental setting has an important influence on the colonisation and future development of epibiota, thus it needs to be taken into account by coastal engineers prior construction of LCS. In contrast, LCS design features are under the control of engineers and can be modified to mitigate impacts and promote positive effects on recreational use and natural resources (see WP3.3, D15 and D16). For example, the structural design could be modified to create habitats and relative assemblages more similar to those of natural rocky shores, thus increasing the recreational value of LCS. Under the ecological viewpoint, low crested structures and other types of coastal defences lead, as most human interventions, to major modifications in the coastal ecosystem and their construction should be limited to the minimum. However, where these structures are a necessary measure against coastal erosion, attempts should be made to promote their integration in the coastal system, minimising ecological impacts and enhancing the socio-economical value, following the requirements of the new European Water Framework Directive.

Dissemination and exploitation of the results

Dissemination of results was achieved through active participation of all Partners involved in this work package to project meetings and workshops, where end users were often present. Results were also disseminated at national and international scientific conferences, often characterised by a multidisciplinary audience. Seminars were also given to wider public, involving coastal managers, representatives of conservation agencies and other stake holders. DELOS project leaflets were distributed and sent to local councils and authorities responsible for coastal management plans and flood defence. Some results have already been published in peer- reviewed international journals and in Conference proceedings and several publication are submitted or in preparation.

Main literature produced

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RESULT N°12

WP 3.2 MBA

D 38 Identification of design features to minimize bioerosion of LCS

Background (description of the problems to be solved)

Bioerosion is a well known phenomena observed on carbonate-based substrata such as limestone and coral reefs. The boring mechanisms and consequent dissolution of carbonate material is not well known, although it seems to be a combination of mechanical action and secretion of acid substances. A large variety of species can bioerode the substratum, including microroganisms, algae, marine invertebrates and fish. These species can abrade, scrape and bore the rock using mechanical action (e.g. with teeth) and chemical (e.g.secretion of acid substances). The intensity of bioerosion varies with latitude; in tropical waters bioerosion causes serious problems for the conservation of coral reefs. Bioerosion caused by microroganisms can be relatively important on rocky shores. Some microorganisms including various kinds of bacteria, fungi, algae and protozoa can promote rock erosion by boring the surface and speeding rock weathering by mobilising mineral constituents with inorganic or organic acids or ligands that they excrete. Macroborers are very common in tropical waters and include sponges, poychaete, sipunculids, and bivalves. The abundance and distribution of these species is regulated by physical factors such as wave exposure, tidal level, geographical location and sedimentation. Macroboring organisms have an important impact not only on degradation and destruction of carbonate rocks but also increase the fine sediment production. Biological factors such as grazing can, however influence the composition of boring communities and also the erosion rates. Macroerosion has been observed also along the Mediterranean coasts.

Bioerosion on artificial reefs has been little investigated. Most of studies focussed on erosion of marine wooden structures. The main group of wood borers is represented by shipworms. Their capacity to bore into wood results in dramatic economic losses due to damages to wooden structures in both marine and estuarine systems worldwide. Several species of Crustaceans are also responsible for damages to pilings and jetties. No literature is available on bioerosion effects on rocky artificial structures. The potential effects of bioerosion were therefore investigated during the broad scale survey on LCS and coastal defence structures during year 1 and 2 in the UK and Italy and, a local scale, in the Gulf of La Spezia.

Scientific/technological and socio-economic objectives

The aim of this study was to investigate for the first time the potential effects of bioerosion on LCS. In particular, the objectives were:

1) To record the type of species boring into the rocks
2) To quantify the abundance and distribution of macroborers
3) To assess the potential damages to the structures.

Applied methodology, scientific achievements and main deliverables

1) Broad scale surveys:

Methodology - In the UK during the broad scale survey carried out in year 2001 and 2002 more than 80 coastal defence structures were sampled. Twenty-six structures were made of granite, five consisted of a mixture of concrete units and limestone blocks and the rest were made of limestone blocks only (see D35 and D46 for details). The presence of boring species was annotated. Each structure was screened for any sign of bioerosion, represented by bore holes, rasp and grazing marks. When present, these were quantified as percentage cover using a 25x25cm quadrat. The size (diameter, depth) of bore holes was also recorded. Similar monitoring was performed by FF during the broad scale survey on LCS along the Adriatic coast.

Scientific results - No sign of bioerosion was detected in any structure surveyed. Some small bore holes were observed only on two series of rock groynes in Cristchurch, and Poole Bay, South of England. On these groynes the limestone blocks showed very small holes (<0.5 cm diameter, <0.3

cm depth) on the seaward face at mid intertidal level. These holes, although relatively dense (approximately 0.5/cm^2), are completely irrelevant in terms of stability of the groynes. Considerable erosion due to weathering was observed on the limestone blocks, especially those on the exposed side of the groynes. This can be due to the type soft limestone used for the construction. No relevant weathering was observed on the other coastal defences made of limestone. Similarly granite and concrete structure did not show any sign of physical or biological erosion.
A similar result was obtained during the broad scale survey carried out by FF along the Adriatic coast in Italy (see D35 and D46). Relevant bioerosion was not detected in any structure surveyed.

2) Descriptive study on the off-shore breakwater in the Gulf of La Spezia, Thyrrhenic Sea, Italy.

Methodology - In summer 2003, a qualitative study was carried out by the MBA on the off-shore breakwater in the Gulf of La Spezia, Italy. This breakwater was chosen because seriously affected by bioerosion. The breakwater was initially built in 900' and is approximately 2km long. It consists of large limestone blocks, approximately between 2 and 3m in diameter. A quantitative sampling of the rocks eroded by macroborers in the subtidal was not allowed for safety and technical reasons, as professional divers are required. However, a semi-quantitative assessment of the extent of bioerosion was carried out on the blocks lying on the top of the breakwater. These were old blocks that were removed from the submersed part of structures and re-allocated on the top. Bioerosion was therefore indirectly estimated by counting and measuring the holes left by the dead boring organisms. Ten blocks were inspected and for each rock 5 quadrat 25x25cm were placed randomly on the surface. The percentage cover of the holes of bivalve (large holes), polychaetes (medium holes) and crustaceans (small holes) was recorded. Also the amount of rock destroyed by macroborers was estimated on selected holes. For each type of holes ten areas were sampled and in each area the volume of 5 holes was estimated. Two methods were used. The first method used the measures of diameter and depth of holes to calculate the volume. Alternatively the volume was estimated by filling the holes with water and then calculating the relative volume of water. In some case however, this second method was not reliable as the holes were communicating.

Scientific results - In the subtidal, rocks are colonised by various macroborers including bivalves, polychaetes and crustaceans. These organisms secrete acidic substances to create holes of different diameters and depths. The holes are used to host the organisms, mainly as a protection and for feeding. Macroborers start excavating holes in the rock at the early stages of the life cycle. As a consequence, hole created by the same species can vary greatly in size. Bore holes made by bivalves were the most abundant on the rock surface. The percentage cover of small and medium holes was much lower. However large variability in the distribution and abundance of bore holes was observed between and within blocks. The amount of rock destroyed in large holes is quite important, whilst the in the medium and small size holes is irrelevant. In rocks densely colonised by these macroborers the erosion effect could be important leading to potential problems for the stability of the structures. In the case of the breakwater in La Spezia, however, this risk is quite low due to the very large size of the building blocks.

Main deliverables:
This result contributed to the following deliverables (in bold the main deliverables):
D2, D4, D9, D13, D26, D35, D36, **D38**, D46, D53, D54, D55, D57, D59, D60.

<u>Conclusions including socio-economic relevance, strategic aspects and policy implications</u>
Bioerosion is the erosion of hard substrata such as wood or rock by marine organisms. These are able to penetrate the substratum making holes by means of mechanical and chemical processes. Bioerosion in the sea occurs worldwide and can have detrimental consequences on natural ecosystems such as coral reefs but also endanger the stability of marine wooden structures. LCS

however appear not to be particularly affected by bioerosion in Europe. This is because most of the structures are built in granite, concrete, i.e. a type of rock which cannot be penetrated by boring organisms. Only structures made of carbonate rocks such as limestone are liable to erosion by borers. In addition, in temperate waters the presence of boring species seems limited only to certain geographical locations. No bioerosion was observed on several LCS and other coastal defence structures in the UK and Italy (Adriatic coast), although presence of various boring organisms (mainly date mussels) was recorded on LCS consisting of limestone blocks in the Gulf of La Spezia. However, also in this case of the effect of bioerosion on stability was negligible, as holes made by bivalves were limited to the surface layer and not deeper than 10 cm. This result shows that bioerosion can be easily avoided by using granite and concrete instead of limestone rock as material for construction of LCS. The deployment of large building blocks would however overcome any potential problems caused by bioerosion in carbonate rocks. Despite bioerosion has a minimal effect on stability of LCS, diversity of epibiota colonising the structures can be positively enhanced, especially if softer carbonate rocks are used as building material. Bioerosion and weathering increase the surface complexity of these rocks by creating crevices, pits and holes which provide more suitable habitats for a higher number of species.

Dissemination and exploitation of the results

Dissemination of results was done through project meetings and workshops, where end users were often present, in particular coastal managers working in local authorities. Results were also disseminated at international scientific conferences. These results were also included in seminars were also given to wider public, involving coastal managers, representatives of conservation agencies and other stakeholders. These results were included in peer- reviewed international journals that are in preparation.

Main literature produced

Moschella P.S. 2002. Ecological effects of coastal defence structures in UK. Science for Water Policy (SWAP). The implications of the Water Framework Directive. Norwich, 2-4 September 2002. Oral presentation and Proceedings.

Moschella P., Abbiati M., Åberg P., Airoldi L., Anderson J.M., Bulleri F., Dinesen G.E., Gacia E., Granhag L., Jonsson P., Satta M.P., Sundelöf A., Thompson R.C., Hawkins S.J. 2004. Low crested structures as artificial habitats for marine life: what grows where and why? Coastal Engineering. In prep.

RESULT N°13

WP 3.4 FF

D 39+40 Established contribution of breakwaters to regional biodiversity

Background (description of the problems to be solved)

As a response to the growing need to defend the coast, hard-substrate defence structures have become common features of coastal landscapes in intertidal and shallow subtidal environments. The primary purposes of defence structures are to prevent or reduce erosion and flooding of high value coastlines, to stabilize and retain beaches and reclaimed land and to increase the amenity value of the coast (e.g. beach use). In Europe, defence structures of different materials (e.g. wood, concrete, stone) have proliferated and in some regions, such as the Italian coasts of the Adriatic sea, they cover over half of the natural shoreline, resulting in dramatic changes to coastal landscapes and environments. Surprisingly little attention has been given to the ecological implications of hard coastal defence. Where no natural hard-substrata exist, man-made structures may act as corridors connecting naturally isolated rocky reefs, thus promoting the expansion of a number of non indigenous species. Evaluating the broad scale alterations, perceived as either positive or negative, that can result as a consequence of the proliferation of structures over large stretches of coasts is crucial to the design and management of LCSs.

Scientific/technological and socio-economic objectives

One of the major aims of WP. 3.4 was to assess the large-scale effects of LCSs spatial arrangement (i.e. relative proximity to natural reefs and other artificial structures) on the distribution and population dynamics of epibiota and fishes. Specific goals included:

a) establish relationships between the arrangement of LCSs and the abundance of epibiota

b) assess “corridor” effects on propagule dispersal and mobility of fishes

c) establish the contribution of LCSs to regional biodiversity, to persistence of rare or endangered species and to the spread of non-indigenous species.

