FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Concursos de Projectos de I&D
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Referência do projecto
Project reference
PTDC/MAR/64627/2006

1. Identificação do projecto
1. Project description -

Financiamento solicitado
Requested funding
199.679,00 Euros

Área científica principal
Main Area
Ciências e Tecnologias do Mar

Área científica Secundária
Secondary area

Título do projecto (em português)
Project title (in portuguese)
Resposta dinâmica do sistema a um amplo restabelecimento artificial da ligação a montante entre os dois braços do estuário do Mondego (Portugal): Implicações para a recuperação, estado ecológico e gestão

Título do projecto (em inglês)
Project title (in english)
System dynamic response to an ample artificial RE-establishment of the upstream CONNECTion between the two arms of the Mondego estuary (Portugal): Implications for recovery, ecological quality status, and management (RECONNECT)

Palavra-chave 1	**Keyword 1**
Estuário eutrofizado	Eutrophic estuary
Palavra-chave 2	**Keyword 2**
Hidrodinâmica	Hydrodynamics
Palavra-chave 3	**Keyword 3**
Recuperação/Resiliência	Recovery/Resilience
Palavra-chave 4	**Keyword 4**
Estado Ecológico	Ecological Quality Status

Objectivos sócio-económicos

Socio-economic objectives

Ambiente

Data de início do projecto **Starting date**	**Duração do projecto em meses** **Duration in months**
01-01-2007	36

2. Instituições participantes
2. Participating institutions

Instituição Proponente
Principal Contractor

Instituto do Mar (IMAR)
Departamento de Zoologia - Faculdade de Ciências e Tecnologia da Universidade de Coimbra
3004-517Coimbra

Instituições Participantes
Participating Institutions

Fundação da Faculdade de Ciências (FFC/FC/UL)
Campo Grande - Edificio C7 -1º Piso
1749-016Lisboa

Unidade de Investigação
Principal Research Unit

Instituto do Mar, Centro Interdisciplinar de Coimbra (IMAR Coimbra/IMAR)
Departamento de Zoologia
3004-517Coimbra

Instituição de Acolhimento
Host Institution

Instituto do Mar (IMAR)
Departamento de Zoologia - Faculdade de Ciências e Tecnologia da Universidade de Coimbra
3004-517Coimbra

3. Orçamento
3. Budget

Instituição Proponente
Principal Contractor

Instituto do Mar

DESCRIÇÃO DESCRIPTION	2007	2008	2009	2010	2011	**TOTAL**
Recursos Humanos Human resources	30615	30615	30615	0	0	91845
Missões Missions	3400	3400	4400	0	0	11200
Consultores Consultants	0	4000	4500	0	0	8500
Aquisição de serviços e manutenção Acquisition of services and maintenance	0	0	0	0	0	0

Outras despesas correntes Other current expenses	7900	7400	4000	0	0	19300
Despesas gerais Overheads	5158	4572	4452	0	0	14182
Equipamento Equipment	9660	300	1000	0	0	10960
TOTAL	56733	50287	48967	0	0	**155987**

Instituições Participantes
Participating Institutions

Fundação da Faculdade de Ciências

DESCRIÇÃO DESCRIPTION	2007	2008	2009	2010	2011	TOTAL
Recursos Humanos Human resources	10205	10205	0	0	0	20410
Missões Missions	3000	3000	1500	0	0	7500
Consultores Consultants	0	0	0	0	0	0
Aquisição de serviços e manutenção Acquisition of services and maintenance	3000	3000	0	0	0	6000
Outras despesas correntes Other current expenses	1000	1000	500	0	0	2500
Despesas gerais Overheads	3441	3441	400	0	0	7282
Equipamento Equipment	0	0	0	0	0	0
TOTAL	20646	20646	2400	0	0	**43692**

Orçamento Global
Global budget

DESCRIÇÃO DESCRIPTION	2007	2008	2009	2010	2011	**TOTAL**
Recursos Humanos Human resources	40820	40820	30615	0	0	112255
Missões Missions	6400	6400	5900	0	0	18700
Consultores Consultants	0	4000	4500	0	0	8500
Aquisição de serviços e manutenção	3000	3000	0	0	0	6000

Acquisition of services and maintenance						
Outras despesas correntes Other current expenses	8900	8400	4500	0	0	21800
Despesas gerais Overheads	8599	8013	4852	0	0	21464
Equipamento Equipment	9660	300	1000	0	0	10960
TOTAL	77379	70933	51367	0	0	**199679**

Plano de financiamento
Finance plan

DESCRIÇÃO DESCRIPTION	2007	2008	2009	2010	2011	**TOTAL**
Financiamento solicitado à FCT Requested funding	77379	70933	51367	0	0	199679
Financiamento próprio Own funding	0	0	0	0	0	0
Outro financiamento público Other public-sector funding	0	0	0	0	0	0
Outro financiamento privado Other private funding	0	0	0	0	0	0
Total do Projecto **Total of the project**	77379	70933	51367	0	0	**199679**

4. Justificação do orçamento
4. Budget justification

-

4.1. Justificação dos recursos humanos
4.1. Human resources justification

Tipo	Nº de pessoas	Duração	Custo envolvido (€)
(BI) Bolsa de Investigação (Lic. ou Bacharel)	2	36	61230

Justificação

The project will mobilize important human resources, including the researchers with the necessary expertises to successfully to accomplish the different tasks. Nevertheless, it will be indispensable to involve in the project enough human resources to execute routine field and laboratory works, which will be achieved through grants.

Tipo	Nº de pessoas	Duração	Custo envolvido (€)
(BI) Bolsa de Investigação (Lic. ou Bacharel)	2	24	40820

Justificação

The project will mobilize important human resources, including the researchers with the necessary expertises to successfully to accomplish the different tasks. Nevertheless, it will be indispensable to involve in the project enough human resources to execute routine field and laboratory works, which will be achieved through grants.

Tipo	Nº de pessoas	Duração	Custo envolvido (€)
(BI) Bolsa de Investigação (Lic. ou Bacharel)	1	12	10205

Justificação

The project will mobilize important human resources, including the researchers with the necessary expertises to successfully to accomplish the different tasks. Nevertheless, it will be indispensable to involve in the project enough

human resources to execute routine field and laboratory works, which will be achieved through grants.

Custo total: 112255

4.2. Justificação de missões
4.2. Mission justification

Tipo	Local	Nº de deslocações	Custo envolvido (€)
Trabalho de campo	Estuário do Mondego	24	18700

Justificação

Data necessary to achieve the different tasks will be provided by the existent database and by field work, which will be entirely carried out in the Mondego estuary. Therefore, researchers from Instituto de Oceanografia (IO-FCUL) will need to travel regularly in order to get their work done. The same applies to the MARETEC team, which despite belonging to the IMAR network is located at IST-UTL, in Lisbon.

Custo total: 18700

4.3. Justificação de consultores
4.3. Consultants justification

Nome	Instituição	Fase do projecto	Custo envolvido (€)
BORJA Angel	AZTI - Tecnalia, Spain	Second and third years of the project	4250

Justificação

Angel Borja, Ph.D, from AZTI – Tecnalia, Centro Tecnologico, Spain, will be consultant. The justification for his involvement in the project is related with his expertise, and also with previous and profitable scientific cooperation. Angel Borja is a known expert on ecological indicators, having developed AMBI (see task 8).

Nome	Instituição	Fase do projecto	Custo envolvido (€)
NIQUIL Nathalie	University of La Rochelle, France	Second and third years of the project	4250

Justificação

Professor Nathalie Niquil, from the La Rochelle University, France, will be consultant. The justification for her nvolvement in the project is related with her expertise, and also with previous and profitable scientific cooperation. Nathalie Niquil is a modeller with large experience on food web models and in integrating in models the results from δ13C and δ15N analysis (see tasks 7 and 8).

Custo total: 8500

4.4. Justificação de aquisição de serviços e manutenção
4.4. Acquisition of services and maintenance justification

Tipo	Custo envolvido (€)
Fishermen assistance in field work	6000

Justificação

The funding requested in this item will mainly support the costs related with the acquisition of ship time for the fishing operations

Custo total: 6000

4.5. Justificação de outras despesas correntes
4.5. Current expenses justification

Tipo de despesa	Custo envolvido (€)
Field and laboratory consumables	20000

Justificação

The funding requested in this item will be mainly used to buy chemicals and plastic containers used in the field and in the laboratory for preservation and processing of the biological material.

Tipo de despesa	Custo envolvido (€)
Office and informatic consummables	1800
Justificação	
The funding requested in this item will be used for the acquisition of the office and informatic material necessary to perform the data analysis and the production of reports.	