The quality, size and spatial arrangement of habitats are major determinants of the diversity and abundance of species present in biological communities. These factors have received wide attention in the management of terrestrial systems for predicting the consequences of the development of urban structures, whereas less attention has been devoted to the quality of habitats in coastal marine areas. This is especially true for structures used for coastal protection. For this reason, WP 3.4. is expected to have particularly relevant outcomes, as knowledge of large-scale effects of LCSs spatial arrangement enables informed decision on the design, deployment and management of LCSs.

Applied methodology, scientific achievements and main deliverables

Large-scale effects of breakwater spatial arrangement were investigated using the Italian coast of the North Adriatic Sea as the main model area, where naturally distant rocky reefs (about 70 to 400 km apart) are separated by large stretches of sandy coast defended by LCSs. The limpet *P. caerulea* was chosen as a model species for the following reasons (see Deliverable D3-Identification of model species for WP3.4): 1) it has a limited dispersal, 2) it has an uneven distribution across structures, and 3) it plays an important ecological role in influencing the distribution of species that are a nuisance to beach tourism, such as ephemeral green algae. Additional experiments were done on the invasive green alga *Codium fragile* ssp. *tomentosoides*. Experiments on the fish *Trypterigion delaisi xanthosoma* were also done in Spain.

The large-scale effects of breakwater spatial arrangement were analysed using 4 integrated approaches: 1) the analysis of variations in abundance (density, percentage cover) of resident benthic macro-algae and invertebrates. Patterns of species distribution were monitored by FF on LCSs located over about 400km of coast by using a hierarchical sampling design that covered a range of spatial scales; 2) the analysis of the population dynamics and demography of the model species *Patella caerulea*, which provided major input to the metapopulation model developed within WP3.5. Demographic variables (size distribution, recruitment, growth rate, mortality and fecundity) necessary to predict dispersal between natural and artificial structures and the risk of local extinction were estimated by following the fate of adult individual limpets and counts of recruits on the structures. A total of 12274 limpets were sampled during the experiments. Experimental set-up, field work and data analysis were mainly carried out by FF, while UGOT and MBA contributed ideas, background knowledge, field work and participated in a discussion of the results; 3) the analysis of the genetic structure of the limpet *P. caerulea* by FF. Biochemical and molecular genetic markers have been developed and used to assess levels of gene flow between populations of *P. caeurulea* on natural reefs and defence structures at different spatial scales, ranging from meters to 100s km. Gene flow among populations was quantified by using a hierarchical sampling design. Additional genetic analyses were carried out for the fish *Trypterigion delais*i by CSIC; and 4) the analysis of the applicability of the usage of assemblages of dead shells as a rapid, cost-effective tools for monitoring the large-scale impact of defence structures on coastal assemblages by FF.

Results showed that, although defence structures become colonised by rocky-bottom species, their assemblages seem to differ from those occurring on nearby natural reefs. Furthermore, artificial structures seem to change the patterns of distribution of locally abundant species and to favour the spread of non-indigenous species. The resulting changes in species composition, abundance and diversity can have important consequences for the functioning of coastal ecosystems, modifying fundamental processes such as productivity, detritus pathways and nutrient cycling. Overall, the spatial arrangement (i.e. location, relative proximity to natural reefs and other artificial structures) of coastal defence structures is of great importance in influencing the type of hard-bottom species that will colonise any novel structure. In particular, the persistence of populations in a network of habitat islands, such as those created by schemes of numerous defence structures, is dependent on the habitat area, quality, spatial distribution of habitats and on the dispersal characteristics of the organisms of interest.

Using biochemical markers no significant differences were found between samples of *Patella caerulea* collected on natural and artificial substrates or between samples from different sites. Based on microsatellite loci analysis, the genetic pattern of *Patella caerulea* samples resulted to be similar. Low values of Nei's genetic distances between populations were found and the observed pattern reflected geographical distances among collections. The obtained results suggest that populations of *P. caerulea* over the investigated geographic range belong to a single breeding unit. Populations of *Trypterigion delaisi* were analysed at different spatial scales. Large genetic differentiation, increasing with the geographical distance, was found. No significant genetic differentiation was detected at the small spatial scale suggesting that restricted adult dispersal and larval retention alone would not be enough, as previously thought, to promote genetic differentiation at the studied scale. These results suggest that *T. delaisi* populations living on LCS are originated by nearby natural reefs, while other LCS located far from areas inhabited by this species are not easily colonised.

No deviations have occurred with respect to the original work plan in terms of inputs to design guidelines and deliverables. Because of the particularly interesting results from the WP 3.4, and because of the importance that long term data sets have on the quality of ecological studies, the analysis of the dynamics and population genetic structure of the model species *Patella caerulea*, and experiments on the second model species *Codium fragile* have been carried on until the end of the project. Results have been used as main input to WP. 3.5. to develop a model to predict the effects of habitat area and quality, the spatial distribution of habitats, and the dispersal characteristics of the organisms on the persistence of populations in a network of habitat islands, as those created by schemes of numerous defence structures.

The work produced 3 deliverables:

D29: Established relationships between breakwater spatial arrangement and the large-scale distribution of epibiota and fishes.

D39: Established contribution of breakwaters to regional biodiversity

D40: Assessment of positive and/or negative "corridor" effects of breakwaters on dispersal of species with different life-histories

<u>Conclusions including socio-economic relevance, strategic aspects and policy implications</u>

The mains conclusions from this work can be synthesised as follows:

1) Environmental processes in the coastal zone operate on various spatial scales. Most LCS schemes are implemented at the local scale and have localised impacts. However, in some areas, such as the Italian coast of the North Adriatic sea, structures have proliferated along entire coastlines. This can result in broad scale alteration of the whole coastline. Thus, local environmental impacts can scale up in a non-linear manner. Both local and broad scales need to be considered in the decision-making process. Sound *eco*-regional strategic planning for coastal cells has been suggested as essential prerequisite to mitigate impacts of LCSs.

2) Major alterations resulting from the introduction of coastal defence structures over large stretches of coast include the increased availability of hard-bottom and sheltered habitats in areas where they do not occur naturally. Indeed, artificial structures, by providing suitable habitat islands for the colonisation of species, function as stepping stones, allowing the dispersal of hard bottom

species beyond the limits set by the availability of suitable natural habitats. The increased number of hard bottom habitat may act as refuges for rare or endangered species, or enhance species that are relevant to commercial or recreational purposes. There is a risk, however, that the artificial structures may promote the expansion of introduced species, or of species that are a nuisance to beach tourism. For example, along the coasts of Emilia Romagna, the introduced species *Codium* has taken advantage of the availability of hard substrata along an exposed sandy coast, and in particular of sheltered habitats that seem to provide better conditions for its growth.

3) Although assemblages on artificial reefs cannot be referred to as "natural", a comprehensive understanding of the biotic interactions between "native" and exotic species is necessary for their management and should be included as background information necessary to the design procedure. This knowledge could improve our ability to limit the successful dispersal (colonisation and persistence) of marine pests across regional and geographic scales.

Dissemination and exploitation of the results

Results were presented to all project partners during DELOS workshops and meeting, and were used in several internal reports. Results are also available to the public on the Internet. Results were included in the extensive Guidelines produced within DELOS. Conclusions were also made available to a broad scientific audience through the publication of scientific papers in high-profile journals and dissemination of results at conferences, seminars and master courses. Further dissemination is forecasted over the next 2 years through the publication of scientific papers in high-profile journals.

Main literature produced

Bacchiocchi, F. and Airoldi, L., 2003. Distribution and dynamics of epibiota on coastal defence works hard-bottom structures for coastal protection. Est. Coast. Shelf. Sci., 56: 1157-1166.

Bulleri F., M. Abbiati, L. Airoldi, 2004 - The colonisation of human-made structures by the invasive alga *Codium fragile* ssp. *tomentosoides* in the north Adriatic Sea (NE Mediterranean). Hydrobiologia, submitted

Moschella P S, Abbiati M, Åberg P, Airoldi L, Bacchiocchi F, Bucchieri F, Dinesen G E, Frost M, Gacia E, Granhag L, Jonsson P R, Satta M P, Sundelöf A, Thompson R C, Hawkins S J. Low crested structures as artificial habitats for marine life: what lives where and why? Submitted to Coastal Engineering

Airoldi L, Abbiati M, Hawkins S J, Jonsson P R, Martin D, Moschella P S, Sundelöf A, Thompson R C, Åberg P. An ecological perspective on the deployment and design of low- crested and other hard coastal defence structures. Submitted to Coastal EngineeringRESULT N°14

WP 2.1 UCA

D 41 Calibrated 3D near field flow: final model

Background (description of the problems to be solved)

Over the past several years significant efforts have devoted at DHI to develop advanced computational fluid dynamics (CFD) tools. The development has been centred around a so-called three-dimensional Navier-Stokes solver, NS3. The model has been developed with the aim of making it applicable to the analysis and investigation of as many flow and sediment transport problems as possible. Thus, the model includes a description of the instantaneous free surface in order to make it applicable to e.g. simulation of breaking waves in the surf zone. Since a reliable and ample description of the three dimensional flow around low-crested structures is nowadays only possible using physical models or field data, in the frame of DELOS the intention has been to apply NS3 to the simulation of flow over and around LCS. The term flow referring both to wave motion (e.g. wave breaking and overtopping) and to the wave-induced currents and over and around the structure. In order to simulate the vertical structure of the flow adequately, the NS3 model has to include a suitable description of the spatial and temporal structure of the turbulence under breaking and broken waves.

Scientific/technological and socio-economic objectives

The main scientific/technological objective has been to analyse the capability of the NS3 model to simulate the near-field flow around impermeable low-crested structures, especially three dimensional processes such as wave breaking under oblique incident waves or wave propagation around the head to the LCS.

Applied methodology, scientific achievements and main deliverables

The Navier Stokes solver solves the instantaneous Navier-Stokes equations in three dimensions using a finite-volume approach on a multi-block grid. The spatial discretisation is based on the finite-volume approach on a multi-block grid. The time integration of the Navier-Stokes equations is performed by application of the fractional step method.

The free surface is resolved using a Volume-of-Fluid (VOF) description. The present method is described in Hirt and Nichols (1981), however, with an improved scheme for the advection of the conservative quantity F, cf. Ubbink (1997). The grid is fixed, while the conservative quantity F moves with the fluid. F is assigned a value of 1 within the fluid domain and 0 in the void domain (the effect of air is not included). F = 0.5 determines the position of the surface. At the surface, setting the pressure equal to the atmospheric pressure fulfils the dynamic boundary condition. The kinematic boundary condition is included by extrapolation of the velocities within the fluid domain to the surface.

The waves are generated at an inlet boundary where Stokes waves up to 5th order, cnoidal waves up to 5^{th} order or to use a stream function waves can be specified. At the beach, the remaining wave energy is absorbed by means of a sponge layer.

The 3D Navier-Stokes solver includes several turbulence models: RANS (Reynolds Averaged Navier-Stokes equations) models such as k-ε, k-ω or LES models (Large-Eddy Simulation) with a Smagorinsky sub-grid scale model or a k-equation for the sub-grid scale turbulence. The general two-equation turbulence models lead to a instability in the models that results in modelling of very high an unrealistic turbulence levels. This mechanism is described for breaking waves in Mayer and Madsen (2000). The instability is related to production under the wave top, where the strain rate is strongest. In fully developed turbulent flows, the production is almost counteracted by a turbulent dissipation. However, this is not the case outside the breaking zone in the wave top, and this has been shown to lead to instability where the turbulent levels continue to grow. Further, the effect of entrained air might reduce the amount of turbulence penetrating from the roller to the water beneath it as discussed in Christensen et al (2002). Generally, it is very difficult to set up a general model for turbulence in breaking waves. Therefore the approach in the study of submerged breakwaters has been to use a rather simple approach in order to reduce the computational time and complexity. Further, the study of overtopping is only influenced of the turbulence to a minor degree. At this stage the model does note porous flow.