Custo total: 21800

4.6. Justificação do Equipamento
4.6. Equipment justification

4.6.1. Equipamento já disponível para a execução do projecto
4.6.1 Available equipment

Tipo de equipamento	Fabricante	Modelo	Ano
Working car	Nissan	Patrol	1997
Working car	Volkswagen	Transporter	1996
Working car	Citroen	Berlingo	2002
Pneumatic boat (3.4 m)	Valiant	Dynamic-340	1998
2 Working boats	Figueira EATES	Trident 3.80	2002
Outboard engine (15 cp)	Honda	Honda Marine BF15	1998
Outboard engine (25 cp)	Yamaha	Yamaha	1996
Cameras, Videos, binocular glasses, telescopes etc	Sony + Zeiss	Not applicable	1990
Manual corers for fauna sampling	Auto Fabrication	Not applicable	1990
Phytoplankton samplers	COMARTEC	Not applicable	1990
Zooplankton and ichthyoplankton samplers	COMARTEC	Not applicable	1990
Fishing devices	Fábrica de Redes de Redes de Pesca	Not applicable	1990
Van Veen drags	Comartec	S.R. model	1994
Ponar grab	Comartec	?	2002
Kajak corer	KC-Denmark	KajaK 3030	2006
Alpha Water Bottle Horizontal	Wildco	NA	2001
Multiparameter probe	YSI	600 XLM	2001
Multiparameter probe	YSI	6600	2004
Multiparameter probe with nitrate sensor	YSI	6600	2004
Multiparameter probe with nitrate sensor	YSI	6820	2006

Datalogger	Promotecnica	NA	2004
Sistema ADCP	Vórtice Lda	Stream Pro	2004
Nutrients Automatic Analyser	SYSTEA	DPA nutrients	2004
Portable photon flux metter	LI-COR	LI-1000	1996
Salinity, Temperature and Conductivity probes	WTW	Cond 330i/SET	2003
pH probes	WTW	Ph 330i/SET	2002
Oxygen probes	WTW	Oxi 330i/SET	2003
Current meters	Valeport	Valeport model 105	1999
Current meters	Hydro-Bios	RHLM	2002
GPS units	Magellan	Meridian GPS	2004
Laser rangefinder	Bushnell	Bushnell Yardage Pro 1000	2002
2 Rooms with controlled temperature	NA	NA	1992
Facilities for keeping living organisms' populations at the laboratory	Auto Fabrication	Not applicable	1990
Facilities for water and sediments analysis	Reagente 5	Not applicable	1990
Flume with accessory equipments	NA	NA	1993
Laminar flow chamber	NA	NA	1994
Orbital agitators	NA	NA	1991
Centrifugues	Heraus	several	2004
Optical spectrophotometer	Milton Roy	Spectronic 601	1992
Microbalance (in installation phase)	Mettler	UMX2	2007
Semi-micro calorimeter	Parr	Parr 1425	1996
Freeze-Dryer (in installation phase)	Snijders	Model LY3TTE	2006
Hotte	N/A	N/A	1992
Microscopes	Leitz (Leica)	Laborlux K and Diaplan	1990
Dissecting microscopes	Wild (Leica)	M3, M5, and M8	1990
Dissecting microscopes	Leica	Leica MZ12	2004
Image acquisition	Leica	Leica DFC280	2004

Stoves (150 l)	Selecta, Heraeus	N/A	1998
Muffles	Nabertherm, Heraeus	N/A	1996
Spectrofotometers UV	Shimadsu	UV 1601	2001
Gas Chromatograph	Hewlet- Packard	HP 5890 series II	1992
TOC and TN analyser	Elementar	Liqui TOC	2006
Ionic Chromatograph	DIONEX	DX120	2001
HPLC SUNMIT	DIONEX	UVD 340S	2001
Isotope Ratio Mass Spectrometer (in installation phase)	Thermo Electron	Delta V Plus	2007
Computing facilities and peripherals	White Line	Not applicable	2004
Working car	NISSAN	Vanette	1994
Working car	Renault	Express	1997

4.6.2. Discriminação do equipamento a adquirir
4.6.2. List of new equipment requested

Tipo de equipamento	Fabricante	Modelo	Custo envolvido (€)
Computer	NA	NA	4300
Justificação			
A computer will be bought in the first year. In the second year some money is foreseen for minor equipments and in the third year for a computer upgrade.			
Plankton nets	NA	NA	6660
Justificação			
Very small field equipment will be acquired for this project. It will consist of plankton nets, to replace some of the existent ones, which are already deteriorated, some accessories (e.g. flux meters).			