The model application for LCS has been validated with a limited set of cases provided by the DELOS experimental work carried out in the Aalborg wave basin, since the model is computationally expensive. Comparisons between numerical and free surface records show a very reasonable agreement especially in front and above the structure.

Conclusions including socio-economic relevance, strategic aspects and policy implications

Even if the model is still under development and not ready for standard engineering applications, results have shown that the potential applications of the model to analyse the three-dimensional flow around the structure are very high. In a few years, considering the increasing computer power capabilities, this kind of model will be a unique tool for LCS design. It is extremely relevant to consider that the number of physical model tests to be carried out will be considerably reduced. Furthermore, most of the limitations due to physical models will be overcome.

Dissemination and exploitation of the results

The model has been presented in several conferences such as Coastal Structures 2004, as well as in the end-users conference held in Rome. Furthermore, the model capabilities and results have been presented in other conferences mainly for surf zone applications.

Main literature produced

D17: Calibrated 3-D Near-field preliminary model

D41: Calibrated 3-D Near-field final model

Losada, I.J., Lara, J.L., E.D. Christensen and Garcia, N. (2004), Breaking process, velocities and turbulence intensity around low-crested structures. Coastal Engineering, ELSEVIER, DELOS Special Issue, submitted.

RESULT N°15

WP 2.1 UCA

D 42 Calibrated 2DH far field wave flow: final model

Background (description of the problems to be solved)

The design of structures to be built in the nearshore region generally involves the evaluation of different possible layouts, under the effects of local wave and current conditions, with the aim of minimizing costs and maximizing the desired results. In particular the design of low-crested structures involves optimisation of several parameters, which influence both the position and the shape of the structures.

The possible layout of the structures to be designed can be tested experimentally in wave tanks and wave flumes using adequate scale models. An alternative and attractive procedure is to employ suitable numerical and mathematical models. In principle, a very advanced numerical model, able to correctly simulate all the nearshore phenomena (turbulence, waves, currents, sediment transport, etc.) could be equivalent or even superior to a physical model. In practice, the numerical models currently employed in engineering activities, use several assumptions and simplifications: the phenomena that can be simulated strictly depend on the governing equations solved by the model.

Scientific/technological and socio-economic objectives

The objectives have been to improve our modelling capabilities of the hydrodynamics in nearshore areas including the presence of LCS. The two dimensional models are suppose to give a reliable prediction of wave and currents in areas adjacent to the LCS and to provide an improved description of the surf and swash zones. This hydrodynamic modelling should be extremely relevant for the analysis of the morphodynamics around LCS schemes.

Applied methodology, scientific achievements and main deliverables

The results of this work are mainly due to contributions form the Universities of Rome and Thessalonika. The work carried out in Thessalonika has been mostly the development of a a 2DH-Boussinesq-type model combined with a depth-averaged Darcy-Forchheimer equation for simulating wave propagation over submerged porous breakwaters. The model was tested against experimental measurements for the case of a rubble mound trapezoidal breakwater on a sloping beach. Both regular and irregular wave cases were used in order to assess model performance.

Initially, model results were evaluated using data collected during the experiments that took place in the wave and current flume of the Coastal Laboratory of the University of Cantabria (UCA), Spain as part of the research carried out for the project. Several data sets corresponding to different regular and irregular wave conditions were used for model verification. Further evaluation of the model results was performed with the use of the experiments that were carried out in the wave flume of the Maritime Engineering Laboratory of UPC, Spain. These experiments in comparison to the UCA experiments provide a helpful tool in order to assess scale effects.

Further, tests of the present model against the 3D hydrodynamic experiments carried out at the 9.7 x 12.5 basin of Aalborg University, Denmark were performed. Two different layouts were considered during these experimental tests. The first one was a symmetrical layout, composed by two detached porous breakwaters forming a rip channel in the middle. The second layout consisted of a single breakwater inclined at 30^0 with respect to the beach

The comparisons indicate that the model simulates quite well wave evolution at the regions before and over the breakwater. Behind the breakwater the decomposition of the leading wave component into higher frequency waves, comparatively to the preliminary version of the model, is predicted with higher accuracy due to the additional higher-order terms. A deficiency of the model affecting the results is that the linear dispersion relationship is not accurate, although improved. Model performance is also influenced by the fact that the wave energy dissipation rate due to porous resistance and wave breaking is not exactly predicted. Present model behaviour is enhanced, compared with the behaviour of weakly non-linear Boussinesq-type models applied in the simulation of wave evolution over impermeable and permeable submerged bars.

The work carried out by the University of Rome has been mostly devoted to the enhancement of 2DH models based on the extended Boussinesq equations in order to analyse consider improved applications in the surf and swash zones nearby LCS.

Among the most relevant achievements are: a new shoreline boundary conditions for use in wave-resolving Boussinesq-type model; a new method for incorporating the swash zone into wave-averaged circulation models and a new method for simulating wave breaking effects into Boussinesq-type models.

The technique developed for the new shoreline boundary conditions allows imposition of the appropriate value of water depth and velocity at the shoreward limit of the computational domain. Validation of the method against analytical solutions suggests good performance of the new boundary conditions.

The new method for incorporating the swash zone into wave-averaged circulation models is based on an integral model. The technique has been validated against both numerical solution of the nonlinear shallow water equations and available experimental data.

The new method for simulating wave breaking has been implemented in a numerical solver and tested with success. Comparison with available experimental data suggests very good performances of the new method.

In order to improve wave breaking simulation, a new criterion for determining weather waves are breaking or not (breaking criterion) is being developed.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The great advantage of numerical and mathematical models is that their application is usually much less expensive than physical ones: it is certainly more economic to modify computer files describing the bathymetry of the area under investigation than to rebuild a physical model layout. Therefore, a first economic implication is that the development of this kind of modelling may result in a lower a more reliable design costs for LCS. From the strategic point of view, the use of this kind of modelling should be considered as part of any guidelines for the design of LCS schemes.

Dissemination and exploitation of the results

The work carried out on 2DH modelling has been disseminated in several publications, the project deliverables as well as in important international conferences such as the Int. Conf. On Hydroscience and Engineering-2002- Poland, the ICCE, 2002, the National Conference on Coastal

Zone management 2002 in Greece or the ICCE 2004 conference to be held in Lisbon in September 2004.

Main literature produced

D42: 2DH Final Boussinesq-type model

H. Johnson DHI; Th. Karambas, J. Avgeris AUTh; B. Zanuttigh UB; I. Caceres UPC; G. Bellotti, M. Brocchini (2004) Modelling of wave and currents around submerged breakwaters. Coastal Engineering (ELSEVIER), DELOS special issue, submitted

RESULT N°16

WP 2.3 UCA

D 43 STRUCTURAL DESIGN: design formula for calculation of quarry rock armour stability in trunk and heads; well controlled closure relations for wave transmission and reflection

Background (description of the problems to be solved)

When waves reach LCSs, they suffer transformation due to the processes of reflection, dissipation and transmission over the structure as well as diffraction around the heads. These changes modify the direction and magnitude of the energy flux reaching the beach, producing changes both in plan form and profile. To design functional LCS's schemes, the designers need formulas for prediction of variables as wave reflection and transmission.

Besides functional design, low crested structures should withstand the wave action during their usable life with damage below a determined level. The main damage mode of low crested rubble mound structures is related to the movement of armour units, so stability formulas for this damage mode should be provided for the design.

Scientific/technological and socio-economic objectives

The objective of Result 16 is to produce well controlled closure relations for armour stability, wave transmission and reflection to be used in the functional design of LCS.

Applied methodology, scientific achievements and main deliverables

Deliverable D 43 complements DELOS deliverable D22 "Structural design preliminary report" oriented towards a revision of available formulae for the design of Low-crested rubble mound structures.

Deliverable D 22 presents a brief summary of the most used formulae for wave transmission and armour stability of LCS's. Deliverable D 43 includes the achievements of DELOS in these fields, specifically on wave reflection, transmission and LCS stability.

As far as wave transformation over LCS's is concerned, the DELOS project was focused on wave transmission. Wave reflection was not considered to be an important aspect and was only treated at the end of the project and some preliminary results obtained with DELOS data sets were presented in D43.

For wave transmission, all previous data sets on wave transmission and results from DELOS laboratory experiments carried out at the University Cantabria and the Polytechnic University of Catalonia were gathered together (2337 tests). The full analysis was carried out by Briganti et al (2003). As a result two new formulae were proposed for narrow and wide -crest LCS's, respectively. These formulas used three non-dimensional parameters to describe wave transmission. Besides this result, the DELOS database on wave transmission was used by Panizo et al (2003) to build a neural network. Using this network, the influence of additional non-dimensional parameters was analysed. The resulting neural network added three new parameters not included in the Briganti et al. (2003) proposed formulae.

The shape of the transmitted spectra was analysed by Van der Meer (2003) who proposed a new methodology to define the shape of the transmitted spectrum. Using data from 3D basin experiments carried out within the DELOS project at Aalborg University, the oblique transmission was analysed, van der Meer et al. (2003).

In relation to 3D LCS armour stability, two existing data sets Vidal et al (1992) and Burger (1995) were gathered together with data obtained in wave basin experiments within DELOS to develop a simplified stability formula for initiation of damage, Kramer and Burcharth (2003) based on the fact that most of LCS's are built in shallow waters where wave height is depth-limited.

Finally, based on the analysis of scour around LCS's carried out within DELOS, new formulae were proposed for the width of the toe berm protection, for both the front slope and the head sections.

Conclusions including socio-economic relevance, strategic aspects and policy implications

New empirical formulae have been obtained for wave transmission, reflection and stability of LCS's. These formulae improve or complement existing formulations, thus providing a way for a more reliable and cost-efficient design of the structure and the complete (beach – structure) LCS scheme.

Dissemination and exploitation of the results

Preliminary results on wave transmission and stability were presented in the Coastal Structures Conference 2003 in Portland, Oregon and will be presented in the International Coastal Engineering Conference, to be held in Lisbon in 2004. The results have been also presented to the end-users in the DELOS. A summary of results on wave transmission and stability will be published in a Coastal Engineering Special Issue. The Guidelines for design, that will be delivered by DELOS, that provide detailed formulae and methodologies for LCS design will delivered to end users and scientific community at the end of the project.

Main literature produced

Briganti, R., J.W. van der Meer, M. Buccino and M. Calíbrese, 2003. "Wave transmission behind low crested structures". ASCE, Coastal Structures 2003 Conference, Portland, Oregon, USA.

Kramer, M. and Burcharth, H.F. 2003. "Stability of low-crested breakwaters in shallow water short crested waves. ASCE, Coastal Structures 2003 Conference Portland, Oregon, USA.

Panizo, A., Briganti, R., van der Meer, J.W. and Franco, L., 2003. "Analysis of wave transmission behind low-crested structures using neural networks". ASCE, Coastal Structures 2003 Conference Portland, Oregon, USA.

Van der Meer, J.W., Wang, B., Wolters, A., Zanuttigh, B. and Kramer, M. (2003). "Oblique wave transmission over low-crested structures". ASCE, Coastal Structures 2003 Conference Portland, Oregon, USA.

RESULT N°17

WP 2.3 UCA

D 44 FLOW VELOCITIES IN THE SURFACE REGION OF LCS: describes tools to evaluate wave load on attached life forms

Background (description of the problems to be solved)

The breaking process over the overtopped structure enhances the pumping of wave-induced mass fluxes over the low-crested detached structure. This results in an enhanced nearshore circulation and consequently the presence of the LCS modifies the sediment fluxes and morphodynamic evolution. Furthermore, the fluxes through the permeable structure may also contribute to additional modifications. Consequently circulation and morphodynamic models assessing morphodynamic evolution in the presence of LCS should include additional information regarding the fluxes on the top and through the structure.

It is well established that hydrodynamic forces due to breaking waves are among the most important sources of shore organism distribution and mortality. Therefore, in order to interpret the biomechanical characteristics of the epibiota on a low-crested structure; stress levels resulting in tissue damages or complete dislodgement; average flow conditions to predict larval settlement and delivery of nutrients or critical periods of very low flow speed causing hypoxia; a feasible description of the flow is required.

These is only possible based on an appropriate modelling of the velocity field and breaking processes in the near field of the structure and how those are affected by incident wave parameters, structure geometry and permeable material characteristics. However, it has to be pointed out that the different applications do not really require the knowledge of the turbulence fluctuations velocity components. The knowledge of the instantaneous mean flow, the seepage velocity, the maximum or minimum mean velocities is sufficient to fullfill most of the questions raised with regard to stability, functionality or ecological issues.

Therefore, as part of the work carried out within WP2.1. a detailed analysis of the flow velocities in the surface region of LCS has been considered to be relevant.

Scientific/technological and socio-economic objectives

The main scientific and technological objective has been to provide reliable information on the velocity distribution around and inside LCS and how the velocity distribution is affected by the incident wave conditions, structure geometry and porous material characteristics. Furthermore, a second goal is to provide reliable tools to evaluate the magnitudes of the velocity fields under design conditions. This information is extremely important to evaluate LCS stability since some of the stability formulations are based on the evaluation of the velocity at the surface of the structure.

Applied methodology, scientific achievements and main deliverables

The applied methodology consists of the combination of the analysis of the experimental data gathered in the frame of the project and the generation of numerical data using the 2DV numerical model based on the VARANS equations (deliverable D19).

Based on both the numerical and experimental results the velocity distribution is studied. The influence of relevant magnitudes such as berm width, freeboard, incident wave conditions, model scale and structure material on the velocity distribution is considered. Comparison between measured and numerical velocities show a very good agreement, showing only small deviations very close to the surface of the structure where local effects are affecting the measurements.

The main deliverable has been a document on flow velocities in the velocity of the surface of LCS. In this document the application of deliverable D19: Calibrated 2DV near-field flow model, to evaluate the velocity field around, on and inside LCS is explained. Several examples for the validation of the results are shown, comparing numerical and experimental data.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The model is proven to reproduce with a high degree of agreement the velocity field around, on the surface and within the structure for different geometries, incident wave conditions and construction material. The shoaling and breaking effects in the seaward and crest zones, as well as the higher harmonics generation phenomenon in the transmission zone, are well simulated, whether the structure freeboard is positive, zero or negative.

The present results show that this model represents a substantial improvement in the numerical modelling of LCS since it includes many processes neglected by previously existing models. Furthermore, most of the existing models based on potential theory and vertically integrated equations are able to accurately predict the free surface evolution, including breaking, but fail to give a good description of the velocity fields. Therefore, reliable estimations of the velocity field, including nonlinear effects and breaking conditions may result and in more reliable and cost-efficient design of the structure. It will also contribute to estimate the habitat conditions of the epibiota on LCS

Dissemination and exploitation of the results

The results of this work has been presented in several conferences: Spanish and French Coastal Engineering conferences, Coastal Structures 03, ASCE and will be presented in the International Coastal Engineering Conference, to be held in Lisbon in 2004. The results have been also presented to the end-users in the DELOS end-user meeting as well as in different seminars in Portuguese and Spanish administrations and Universities.

Main literature produced

Garcia, N., Lara J.L. and Losada, I.J. (2003) 2-D Experimental and numerical analysis of wave interaction with low-crested breakwaters including breaking and flow recirculation. Coastal Engineering (ELSEVIER), submitted.

Losada, I.J., Lara, J.L., E.D. Christensen and Garcia, N (2004) . Breaking process, velocities and turbulence intensity around low-crested structures. Coastal Engineering (ELSEVIER), DELOS special issue, submitted.

Losada, I.J., Lara J.L. and Garcia, N. (2003). 2-D Experimental and numerical analysis of wave interaction with low-crested breakwaters including breaking and flow recirculation. Proceedings Coastal Structure 03, ASCE. (in press).

Losada, I.J., Garcia, N. and Lara, J.L. Deliverables D23 and D44: Report on turbulent flow velocities in the surface region of LCS. DELOS project.

RESULT N°18

WP 3.1 CSIC

D 33+34+45 Key data on breakwater design features for the maintenance and enhancement of biodiversity and functional organisation of soft-bottom assemblages

Background (description of the problems to be solved)

Any artificial structure placed in a coastal environment, including Low Crested Structures (LCS) built up to prevent coastline erosion, is expected to modify the wave regime and depositional processes. These changes, in turn, will have relevant consequences on the soft-bottom benthic assemblages (i.e. main impacts on species composition, abundance and the trophic structure) by altering both hydrodynamic and sedimentary characteristics of the surrounding soft-bottom habitats. The impact of LCS on soft-bottom macrofaunal assemblages may be investigated by comparing their composition, structure (in abundance and biomass) and trophic-functional organization around (landward and seaward sides) on different types of LCSs and in control areas without structures.

Scientific/technological and socio-economic objectives

The objectives of Result 18 are: 1) To analyse the changes of the bottom sediments and detrital pathways related to the potential alteration of hydrodynamic regimes caused by the presence of LCS. 2) To identify and quantify the impacts, either positive or negative, on the composition, structure and functional organization of soft-bottom coastal assemblages surrounding LCS.

Through an integrated collaboration among researchers of different European countries and different specialities, it has been possible to describe and quantify the impacts of the LCS on the diversity and functioning of soft-bottom macroinvertebrate communities at a range of spatial (local, regional and European) scale and in relation to different environmental conditions (micro- macrotidal ranges, wave action, surrounding habitats and different LCS typologies), as well as to identify the key data on LCS design features allowing to maintain and/or enhance of the biodiversity and functional organisation of the surrounding soft-bottom assemblages.

Applied methodology, scientific achievements and main deliverables

The main achievements of R18 has been obtained within the frame of the DELOS WP3.1 at five different study sites with different LCS systems and environments. These ere Cubelles and Altafulla in Spain, Lido di Dante in Italy and Elmer and Liverpool in UK.

The sediment descriptors chosen were: depth of the water column, granulometry (percentages of silt/clay and coarse sand, and mean and median grain size), total organic matter content and chlorophyll-a content (see D2, D18). The descriptors of infaunal assemblages (based on species level identifications) were: species richness, Shannon diversity index, abundance and biomass, as well as trophic-functional structure (organisms grouped into classic trophic guilds) (see D2, D18, D33).

The sampling strategies used were: 1) A balanced hierarchical design with three treatments for each LCS system (landward, seaward and control), four stations randomly selected within treatments and several random replicate samples within stations (see D18, D4). 2) An assessment of the extent of the area of influence at successive distances from the LCS based on designs specifically adapted to the particular scheme and environmental conditions of each studied LCS (see D34). Data were analysed under several statistical procedures. Univariate analyses were nested two-factor ANOVA, with the random factor site stations nested in factor treatment, and contour maps. Multivariate approaches included non-metric multidimensional scaling (nMDS), two-way nested analysis of similarities (ANOSIM) and Principal Component Analyses (PCA).

The main results obtained were:

1.- The use of sediment descriptors is a basic tool to assess the changes induced by LCS on habitat complexity. However, the effect is very low and these variables seldom reveal differences under a nested ANOVA. The high within-treatment variability tends to mask between-treatment differences for each individual sediment descriptor (see D18).

2.- The assessment of habitat complexity based on PCA (D18) usually provides better indications of between-treatments distinctive patterns. However, the different designs of the LCS together with the different hydrodynamic conditions (e.g. tidal range, see D34) give rise to different levels of response.

3.- Nested ANOVA based on the infaunal soft-bottom assemblages also shows the existence of a high within-treatment variability for all analysed variables. Conversely, based on functional and structural descriptors, marked between-treatment differences, independently of the different environmental conditions, were demonstrated (see D33).

4.- Using nested ANOVA, the number of species, abundance, biomass, and trophic-functional groups arise as a better tool to reveal the impact caused by the LCS than the analysis of soft bottom physico-chemical characteristics.

5.- MDS, PCA and ANOSIM allowed to obtain most meaningful results, showing differences among treatments independent of the distinctiveness of the raw data. However, the resolution of the analysis may vary depending on the studied situation. In all cases, the largest dissimilarity was always observed between the landward side of the structures and control areas.

6.- The degree of exposition and the hydrodynamic regime at the landward side, as well as the influence of the LCS on this regime, seems to be one of the key features among those influencing diversity of soft bottom assemblages around the LCS (see D33).

7.- The sampling design based on samples collected at successive distances from LCS is able to produce an integrated picture of the systems under study, that could be linked (easily) both to the trends showed by the environmental factors and to dynamic models in order to assess the influence of hydro- and sediment dynamics on the soft-bottom assemblages (D34). However, this approach also demonstrated that the effect of LCS occurred mainly in the proximity of the structures (e.g. less than 30 m in Altafulla).

8.- The consequences derived from the construction of an LCS always depend on the response of the regional pool of species (D45). However, the overall habitat diversity of the stretch of coast where the structures are built usually tends to increase and, as a consequence, the species diversity also tends to increase (D45). In most cases, this increase was caused by accidental species coming from the newly added hard bottoms or from species more or less associated to increasing disturbances (e.g., organic enrichment, presence of stagnant or brackish waters).

Additional contributions to Deliverables were included in: D1, D2, D3,D4, D5, D9, D13, D18, D26, D33, D34, D36, D46, D53, D54, D55, D57, D58, D59 and D60.

Conclusions including socio-economic relevance, strategic aspects and policy implications

Changes in sediment characteristics and infaunal benthic communities seem to be an inevitable consequence of the construction of LCS. Their presence induces a disruption in the normal succession of assemblages from deep waters to shoreline (see D34). Independently of the arrangement of the LCS, their presence usually tends to induce negative changes, mainly in relation to the degree of hydrodynamism, being particularly stronger at landward and in the presence of additional structures (such as parallel groins) or after beach nourishment (D45).

Despite the differences observed around the LCS, the overall habitat diversity of the stretch of coast where the structures are built usually tends to increase and, as a consequence, the species diversity also tends to increase (D45). Although this could be regarded as a positive consequence of the LCS under a naturalistic (or, even, recreational) point of view, it is also evident that may be regarded as negative under an ecological viewpoint.

Although all studies have been carried out in very different coastal systems (different tidal range, different seas, different current regime and wave climate, different type of beaches) the results are consistent. This strengthens the findings obtained within DELOS, with the generality of results allowing the formulation of LCS design guidelines that would be applicable to different coastal system in Europe. Design criteria tending to facilitate a positive evolution of the assemblages after the LCS construction (D45) are addressed to avoid the development of insalubrious areas in the protected zone, for instance to reduce the impact at landward by increasing the water flow through the structures.

The effects of LCS on soft-bottoms should always be minimised, independently if they cause an increase in diversity or not. The main principle should be to maintain the most natural ecosystem conditions and to protect them from any human intervention (D45). For example, once the decision to build an LCS is taken, it is always better to reduce the number of LCS (and subsequent interventions such as beach nourishment) to the minimum necessary to protect the coast, in order to avoid large-scale effects of habitat loss and community changes. The combined use of basic monitoring approaches and models allowing to forecast likely impacts on the surrounding biotopes (such as the model developed by Delft Hydraulics within the DELOS) will certainly allow to mitigate the impacts of the LCS, as well as to play a relevant role in the management of the possible consequences.