Custo total: 10960

5. Equipa de investigação
5. Research team

5.1 Lista de membros (22)
5.1. Members list (22)

Nome **Name**	**Função** **Role**	**Grau académico** **Academic degree**	**%tempo** **%time**
João Carlos Sousa Marques	Inv. Responsável	Aggregation	30
Maria José Rosado Costa	Investigador	Catedrático	10
Henrique Manuel Roque Nogueira Cabral	Investigador	DOUTORAMENTO	5
Ulisses Manuel de Miranda Azeiteiro	Investigador	AGREGAÇÃO	20

Maria Helena Soares Martins Adão	Investigador	DOUTORAMENTO	30
Maria Sofia Júdice Gamito Pires	Investigador	DOUTORAMENTO	25
Ramiro Joaquim Jesus Neves	Investigador	DOUTORAMENTO	15
Fuensanta Salas Herrero	Investigador	DOUTORAMENTO	20
Irene Isabel Cruz Martins	Investigador	DOUTORAMENTO	30
Joana Mateus Patrício	Investigador	DOUTORAMENTO	30
João Miguel Magalhães Neto	Investigador	DOUTORAMENTO	20
José Lino Vieira de Oliveira Costa	Investigador	DOUTORAMENTO	10
Paula Bacelar Valente da Costa Nicola...	Investigador	DOUTORAMENTO	20
Pedro Miguel Nogueira de Pina	Investigador	MESTRADO	20
Maria João da Silva Martins	Investigador	MESTRADO	20
Alexandra Sofia Baptista Vicente Baet...	Bolseiro	MESTRADO	80
Heliana Lilita Gonçalves Teixeira	Bolseiro	MESTRADO	50
Helena Leite Veríssimo de Carvalho	Bolseiro	LICENCIATURA	80
Rute Isabel Costa Pinto	Bolseiro	LICENCIATURA	80
Tiago Gonçalo Martins Verdelhos	Bolseiro	MESTRADO	20
Elsa Teresa Santos Rodrigues	Outro	MESTRADO	50
Maria Gabriel Fontes Marques	Outro	LICENCIATURA	30

(O curriculum vitae de cada membro da equipa está disponível clicando no nome correspondente)
(Curriculum vitae for each research team member is available by clicking on the corresponding name)

5.2. Lista de membros a contratar durante a execução do projecto (5)
5.2. Members list to hire during project's execution (5)

Membro da equipa **Team member**	**Função** **Role**	**Duração** **Duration**	**% tempo** **% time**
(BI) Bolseiro de Investigação (Lic. ou Bacharel) 1	Bolseiro	36	100
(BI) Bolseiro de Investigação (Lic. ou Bacharel) 2	Bolseiro	36	100
(BI) Bolseiro de Investigação (Lic. ou Bacharel) 3	Bolseiro	24	100
(BI) Bolseiro de Investigação (Lic. ou Bacharel) 4	Bolseiro	24	100
(BI) Bolseiro de Investigação (Lic. ou Bacharel) 5	Bolseiro	12	100

6. Projectos financiados
6. Funded projects

-

Lista de projectos financiados (3)
Funded projects list (3)

Referência	**Título**	**Estado**
POCI/MAR/61324/2004	Efeitos dos caudais dulciaquíc...	Em curso

POCI/CLI/58348/2004	Clima Costeiro Presente e Futu...	Em curso
POCI/AMB/59262/2004	Efeitos da bioturbação nos cic...	Em curso

(Os detalhes de cada projectos estão disponíveis clicando na referência correspondente)
(Details for each project are available by clicking on the corresponding reference)

7. Indicadores previstos
7. Expected indicators

-

Indicadores de realização previstos para o projecto
Expected output indicators

Dados temporariamente indisponíveis

8. Anexo técnico
8. Technical addendum

-

8.1. Resumo
8.1. Abstract

Resumo (em português)
Abstract (in portuguese)

Desde o início da década de 1960, a bacia hidrográfica do Mondego sofreu uma modificação morfológica artificial em larga escala a qual visou: a) controlar as cheias, b) optimizar o uso da água, nomeadamente para populações, indústrias e agricultura, e c) produzir energia eléctrica. Tal causou um forte impacto antrópico, modificando a topografia do rio e alterando a hidrodinâmica do sistema.