The ecological relevance of the disturbance induced by the LCS on the surrounding sediment and infaunal benthic assemblages requires special attention addressed to study the regional pool of species responsible of possible changes in biodiversity, prior to the start the construction works (D45), in order to be able to assess their possible subsequent evolution (e.g. species disappearance-from and/or colonization-of the new environment). Once constructed, special care should be addressed to monitor the impacts and to detect the presence of accidental and stress-indicator species, allowing to decide whether the induced modifications have to be considered as negative transformations of the environment or not.

The design criteria allowing to minimize the extent of the impact on the assemblages around the LCS should be addressed to avoid the development of insalubrious areas in the protected zone (i.e. at landward). For instance, by keeping the modifications of both the onshore wave transport and water flow to the minimum necessary. Possible interventions are: maximise the overtopping and the porosity of structure, maximise the gap size and their frequency within each LCS, minimise the structure length and number, avoid beach nourishment (specially if planned to be carried out in successive periods) and minimise the enclosure of the protected zone (avoiding lateral groynes if possible).

Dissemination and exploitation of the results

The dissemination and exploitation of the information of R18 has been (and will be) done by means of papers to be submitted to Scientific Journals, Seminars open to the scientific community as well as to local and regional authorities and Meetings of different specialities (such as ecology or marine biology).

During the progress of the project, several activities contribute to disseminate the obtained results. Among them:

1) Distribution of DELOS leaflet to local authorities in charge of coastal protection in different countries.

2) Interviews with local authorities to explain personally the DELOS project.

3) Link to the web address of the project, which have been included in the main page of the partner institutions.

4) Presentation of Deliverables.

5) Contribution to the design guidelines.

Main literature produced

Martin Daniel., Fabio Bertasi, Marina A. Colangelo, Matthew Frost, Stephen J. Hawkins, Enrique Macpherson, Paula S. Moschella, Maria Paola Satta, Richard C. Thompson, Mindert deVries, Victor U. Ceccherelli. 2004.- Ecological impacts of low crested structures on soft bottoms and mobile infauna: how to evaluate and forecast the consequences of an unavoidable modification of the native habitats. Coastal Engineering.

Airoldi L., Abbiati M., Hawkins, Jonsson P.R., Martin D., Moschella P., Thompson R., Åberg P. 2004.- An ecological perspective on deployment and design of low crested structures. Coastal Engineering.

Airoldi L., M. Abbiati, P. Åberg, H. Burchart, V.U. Ceccherelli, S.J. Hawkins, A. Lamberti, D. Martin, A. van der Veen, C. Vidal, 2000 Promoting environmentally compatible design of coastal defence structures: a European-scale project. 2° Convegno Nazionale delle Scienze del Mare, Genova. Proceedings of the 2° Convegno Nazionale delle Scienze del Mare, Genova. Poster

Martin, D. & M.P. Satta 2002 RT3 - Ecology - WP 3.1: The effects of breakwaters on surrounding soft bottoms: Preliminary results in NW Mediterranean (Platja de la Tèrmica - Cubelles). First Year Meeting. Oral presentation and contribution to the proceedings

Martin, D., M Colangelo, P Moschella, et al. 2002 RT3 - Ecology - WP 3.1: The effects of breakwaters on surrounding soft bottoms: Preliminary results in Spain, Italy and UK. First Year Meeting. Oral presentation

Martin, D., E. Gacia, E. Macpherson & M.P. Satta 2002 Environmental design of low crested coastal defence structures: DELOS. Seminars at the CEAB (CSIC). Oral presentation

Martin, D. & M.P. Satta. 2002.- Effects of low crested on the surrounding soft bottoms habitats: preliminary analisys of two NW Mediterranean study sites using two contrasting sampling strategies. ELOISE- European land Ocean Interaction Studies. European Conference of Coastal zone Research. Marzo 24-27. Gdansk (Polonia) -University of Technology. Poster.

Martin, D. & Satta, M.P. 2003 Extent of the area of influence on the surrounding soft bottoms and infauna of a LCS: preliminary results in Altafulla (NW Mediterranean) Second Year Meeting. Oral presentation

Martin, D., M. Colangelo, P. Moschella 2003 Area of influence of LCS on the surrounding soft bottoms of infauna: preliminary results in Spain, Italy and U.K. Second Year Meeting. Oral presentation

Martin D., Fabio Bertasi, Marina A. Colangelo, Matthew Frost, Stephen J. Hawkins, Enrique Macpherson, Paula S. Moschella, Maria Paola Satta, Richard C. Thompson, Mindert deVries, Victor U. Ceccherelli. 2004 Ecological impacts of low crested structures on soft bottoms and mobile infauna: how to evaluate and forecast the consequences of an unavoidable modification of the native habitats Final Meeting Oral presentation

Airoldi L., Abbiati M., Hawkins, Jonsson P.R., Martin D., Moschella P., Thompson R., Åberg P 2004 An ecological perspective on deployment and design of low crested structures. Final Meeting. Oral presentation

RESULT N°19

WP 3.4 FF

D 47 Evaluation of overall potential of breakwater as a tool for the management of coastal assemblages

Background (description of the problems to be solved)

Once it has been decided to build a structure on rational grounds to protect an area of coastline there will be consequences for the environment. In most countries it is a requirement that design options are considered that minimise impacts of human actions at existing environmental conditions. In the case of LCSs, this includes minimising changes on existing soft-bottom depositional ecosystems and growth of epibiota on the structures. Alternatively, in situations, such as severely degraded or heavily managed environments, it may be possible to identify design options that maximise some of the by-products of the structures to meet specific secondary management end points. Examples could include maximizing growth of filter feeders to improve water quality and transparency, or maximising provision of habitat for marine wildlife that are the focus for conservation purposes or for recreational or educational activities. Knowledge of the environmental consequences of LCSs is fundamental to an effective design and management of coastal defence structures.

Scientific/technological and socio-economic objectives

The final aim of WP.3.4. was to identify and quantify the impacts of LCSs at large spatial scales and offer some general advice about options to mitigate impacts of LCSs on existing soft-bottom depositional ecosystems and manage the growth of epibiota. Mitigating environmental changes occurring as a consequence of the construction of LCSs or maximising specific changes in order to achieve desired end-points are often conflicting management options, that can lead to different environmental states and that require different design concepts. In order to achieve an effective design and a sustainable long-term management of coastal defence structures it is fundamental that predicted outcomes from the construction of coastal defence structures are clearly identified.

Applied methodology, scientific achievements and main deliverables

The experiments done within WP.3.4. have allowed to identify the large-scale effects of LCSs spatial arrangement on the distribution and population dynamics of coastal assemblages, and to establish the contribution of LCSs to regional biodiversity, to persistence of rare or endangered species and to the spread of non-indigenous species (see Result N°13). Based on results of WP.3.4., past experience and general ecological knowledge we have identified some key factors that affect the type and magnitude of impacts of coastal defence structures on soft-bottom and hard-bottom assemblages and on mobile fauna. This knowledge was directly used to formulate the guidelines.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The mains conclusions from this work can be synthesised as follows:

1) Results clearly raise concern that the “artificial” addition of new habitats and species can cause considerable change to the identity and distribution of species within a region and can have important far reaching effects on existing assemblages and ecosystem functioning. Along the coasts of Emilia Romagna, for example, coastal defence structures have been colonised by assemblages of opportunistic, ephemeral species, including numerous non-indigenous and pest species that are likely favoured by the large amount of bare space and the frequent disturbances (e.g. from wave action, scour, overturning of blocks, maintenance works, trampling and harvesting of mussels). Some of these species eventually have negative effects on the economy of the region. For example, the flowering of green ephemeral algae, that are torn off the structures and washed up the shore where they rotten, is a nuisance for beach tourism, decreasing the recreational value of the beach and leading to expensive cleaning works.

2) the most recommended advise to mitigate the impacts due to the introduction of hard-bottom species is to prevent proliferation of structures by minimizing downstream effects and implementing sound *eco*-regional strategic planning for coastal cells. Proliferation of structures can lead, in fact, to broad-scale alteration of the whole coastline, which cannot be predicted by scaling up local impacts.

3) clearly identifying the expected outcomes from the construction of coastal defence structures, in the light of the regional environmental and social context (e.g. climate, predominant habitats and species, societal and economical framework, regional planning, existing structures, predicted need for new structures) and implementing sound monitoring to assess their effectiveness are prerequisite to an effective design and a sustainable long-term management of coastal defence structures.

No deviations have occurred with respect to the original work plan in terms of inputs to design guidelines and deliverables. The work has been synthesised into deliverable D47: Evaluation of the overall potential of breakwaters as a tool to aid in the conservation of coastal assemblages.

Dissemination and exploitation of the results

Results were presented to all project partners during DELOS workshops and meeting, and were used in several internal reports. Results are also available to the public on the Internet. Results were included in the extensive Guidelines produced within DELOS. Conclusions were also made available to a broad scientific audience through the publication of scientific papers in high-profile journals and dissemination of results at conferences, seminars and master courses. Further dissemination is forecasted over the next 2 years through the publication of scientific papers in high-profile journals.

Main literature produced

Bacchiocchi, F. and Airoldi, L., 2003. Distribution and dynamics of epibiota on coastal defence works hard-bottom structures for coastal protection. Est. Coast. Shelf. Sci., 56: 1157-1166.

Bulleri F., M. Abbiati, L. Airoldi, 2004 - The colonisation of human-made structures by the invasive alga *Codium fragile* ssp. *tomentosoides* in the north Adriatic Sea (NE Mediterranean). Hydrobiologia, in press

Moschella P S, Abbiati M, Åberg P, Airoldi L, Bacchiocchi F, Bucchieri F, Dinesen G E, Frost M, Gacia E, Granhag L, Jonsson P R, Satta M P, Sundelöf A, Thompson R C, Hawkins S J. Low crested structures as artificial habitats for marine life: what lives where and why? To be submitted to Coastal Engineering

Airoldi L, Abbiati M, Hawkins S J, Jonsson P R, Martin D, Moschella P S, Sundelöf A, Thompson R C, Åberg P. An ecological perspective on the deployment and design of low- crested and other hard coastal defence structures. To be submitted to Coastal Engineering

RESULT N°20

WP 3.5 UGOT

D 48 Report on model of suitable habitats for key species on breakwaters as a function of local hydrodynamics

Background (description of the problems to be solved)

Breakwaters form a surface that will be colonised by a variety of marine epibiota. It is known that many epibiotic species respond to surface characteristics and the physical forcing from wave exposure. The main problem to be solved is to find models predicting the development of epibiota on LCS in order to evaluate effects of different LCS designs on epibiotic distribution.

Scientific/technological and socio-economic objectives

Specific scientific objective is to predict the development of marine life on LCS as a function of the morphology and hydrodynamics of breakwaters. The socio-economic objective is to use developed models to predict the development of epibiota on LCS perceived as nuicance or valuable from an aesthetic or natural resource perspective.

Applied methodology, scientific achievements and main deliverables

Statistical models were used to test for patterns in the distribution of epibiota on different parts of LCS and as a function of LCS geometry, age and location. The geographic areas included were the English coast, the northern Italian coast of the Adriatic Sea, The Costa Brava in Spain, and the Northern Jutland coast in Denmark. Statistical analytical techniques were mainly regressions, analysis of variance (ANOVA), and multidimensional scaling (MDS) based on multivariate data. Results of statistical analyses show that there is indeed predictive patterns of the distribution of epibiota on LCS but that these are different in different geographic regions. Even within a coast there may be significant regional differences. There are also predictive patterns in relation to the depth of submergence where LCS lower on the shore have a more diverse epibiota. On small scales there are gradients towards the toe with less epibiota probably caused by scour. Several scales of surface complexity was shown to increase the biodiversity on LCS. Interestingly, the diversity of epibiota on LCS is less than on nearby natural rocky reefs. At least in the Adriatic Sea this seems to be related to recurrent maintenance work. Detailed results are found in the deliverables D35. D46 and D48.

Wave-induced hydrodynamic forces are factors expected to influence the development of epibiota on LCS. Accordingly, a mechanistic approach was used to predict potential hydrodynamic impact on epibiota. First the hydrodynamic drag, lift and acceleration reaction on the scale of epibiota were predicted from a model based on theory and time-series of wave data. These forces were then compared to empirically found critical adhesion forces of selected epibiota. Predictions of detachment of epibiota was then validated with both empirical measurements of wave-induced forces and with experimental manipulation including transplantations of macroalgae to sites differing in hydrodynamic regime. The results show that hydrodynamic forces are indeed expected to restrict the distribution of foliose, long-lived algae and mobile fauna, but that the intensity of grazing may interact with hydrodynamics explain the distribution pattern found on LCS. Detailed results are found in D48.

Mechanistic models were further used to define critical pore sizes of LCS that may limit internal biota due to oxygen deficiency or nutrient depletion. The models predict that if pore size is above ca 0.2 m the risk is small for oxygen deficiency or nutrient depletion. See D48 for more details.

Conclusions including socio-economic relevance, strategic aspects and policy implications

Results within WP 3.5 shows that it is possible to predict the general development of epibiota if the geographic location is given. A combination of previous ecological knowledge about naturally occurring epibiota, statistical models generated within DELOS and a hydrodynamic model that generates time-dependent velocities on scales of a few cm may be used to predict the community of epibiota on different parts of the LCS. The result within WP 3.5 are relevant for the socio-economic analysis of the LCS option in several respects. First, it allows an assessment of the possible change in habitat types and biodiversity and how this complies with other policies. It further indicates if desired natural resources (e.g. mussels) and nuisance species (e.g. ephemeral green algae) will colonise the LCS.

Dissemination and exploitation of the results

Most of the conclusions from WP 3.5 are included in the extensive Guidelines produced within DELOS. These conclusions are also made available to a broader audience through three publications in a special issue in Coastal Engineering. In addition, some of the more scientifically exciting results will appear in high-profile ecological journals.

Main literature produced

Granhag L M, Finlay J A, Jonsson P R, Callow J A and M E Callow. Roughness-dependent removal of settled spores of the green alga *Ulva* (*Enteromorpha)* exposed to hydrodynamic forces from a water jet. Biofouling (accepted)

Moschella P S, Abbiati M, Åberg P, Airoldi L, Bacchiocchi F, Bucchieri F, Dinesen G E, Frost M, Gacia E, Granhag L, Jonsson P R, Satta M P, Sundelöf A, Thompson R C, Hawkins S J. Low crested structures as artificial habitats for marine life: what lives where and why? submitted to Coastal Engineering

RESULT N°21

WP 3.5 UGOT

D 49 Report on habitat Evaluation Procedure of sediments around different types of breakwaters

Background (description of the problems to be solved)

The presence of LCS will change the wave climate around the structure. The changed pattern of energy delivery to the sediment surrounding LCS will alter sediment structure and the accumulation of matter with possible changes in biodiversity. The problem here to be solved is to find a model making it posssible to evaluate changes in biodiversity caused by the deployment of LCS.

Scientific/technological and socio-economic objectives

Specific scientific objectives of WP 3.5 are to predict the development of marine life around LCS as a function of the morphology and hydrodynamics of breakwaters. In a socio-economic perspective it will be of interest to forcast possible changes in biodiversity around LCS with implications for the distribution of valuable sediment species (e.g. cockles and clams) and effects on fish recruitment.

Applied methodology, scientific achievements and main deliverables

The main purpose of an LCS is to reduce the wave energy delivered to the coast. This will have an impact on the sediment surrounding LCS with effects on sediment-living biota and potentially change organism abundance and diversity. To predict changes in the surrounding sediment biota a mechanistic approach was developed. A numerical fluid dynamic model predicted the local field of velocities due to currents and waves and shear stresses around an LCS were calculated. Bed shear stress correlates with sediment grain size and organic content and were used as an index of sediment quality. Bed shear stress, salinity and tide were then used in a so called Habitat Evaluation Procedure where the physical requirements of a set of sediment species are defined. Based on the defined requirements it is then possible to map the potential habitat for each target species and to evaluate how these habitats change when one or a set of LCS are constructed. This procedure was run with Elmer, UK as a test case. The results indicate a significant but moderate predicted change in the sediment-living community. In particular, the creation of muddy beds on parts of the landward side of LCS will change the sediment biota. For more details see D49.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The modelling of changes of sediment communities around LCS is more challenging, mainly because of insufficient knowledge of the requirements of many sediment organisms. However, the Habitat Evaluation Procedure is a promising technique that can be used in pre-construction assessment of likely changes in habitat types with associated changes in sediment communities.

Dissemination and exploitation of the results

Most of the conclusions from WP 3.5 are included in the extensive Guidelines produced within DELOS. These conclusions are also made available to a broader audience through three publications in a special issue in Coastal Engineering. In addition, some of the more scientifically exciting results will appear in high-profile ecological journals.

RESULT N°22

WP 3.5 UGOT

D 50 Report on meta-population model as a function of the large -scale distribution of breakwaters

Background (description of the problems to be solved)

The construction of LCS in a sandy beach environment creates virgin habitat for rocky shore organisms. Earlier isolated patches of natural habitat may become connected via a chain of “stepping-stones” such that gene flow is permitted and also the dynamics of some or all species is shifted from the original situation. Such a situation may promote the invasion of introduced or alien species. Depending on the actual positions of new LCS the dispersal speeds, i.e., km/generation or similar, may differ.

Scientific/technological and socio-economic objectives

W.P 3.5 dispersal and metapopulation models have been developed to assess the regional-scale effects of breakwaters on the distribution and abundance of species.

Applied methodology, scientific achievements and main deliverables

Model results for limpets show that depending on variations in flow and behaviour of larvae dispersal may range between 10 and 90 km. This means that the probability of gene flow between the natural rocky reefs in the area was extremely low before the construction of chains of LCS. Model results also show that the position of a LCS’ has a great effect on the population dynamics following removal of structures.

There are no longer any stretches of beaches without structures of 89 km or longer. We conclude that although we cannot at present quantify the probability of gene flow, or migrants per generation, between the natural rocky reefs in the studied area, there exists a substantial transport of larvae along the Ravenna shoreline. Through the action of the structures as “stepping-stones” the natural reefs will undoubtedly experience gene flow. Detailed results are found in D50.

Conclusions including socio-economic relevance, strategic aspects and policy implications

An often overlooked aspect is the possible ecological effects on regional-scale caused by assemblages of LCS. If assemblages are sufficiently close they may act as dispersal corridors facilitating the introduction of species not present before the LCS deployment. Finally, it is possible to include regional-scale models in risk assessment for introductions of alien species caused by extensive assemblages of LCS. For more details about strategic aspects and policy implications see the Guidelines.

Dissemination and exploitation of the results

Most of the conclusions from WP 3.5 are included in the extensive Guidelines produced within DELOS. These conclusions are also made available to a broader audience through three publications in a special issue in Coastal Engineering. In addition, some of the more scientifically exciting results will appear in high-profile ecological journals.

Main literature produced

Airoldi L, Abbiati M, Hawkins S J, Jonsson P R, Martin D, Moschella P S, Sundelöf A, Thompson R C, Åberg P. An ecological perspective on the deployment and design of low- crested and other hard coastal defence structures. submitted to Coastal Engineering

RESULT N°23

WP 2.5 UoS

D 52 Report on scale effects for LCS

Background (description of the problems to be solved)

None of the standard scaling laws for hydraulic models (Froude, Cauchy, Reynolds, Weber) provides accurate scaling for all processes of wave-related breakwater models. When a scale rule is chosen, it is unavoidable introduce some sort of scale effects for the variables that do not correctly scale according to the selected law.

Scientific/technological and socio-economic objectives

The objective of this report is to provide a detailed and critical review of all typologies of scale effects (including model effects), to be taken in account when dealing with physical modelling of rubble-mound breakwaters.

Conclusions including socio-economic relevance, strategic aspects and policy implications

Scale effects (from prototype to model) can be divided into proper scale effects and model effects, due mainly due to: intrinsic properties of breakers (surface tension, air content); wave-structure interactions; different ambient conditions in field and laboratory (sediment scaling and effects of algae and mussels).

The main scale effects in wave-structure interactions are: wave impacts on armour blocks; run-up and overtopping; structure deformation; wave-generated flow in the porous structure; and flow forces on plants and organisms, attached to the structure. Impact wave loads on mound breakwaters consist of two components: impulsive load (sharp peak, high magnitude, short rise time); and pulsating (quasi-static) load, associated to the mass of water “travelling” through the structure. No major scale effects are evident when dealing with pulsating loads. In this case, Froude scaling is accurate enough to transfer model results to prototype scale. Impulsive loads induced by breaking waves involve compressibility of air over a very short time period. The fluid interacting with the structure becomes a air/water mixture and cannot be treated as an incompressible fluid. Froude and

Cauchy Laws are not adequate, for scaling model results on impulsive events. Surface tension effects become increasingly important as the wavelength and intensity of the breaker decreases. Without surface tension, the crest deforms to generate a jet (or perhaps a three-dimensional jet-like structure) at the crest; this plunges into the wave face to start the turbulent spilling process. When surface tension effects become dominant, this jet is replaced by a bulge-capillary structure at the crest. Turbulence is produced by separation at the point of high-upward surface curvature (toe), at the leading edge of the bulge. During the turbulent spilling process, for cases where surface tension is unimportant, dramatic splashing motions occur: air bubbles and water droplets are produced. When surface tension is dominant, the surface fluctuations (and perhaps turbulence) are reduced; a single continuous bumpy surface makes up the boundary between air and water. Theoretical and experimental investigations have emphasised the importance of the shear layer between the fluid in the leading edge of the breaking region and the fast-moving underlying flow as the sit of strong turbulence generation. Because in the natural world, surfactants are nearly always present, their effect on spilling breakers should be investigated. Surfactants will have strong effects on surface-tension-dominated breakers. The different compressibility of water is due to the different process of bubble formation, from freshwater (used in physical models) to seawater. Typical air bubbles are smaller in seawater than in freshwater; they have the tendency to remain entrained in a breaking wave. Furthermore, their size distribution differs also freshwater in comparison to seawater. The factors causing the differences in bubble sizes and distribution, between prototype seawater and model freshwater can be identified as: salt concentration; ionic structure; exudates of marine organisms; surface tension; temperature and viscosity. The main effects of the different compressibility of water, from model to prototype, is in an overestimation of pressure magnitude and underestimation of pressure rise time for impulsive loading, if Froude or Cauchy Laws are used for transferring model to prototype results. This happens because, in aerated water (seawater), the presence of air produces a "cushioning" effect; this weakens the magnitude of the impact and extends its duration. Considering that inertia forces scale as U^2, also a straightforward use of Weber Law would lead to errors, given that $We = \frac{\rho U^2 l}{\sigma}$, and that surface tension does not scale from model to prototype. It is suggested wave loading should be analysed through the use of the parameter impulse: $\int \mathrm{p(t)}\, dt$, i.e. the integral of pressure or force, over time, during the impulsive event. Scaling model impulses to prototype dimensions, by use of the Froude law generally gives accurate results even for highly impulsive events. Another parameter which can be used for impulsive events analysis is $\int \frac{dp}{\rho}$. This parameter is a function of percentage void ratio. Therefore, the use of this parameter involves the need for accurate measurements of air content at model and prototype scales. Even when comparing model tests carried out with seawater, to fullscale field results, differences can be noted in the maximum impulsive pressures.