A drenagem da bacia hidrográfica converge obviamente para o estuário, transportando uma elevada descarga de nutrientes. O estuário é, além disso, local de actividades industriais, salinas e explorações aquícolas, sendo ainda a localização da Figueira da Foz, porto importante e centro de actividades turísticas sazonais.

O estuário apresenta dois braços, norte e sul, com condições hidrográficas muito diferentes. No início da década de 1990, o braço sul estava bastante assoreado a montante, ocorrendo a descarga de água doce essencialmente pelo braço norte. No braço sul, a circulação devia-se essencialmente às marés e à pequena descarga de água doce do rio Pranto, um tributário, artificialmente controlada por uma comporta. Uma nova intervenção, ocorrida em 1990-1992, interrompeu totalmente a comunicação entre os dois braços a montante.

Apesar de todas as modificações anteriormente introduzidas no curso natural do rio, não tinham sido detectados sintomas de eutrofização no estuário até ao início da década de 1990. No entanto, após a total interrupção da comunicação entre os dois braços, a montante, verificou-se uma rápida deterioração das condições ecológicas no braço sul. O efeito conjugado de um maior tempo de residência da água e da concentração de nutrientes tornou-se determinante no surgimento de claros sintomas de eutrofização. Foi observada a ocorrência de grandes exuberâncias de Ulva spp e, paralelamente, uma severa redução da área ocupada por Zostera noltii, especialmente entre 1991 e 1997, provavelmente devido a competição com as algas. Com o tempo, esta mudança nos produtores primários causou alterações na composição específica das comunidades e induziu a emergência de uma nova estrutura trófica.

Para diminuir os sintomas de eutrofização e testar maneiras de melhorar o estado ecológico do sistema, uma intervenção, em pequena escala, foi conduzida em 1998: a) O fluxo da comporta do Pranto para o braço sul foi reduzido ao mínimo, para diminuir a descarga de nutrientes; b) A comunicação entre os braços norte e sul foi restabelecida, de forma limitada, para melhorar a circulação hidráulica.

Após o limitado restabelecimento da comunicação entre os dois braços, verificou-se alguma recuperação da área ocupada por Zostera noltii, tendo igualmente cessado as exuberâncias de Ulva spp, sugerindo que um completo restabelecimento da comunicação entre os dois braços poderia conduzir a uma melhoria da qualidade ecológica do sistema, permitindo a circulação de um volume de água muito maior no braço sul, diminuindo o tempo de residência da água e aumentando a capacidade de transporte. Tal medida, aliás concordante com a nova "Estratégia Marinha Europeia, foi proposta, subsequentemente aprovada e implementada na Primavera de 2006. Esta intervenção no

sistema criou uma rara oportunidade de, através da investigação da resposta do ecossistema, obter inestimáveis conhecimentos teóricos e práticos.

Os objectivos do projecto são:

a) Validar um modelo físico, anteriormente calibrado (incluindo o transporte de sedimentos, coesivos e não coesivos), simulando a evolução da morfologia do estuário após a intervenção;

b) Validar um modelo de qualidade da água e do crescimento de macroalgas, anteriormente calibrado, avaliando as condições tróficas do sistema no novo cenário hidrodinâmico;

c) Analisar a resposta estrutural e funcional das comunidades biológicas às novas condições físicas, avaliando a recuperação e a resiliência do sistema;

d) Seguir as mudanças de qualidade ecológica em curso e avaliar o novo estado de qualidade ecológica daí resultante, através da aplicação de múltiplos indicadores;

e) Determinar em que medida o novo estado ecológico do sistema satisfaz as exigências das directivas Europeias, avaliando o potencial da intervenção ocorrida em termos de políticas e práticas de gestão de águas costeiras e de transição.

Para prossecução dos objectivos, estará disponível uma base de dados bastante completa sobre o estuário do Mondego (últimos 15 anos), que será complementada com novos dados. Qualidade da água, bentos, plâncton e peixes serão tidos em conta na avaliação da resposta do sistema. Alterações na origem dos nutrientes usados na produção primária serão investigadas através da análise de δ13C e δ15N e serão desenvolvidos modelos da cadeia trófica. Os períodos antes e depois da intervenção serão comparados em termos de: a) hidrodinâmica e qualidade da água; b) Estado ecológico.

Os resultados serão cientificamente relevantes, em termos teóricos e práticos, e terão repercussões sócio-económicas directas para a Região Centro de Portugal.