The different environments (laboratory and field) play a decisive role and affect the ambient conditions of the experiment. Run-up appears to be influenced by scale effects, even though only limited quantitative data are available. A consistent underestimation of run-up has been noted when analysing laboratory large-scale data, with respect to prototype data. Overtopping appears to scale down accurately by use of the Froude Law, even though for small values of discharge some scale effects might cause underestimation in small-scale models. Porous flow within the model is almost entirely laminar whereas, under field conditions, the motion is turbulent.

Some empirical engineering methods exist for scale corrections. In relation to sediment scaling, the transport mode in the prototype should be maintained, within the model. In situations where both modes of transport occur, only qualitative results can be obtained, as it is not possible to scale bed load and suspended load simultaneously. Marine organisms attached to breakwaters increase structure roughness, reduce the water flow through the structure and can trap large quantities of sediment. The combinations of these effects affects significantly flow through the structure. Therefore, care must be taken when scaling from field to model conditions, in order to evaluate correctly these effects. Forces on plants and organisms should be measured directly in field conditions, as model tests are highly influenced by complex scale effects.

Dissemination and exploitation of the results

These results should be useful to the coastal engineer/scientist who has to face the problem of analysing and interpreting physical model data for the design/assessment of LCS projects. The main results are summarised in the literature outlined below.

Main literature produced

Tirindelli M., Lamberti A., Paphitis, D., Collins, M.B., Vidal, C., Hawkins, S., Moschella, P., Burchart, H., Sanchez-Arcccilla, A. (2004) “Wave Action on Rubble Mound Breakwaters: the Problem of Scale Effects” Deliverable 52, DELOS EVK3-CT-2000-00041, pp 36 + Appendices.

Section 6 of Matteo Tirindelli's PhD dissertation "Wave-induced forces on maritime structures", Polytechnic of Milan / University of Bologna, Italy, April 2004, pp. 31.

Tirindelli M. & Lamberti A. (2004) “Evaluation of Wave-Induced Loads on Low-Crested Structure Elements” ICCE 2004, Lisbon, Portugal (Accepted Abstract).

Tirindelli M. & Lamberti A. (2004) “Impulsive forces induced by breaking waves on biotic elements attached to low crested structures” for Hydraulic National Conference 2004, Trento, Italy (Accepted Abstract).

RESULT N°24

WP 5.1 UGOT

D 53 Engineering, ecological and socio-economical input to design guidelines

The objective of this result was to provide input to the design guidelines from engineering, ecological and socio-economical perspective of design of low crested structures. The result is thus the transfer of knowledge from other results in this project to the production of guidelines. D59 WP5.3 DESIGN GUIDELINES FOR LCS INCLUDING EXAMPLE APPLICATIONS: cross-disciplinary design guidelines reflecting consideration of both structural, coastal protection, ecological and socio-economical performances. All major conclusions that were transferred to WP.5.3 are summarised in deliverable D53.

RESULT N°25

WP 5.2 UB

D 54+56 Verified partial inputs to design guidelines (Application to the project study sites and selected case studies)

Background (description of the problems to be solved)

Due to the difficulty of building-up a reliable new case to which Guidelines could be applied, an existent study site was chosen for this exercise: Lido di Dante.

The use of the beach for recreational activities, the extent of beach erosion and environmental problems common to the highly defended regional littoral facing in an eutrophic sea made this site an interesting case study.

Scientific/technological and socio-economic objectives

Aim of this result was to perform integrated design of a coastal defence, by applying the knowledge achieved within DELOS and presented in the Guidelines to an existent prototype case.

Applied methodology, scientific achievements and main deliverables

The site was first analysed focusing on the factors that mainly interact with the defence works, as wave climate, existing habitat and sediment transport. Then different possible design alternatives were identified and based on social and environmental constraints, five of them were preliminary selected: pure nourishment; a submerged barrier; emerged barriers parallel to the shore; prolongation of the two external existing groynes; a submerged barrier with submerged connectors to the existing groynes. Numerical simulations with the 2DH model MIKE 21 were then carried out in order to predict waves, currents and sediment transport induced by each selected alternative. Based on numerical results, maintenance plans are made and both building and maintenance costs are estimated. Ecological and socio-economic effects of design alternatives based on output from numerical modelling were then investigated. The engineering performance, the likely ecological effects, the social demand and the construction costs were finally combined to make the final choice among the alternatives. The chosen alternative was then optimised and a detailed design is performed together with the hydro-morpho-dynamic verification of expected optimisations through numerical simulations.

Conclusions including socio-economic relevance, strategic aspects and policy implications

In order to promote an integrated coastal zone management in every day practice, under the framework of DELOS design guidelines have been prepared to be appropriate throughout the European Union accounting for current EC policies and directives. The inputs for the integrated design consisted of available data on climate, environmental conditions, habitat and species, preferences of visitors; tools (derived from DELOS guidelines) for establishment of design wave climate, selection structure type and their lay-out and geometries; tools for simulating waves and currents induced by the structures and the consequent morphological changes. Engineers would have selected emerged barriers or submerged barrier with connectors as preferred schemes for beach defence; ecologists would have preferred submerged barriers for minimising ecological impacts or the prolongation of groynes for maximising species biodiversity and natural resources; socio-economists would have chosen submerged structures mainly for aesthetic reasons but also for water quality. The global evaluation of design alternatives brought to the selection of the submerged barrier which was then optimised accounting for general multidisciplinary suggestions achieved within DELOS and presented in DELOS guidelines. The analysis performed and the results presented for this site enhanced the strict interactions among LCS construction, habitat changes, hydrodynamics, beach erosion, water quality and thus beach value; it appears therefore necessary to follow general LCS design guidelines to account for the multiple effects of LCS on the littoral environment and thus promote an effectively sustainable defence scheme.

Main literature produced

This result is documented by Chapter 12 of the Guidelines and by a paper submitted to the DELOS Special Issue of European Community.

RESULT N°26

WP 5.3 AAU

D 59 DESIGN GUIDELINES FOR LCS INCLUDING EXAMPLE APPLICATIONS: cross-disciplinary design guidelines reflecting consideration of both structural, coastal protection, ecological and socio-economical performances

Background (description of the problems to be solved)

The effect of manmade activities is primarily local but can extend far away from the location of intervention. This underlines the importance of establishing coastal zone management plans covering large stretches of coastlines. The present guidelines on Low Crested Structures (LCS's) attempts to provide methodological tools both for the engineering design of the structures and for the prediction of performance and environmental impacts of such structures. It is believed that the guidelines will provide valuable inputs to coastal zone management plans.

Scientific/technological and socio-economic objectives

The target audience for this set of guidelines is consulting engineers or engineering officers and officials of local authorities dealing with coastal protection schemes. The guidelines are also of relevance in providing a briefing of current best practice for local and national planning authorities, statutory agencies and other stakeholders in the coastal zone. The guidelines have been drafted in a generic way to be appropriate throughout the European Union taking into regard current European Commission policy and directives to promote sustainable development and integrated coastal zone management.

Applied methodology, scientific achievements and main deliverables

Initially an outline of the document "LCS Design Guidelines" was proposed. Several draft versions of the outline have circulated among partners, and contributions, comments and suggestions were incorporated. The chapters in the document are written by many of the partners in the DELOS project. The document is presented on the Internet www.delos.dk. This site served as a common place for sharing documents and information during the revising process. At the end of the DELOS project the main deliverable D59 was still in a preliminary draft version. Several draft chapters of D59 was completed, but the whole document was not reviewed and some chapters/contributions were still not completed.

Conclusions including socio-economic relevance, strategic aspects and policy implications

The guidelines provide new tools suitable for design of LCS's. The use of the tools is demonstrated in example applications, and case studies are given to show how existing LCS-schemes are designed. The guidelines is a unique tool for endusers dealing with design of coastal protection schemes which includes LCS's.

Dissemination and exploitation of the results

When finished, the resulting document "LCS design guidelines" will be freely available for download to the public on the Internet www.delos.unibo.it. Further the document might be published as a book. The knowledge will be spread to endusers in EU dealing with design of coastal protection schemes. DELOS partners in the different EU countries will accomplish the dissemination.

Main literature produced

At the end of the DELOS project the main deliverable D59 was still in a preliminary draft version.

Comparison between planned and used manpower during the three Years of DELOS Project for each Work Package and Partner

DELOS WP			Manpower Table – Three Years																	
WP List			Person-months per participant																	
			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
1.1	Inventory of engineering properties of LCS	***Planned***	**6**		**3**	**3**	**3**		**0.5**	**1**		**3.5**				**0.5**		**2**	**2**	
		Used 1st year	6		2.5	3	3		0.5	1		3.5				0.4		2	2	
		Used 2nd year	0		0.5	0	0		0	0		1.22				0.1		0		
		Used 3rd year	**0**		**0**	**0**	**0**		**0**	**0**								**0**		
1.2	Ecological pilot studies	***Planned***		**4**							**2**		**4**				**3**			
		Used 1st year		4							2		4				3			
		Used 2nd year		0							0		0				0			
		Used 3rd year		**0**							**0**		**0**				**0**			
1.3	Inventory of economic models to value the environment	***Planned***	**4**											**4**						
		Used 1st year	4											4						
		Used 2nd year	0											0						
		Used 3rd year	**0**											**0**						
2.1	Flow description	***Planned***	**15**		**12**		**9**	**9**	**4-6.3**	**12-17**		**8**			**2**	**0.5**			**11**	
		Used 1st year	6		5.5		3	3	3	1		2.72			1	0.4			7	
		Used 2nd year	6		4		3	3	2.8	16		4			1	0.1			3	
		Used 3rd year	**3**		**10**		**3**	**3**	**0.5**	**12**		**1**							**1**	

Comparison between planned and used manpower during the three Years of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
2.2	Morphodynamics	***Planned***			**9**	**8**		**9**	**7**			**18**						**4**		
		Used 1st year			3.5	4		3	0.56			5.5						3		
		Used 2nd year			3.5	3		3	1.05			3.5						0.5		
		Used 3rd year			**2**	**1**		**3**	**5.4**			**3.8**						**0.5**		
2.3	LCS Design	***Planned***	**5**		**4**	**2**	**2.5-4.5**			**4**						**0.5**			**6**	
		Used 1st year	0		0	0	0.5			0						0.1			0	
		Used 2nd year	0		2	0.5	1			4.5						0.4			4	
		Used 3rd year	**5**		**4**	**1.5**	**3**			**1**						**0**			**2**	
2.4		***Planned***	**34**		**9**		**19.5**	**9**	**1-0**	**20-15**		**10**				**0.9**				
		Used 1st year	10		3		6	2	0	15		7				0				
		Used 2nd year	22		5		13.5	4	0	7.4		8.5				0.8				
		Used 3rd year	**2**		**0**		**0**	**3**		**0**		**0**				**0.7**				
2.5	Prototype observations and hindcasting	***Planned***	**14**		**9**	**8**	**1**								**1**			**22**		
		Used 1st year	6		2	2	1								1			12		
		Used 2nd year	8		3	3	0								0			6		
		Used 3rd year	**4**		**4**	**3**	**0**								**0**			**4**		