Resumo (em inglês)

Abstract (in english)

Since the 1960s, the Mondego catchment area underwent a large scale artificial morphological modification aiming at: a) control floods, b) improve the uses of water resources, namely regarding populations, industries, and agriculture, and c) produce electric power. This caused a strong anthropogenic impact in to the system, modifying the riverbed topography and changing the system hydrodynamics.

Drainage from the entire catchment area converges in the estuary, representing a high anthropogenic loading of nutrients. Besides, the estuary supports industrial activities, salt-works, and aquaculture farms, and is location of Figueira da Foz, a harbour and a centre of seasonal touristic activity.

The estuary consists of two arms, north and south, with very different hydrographic characteristics. In the early 1990s the south arm was rather silted up in the upstream areas, which caused the Mondego outflow to run essentially through the north arm. The water circulation in the south arm was mostly due to tides and to the relatively small fresh water input of a tributary, the Pranto River, which was artificially controlled by a sluice. Subsequently, an engineering intervention carried out in 1990-1992 totally interrupted the communication between the two arms.

Despite all the previous changes introduced in the natural river course, the estuary did not exhibit noticeable eutrophication symptoms until the early 1990s. But the interruption of the communication between the two arms caused a rapid deterioration of ecological conditions in the south arm. The combined effect of increased water residence time and nutrients concentration became major driving forces, causing the emergence of clear eutrophication symptoms. The occurrence of large seasonal macroalgal blooms (mostly Ulva spp.) has been reported. Concomitantly, the area occupied by Zostera noltii beds suffered a severe reduction, especially from 1991 to 1997, presumably, as a function of competition with Ulva. Through time, such shift in the benthic primary producers caused a perceptible change in species composition and induced the emergence of a new selected trophic structure.

A small scale experimental intervention took place in 1998, aiming at decrease the eutrophication symptoms and test ways of ameliorating the system's condition: a) The Pranto river sluice freshwater discharge in to the south arm was reduced to a minimum to decrease nutrients discharge; b) The communication between the north and south arms was re-established into a very limited extent to improve water circulation.

After this small scale intervention, the area occupied by Zostera noltii partially recovered and green macroalgae (Ulva spp.) blooms ceased. This suggested that an ample re-establishment of the communication between the two arms could drive to an improvement of the system ecological quality by allowing the circulation of a much larger volume of water in the south arm, decreasing the residence time and increasing the transport capacity. Such measure, fully compliant with the new European Marine Strategy, was proposed and subsequently approved, and its implementation was carried out during the spring of 2006. This system's management intervention created a rare opportunity to obtain inestimable new theoretical and empirical knowledge by investigating the ecosystem's response, which is indeed a must.

The objectives of the project are:

a) Validate a previously calibrated physical model, including cohesive and non-cohesive sediments transport, simulating the evolution of the estuarine morphology after channels intervention;

b) Validate a previously calibrated water quality and macroalgae model, assessing the system's trophic conditions in the new hydrodynamic scenario;

c) Analyse the structural and functional responses of the biological communities in the new physical conditions, assessing the system's recovery and resilience;

d) Follow the ecological quality changes and evaluate the resulting ecological quality status through the application of multiple indicators;

e) Examine the compliance of the system's new ecological quality status with different European directives assessing the potential of the applied approach for coastal and transitional waters management policy and practice.

To help achieving these objectives, a comprehensive database on the Mondego estuary over the previous 15 years is available. Additionally, water quality, benthos, plankton, and fish will be surveyed for their response in the new conditions. Changes regarding sources of nutrients for primary production will be investigated from δ13C and δ15N analysis, and steady state food web models will be developed. Periods before and after the intervention in the estuary will be compared with regard to: a) hydrodynamics and water quality; b) Ecological quality status.

Results will be scientifically relevant, both theoretically and practically, and will have direct socio-economic repercussions for the Central Region of Portugal.

8.2. Objectivos
8.2. Objectives

Descrição dos Objectivos do Projecto
Project Objectives (description)

After an intervention in the Mondego estuary to decrease eutrophication symptoms, following the system's response is a must. The project objectives are:

a) Validate a previously calibrated physical model, including cohesive and non-cohesive sediments transport, simulating the evolution of the estuarine morphology after channels intervention;
b) Validate a previously calibrated water quality and macroalgae model, assessing the system's trophic conditions in the new hydrodynamic scenario;
c) Analyse the structural and functional responses of the biological communities in the new physical conditions, assessing the system's recovery and resilience;
d) Evaluate ecological quality changes and the resulting ecological quality status through the application of multiple indicators;
e) Examine the compliance of the system's new ecological quality status with different European directives assessing the applied approach potential for coastal and transitional waters management policy and practice.