Comparison between planned and used manpower during the three Years of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
3.1	Effects on soft-bottom assemblages	***Planned***		**17**							**36**				**3**		**12-13**			
		Used 1st year		5							12				1		5			
		Used 2nd year		12							15				2		7			
		Used 3rd year		**12**							**9**				**1.7**		**1**			
3.2	Effects on breakwater epibiota	***Planned***		**34**			**3.5-1.5**				**8**						**15-16**	**5**		**11**
		Used 1st year		7			0.3				5.3						6	0		2.1
		Used 2nd year		16			0.7				2						7	5		0.9
		Used 3rd year		**15**			**0.5**				**0.7**						**3**	**0**		**8.0**
3.3	Effects on mobile fauna and human usage	***Planned***		**6**							**16**						**7**	**5**		
		Used 1st year		1							5.3						2	0		
		Used 2nd year		5							5.3						3	5		
		Used 3rd year		**0**							**5.4**						**2**	**0**		
3.4	Large-scale effects of breakwater spatial arrangement	*Planned*		**28**							**10**		**4**				**3-1**			
		Used 1st year		4							2.7		1				0.5			
		Used 2nd year		20							5		3				0.5			
		Used 3rd year		**16**							**2.3**		**0**				**0**			

Comparison between planned and used manpower during the three Years of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
3.5	Ecological modelling of breakwater impacts	*Planned*		**1**							**7.5**		**32**		**4.3**		**1**			
		Used 1st year		0							0.7		16		1.3		0.1			
		Used 2nd year		0							5		10		3		0.5			
		***Used* 3rd year**		**1**							**1.8**		**6**		**0**		**0.4**			
4.1	Extracting a Benefit Transfer Function from CV studies	*Planned*	**6-0**		**2**									**6 - 5**						
		Used 1st year			0									4						
		Used 2nd year			0									1						
		***Used* 3rd year**			**0**									**0**						
4.2	Case studies on monetary valuation of environmental changes	*Planned*	**11-17**		**3**									**7 - 8**						
		Used 1st year	6		0									1						
		Used 2nd year	7		2									5.6						
		***Used* 3rd year**	**4**		**1**									**2.4**						
5.1	Performance-related inputs to guidelines	*Planned*	**3**	**2**			**3**		**1.5-0.87**	**2**		**0.5**	**2**	**1**	**1**		**2**			
		Used 1st year	0	0			0		0	0		0	0	0	0		0			
		Used 2nd year	0	0.5			0		0	0		0	0	0	0		0.5			
		***Used* 3rd year**	**3**	**1.5**			**0**		**0.87**	**2**			**2**	**1.5**	**1**		**1.5**			

Comparison between planned and used manpower during the three Years of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
5.2	Example applications of the design guidelines to typical site conditions	*Planned* 1st year	**13**	**2**	**2**	**1**	**1.5**		**1-0.5**		**2**	**1**			**3**		**2**	**1**		
		Used 1st year	0	0	0	1	0		0		0	0			0		0	0		
		Used 2nd year	0	0	0	0	0		0		0	0			0.5		0	0.5		
		Used 3rd year	**13**	**2**	**2**	**0**	**1.5**		**0.5**		**2**				**1**		**2**	**0.5**		
5.3	Formulation of guidelines for multi-performance design	*Planned*	**5**				**5.5**	**3**		**2**		**1**	**2**	**1**		**0.6**		**1**	**2**	
		Used 1st year	0				0	0		0		0	0	0		0		0	0	
		Used 2nd year	0				0	0		0		0	0	0		0		0.5	0	
		Used 3rd year	**5**				**5.5**	**3**		**3**			**2**	**1**		**0.6**		**0.5**	**2**	
6.1	Meetings, workshops and reporting	*Planned*	**11**	**4**	**3**	**1**	**4**	**3**	**1**	**3**	**3.5**	**3**	**3**	**3**	**1**	**1**	**2**	**3**	**5**	**0.5**
		Used 1st year	3	1	0	0	1.3	1	0.33	0.8	0.6	1	1	1	0.3	0.4	1	1	3	0.3
		Used 2nd year	4	1	0	0	1.7	1	0.33	2.2	1.5	0.5	0	1	0.4	0.3	0.5	1	1	0
		Used 3rd year	**4**	**3.5**	**3**	**1**	**1**	**1**	**0.33**	**0.5**	**1.4**	**0.2**	**2**	**1**	**0.3**	**0.3**	**0.5**	**1**	**1**	**0.2**
6.2	Dissemination	*Planned*	**7**	**1**		**1.5**				**1**	**2**		**1**	**1**			**1**	**1**		
		Used 1st year	3	0		0				0.2	0		0	0			0.2	0.3		
		Used 2nd year	2	0.5	0.5	0				0.4	1		0	0			0.2	0.3		
		Used 3rd year	**2**	**3**	**0.5**	**1.5**				**0.4**	**1**		**1**	**2**			**0.6**	**0.4**		

Comparison between planned and used manpower during the three Years of DELOS Project for each Work Package and Partner

		UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
Total	*Planned*	**134**	**99.0**	**56**	**24.5**	**50.0**	**33.0**	**16.0**	**45.0**	**87.0**	**42.0**	**52.0**	**23.0**	**15.5**	**4.0**	**48.0**	**44.0**	**26.0**	**11.5**
	Used 1st year + 2nd year + *3rd year* = *Sum*	44 + 49 + 45 = **138**	22.0 + 55 + 54 = **131.0**	17 + 20.5 + 26.5 = **63.5**	10 + 6.5 + 8 = **24.5**	14.8 + 19.9 + 17.5 = **52.5**	9.0 + 11 + 13 = **33**	4.39 + 4.19 + 7.6 = **16.18**	18.00 + 30.5 + 18.9 = **67.4**	28.6 + 34.8 + 23.6 = **87**	19.72 + 17.72 + 5 = **42.44**	23 + 17 + 13 = **53**	10.0 + 7.6 + 7.9 = **25.5**	4.6 + 6.9 + 4 = **15.5**	1.3 + 1.7 + 1.6 = **4.6**	17.8 + 19.2 + 11 = **48**	18.3 + 18.8 + 6.9 **44**	12.0 + 8 + 6 = **26**	2.1 + 0.9 + 8.5 = **11**

Financial resources used during the 3 Years of DELOS Project for each Work Package and Partner

DELOS WP			**Financial Table – Three Years**																	
WP List			**Financial resources (Euro) per participant for the 3 years reporting period**																	
			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
1.1	Inventory of engineering properties of LCS	*Used* 1st year	7.409		3.683	10.274	11.115		5.382	576		22.944				6.400		15.054	3.475	
		Used 2nd year			1242.59				0			3542,15				1160.3		0		
		Used 3rd year																		
1.2	Ecological pilot studies	*Used* 1st year		3.000							8.189		22.000				6.673			
		Used 2nd year																		
		Used 3rd year																		
1.3	Inventory of economic models to value the environment	*Used* 1st year	4.229											55.056						
		Used 2nd year																		
		Used 3rd year																		
2.1	Flow description	*Used 1st year*	7.240		16.270		11.115	5802	32292	696		13.059			26.134	6.400			18.640	
		Used 2nd year	13839.7		9940.68			12.125	36856	29701.54		21336,11			17068.1	1160.3			6300	
		Used 3rd year	9297.54		6660.00			18647	3508	25481.79		5922							2100	
2.2	Morphodynamics	*Used* 1st year			4.296	8.402		5803	6.229			26.541						22.581		
		Used 2nd year			8698.1	8954.58		12.125	13772			20942,3						2224		
		Used 3rd year			1332.00	2356.60		18647	37880			28514.43						930		

Financial resources used during the 3 Years of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
2.3	LCS Design	*Used* 1st year					1.853			0						1.600				
		Used 2nd year			4970.34	1492.43				6016.63									8400	
		Used 3rd year	16057.11		2664.00	3534.91	308			6380									2100	
2.4		*Used* 1st year	12.277		10.449		22.231	5803		9.886		25.519								
		Used 2nd year	50745.86		12425.85		924	12.125	0	10877.29		36.925,94				9282.4				
		Used 3rd year	5917.75					18647								7000				
2.5	Prototype observations and hindcasting	*Used* 1st year	5.051			6.300	3.705											90.323		
		Used 2nd year	18453.04		7455.51	8954.58				3654.36					0			26684		
		Used 3rd year	12677.33		2664.00	7069.81												7450		
3.1	Effects on soft-bottom assemblages	*Used* 1st year		7.800							49.152				26.134		10.211			
		Used 2nd year		15428							47705.61				34136.230		17300			
		Used 3rd year		9271							37189.66				16646		13459			
3.2	Effects on breakwater epibiota	*Used* 1st year		14.800			1.112				21.704		5.500				17.673			6.729
		Used 2nd year		17313			7.748				21065.14		8 500				17350	0		8.452
		Used 3rd year		19544							2896.00						24710			47554.85

Financial resources used during the 3 Years of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
3.3	Effects on mobile fauna and human usage	*Used* 1st year		2.000							21.704						6.586			
		Used 2nd year		5395							21065.14						7726	0		
		Used 3rd year									22309.90						18329			
3.4	Large-scale effects of breakwater spatial arrangement	*Used* 1st year		7.600							11.055		5.500				2.015			
		Used 2nd year		24050							10730.36		8 500				2214			
		Used 3rd year		32918							9507.06									
3.5	Ecological modelling of breakwater impacts	*Used* 1st year									13.513		35.466		33.975		1.306			
		Used 2nd year									13116.26		36 341		51204.35		2214			
		Used 3rd year		2000							7430.14		49000				4993			
4.1	Extracting a Benefit Transfer Function from CV studies	*Used* 1st year												55.056						
		Used 2nd year												12000						
		Used 3rd year																		
4.2	Case studies on monetary valuation of environmental changes	*Used* 1st year	2.680											13.765						
		Used 2nd year	16146.41		4970.34									67300						
		Used 3rd year	12677.33		666.00									22189						

Financial resources used during the 3 Years of DELOS Project for each Work Package and Partner

			UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
5.1	Performance-related inputs to guidelines	*Used* 1st year																		
		Used 2nd year		863					0	3654.36					0		2214			
		Used 3rd year	9297.54	1250					6103	7860			7000	13868	9792		15074			
5.2	Example applications of the design guidelines to typical site conditions	*Used* 1st year				1.800														
		Used 2nd year							0						8534.06			2224		
		Used 3rd year	22816.69	1500	1332.00	1178.3			5612		8258.96				9792		18528	930		
5.3	Formulation of guidelines for multi-performance design	*Used* 1st year																		
		Used 2nd year						0										2224		
		Used 3rd year	16057.26					18647		16160			14000	9245		4672		930	2100	
6.1	Meetings, workshops and reporting	*Used* 1st year	15.685	5.040	4.715		6.469	4.868	8.494	2.088	2.051	5.078	7.000	6.556	4.017	8.862	7.941	5.108	5.420	1.972
		Used 2nd year	9226.52	3517			2.567	809	7159	8868.98	1990.31	5.249,41	7 439	6207	6827.25	3480.9	4711	4448	6878	
		Used 3rd year	26196.47	9935	1998.00	2356.6	6819	9160	2315	22617.79	5782.24	9901.7	20500	9245	2938	3000	10160	1860	2100	
6.2	Dissemination	*Used* 1st year	2.625			462				696		670					1.549	2.258		
		Used 2nd year	4613.26	3450	1242.85					5636.06			1 000				1635	1333		
		Used 3rd year	12677.18	3683	333.60	1178.3				12834.94	4134.36		7000	18491			6769	744		

Financial resources used during the 3 Years of DELOS Project for each Work Package and Partner

		UB	FF	UR3	MOD	AAU	ISVA	DHI	UCA	CSIC	UPC	UGOT	UTW	DH	INF	MBA	US	AUTH	BIAU
Total	Used 3 years	313893	190357	108007	64313	75965	143207	163498	173685	348499	225475	234746	300468	226428	53018	221340	187304	61829	64707

In blue: Total cost with UE financial contribution of 50%

		UB as COO
Total co-ordination costs	Used 3 years	63318