Descrição dos Objectivos do Investigador Responsável
Principal Investigator Objectives (description)

The principal investigator has been studying the functioning of coastal and estuarine ecosystems in the last twenty years, combining empirical research, theoretical development and modelling. Moreover, special attention had been given to the application and development of ecological indicators to assess ecological quality status from a holistic perspective (ecosystem approach).

Therefore, this project proposal is fully compliant with his main stream research objectives. In fact, the new scenario emerging from the very recent intervention in the Mondego estuary created a rare occasion to increase theoretical and empirical knowledge by investigating the system's response, constituting an excellent scientific opportunity for the whole research group. Additionally, besides the cooperation with the MARETEC research group

(which belongs to the IMAR network), the project will allow strengthening the scientific cooperation and relationships with the INSTITUTE OF OCEANOGRAPHY (IO - FCUL).

8.3. Estado da Arte
8.3. State of the Art

Descrição do Estado da Arte
State of the Art (description)

The Mondego River drains a catchment area of approximately 6670 Km2 and its valley, which is considerably steep in upstream sections, forms a large alluvial plain consisting of good agricultural land downstream from Coimbra (Figure 1).

Since the 1960s, the Mondego catchment area underwent a large scale morphological modification, involving the construction of stone walls and small water reservoirs, to regulate the river water flow and enlarge the harbour facilities. The aim was to control floods, improve the uses of water resources, namely regarding populations, industries, and agriculture, and produce electric power. The works continued during the 1970s and the 1980s, although the original plan was only partially accomplished. Nevertheless, interventions caused a strong anthropogenic impact in to the system, modifying the riverbed topography and changing the system hydrodynamics.

The entire catchment area drainage contributes presently with a high anthropogenic loading of nutrients and several chemicals into the Mondego estuary (Western coast of Portugal - North Atlantic Ocean Eco-region), which as many other coastal and marine water bodies have experienced what may be named as cultural eutrophication (Hauxwell & Valiela, 2004). Besides, the estuary supports industrial activities, salt-works, and aquaculture farms, and is location of Figueira da Foz, a harbour and a centre of seasonal touristic activity.

The Mondego estuary is a relatively small (1600 ha) warm-temperate polyhaline intertidal system, which receives the agricultural runoff from 15 000 ha of upstream cultivated land (mainly rice fields). Its terminal part is 7 km long and is 2-3 km across at its widest part, consisting of two arms, north and south, separated by the Murraceira Island (Figure 2: A).

The two arms of the estuary have very different hydrographic characteristics. The north arm is deeper (5-10 m during high tide, tidal range 0.5-3.5 m), constituting the main navigation channel and the location of the harbour. The south arm is shallower (2-4 m during high tide), and is characterised by large areas of intertidal flats exposed during low tide.

In the early 1990s the south arm was rather silted up in the upstream areas, which caused the Mondego outflow to run essentially through the north arm. The water circulation in the south arm was mostly due to tides and to the relatively small fresh water input of a tributary, the Pranto River, which was artificially controlled by a sluice, located at 3 km from the confluence with the south arm of the estuary. In addition, due to differences in depth, the penetration of the tide was faster in the north arm, causing daily changes in salinity to be much stronger, whereas daily temperature changes were higher in the south arm. During the 1990s, in terms of hydraulics, two major changes occurred in the estuary:

a) A first engineering intervention carried out in 1990-1992 totally interrupted the communication between the two arms of the estuary in the upstream area. Actually, 4 water pipes with a Ø 0,4 m section were left aiming at ensuring a minimum communication, but rapidly became totally silted up and the water stopped passing;

b) A second and much smaller experimental intervention took place in 1998, aiming at decrease eutrophication symptoms and test ways of ameliorating the system's condition: a) The Pranto river sluice freshwater discharge in to the south arm was reduced to a minimum to decrease nutrients discharge, being instead diverted to the northern arm by another sluice located more upstream; b) The communication between the north and south arms was re-established into a very limited extent (periods of only 1.5 to 2 hours before and after each high tide peak and through a section of only 1m2 to improve water circulation.

A comprehensive study on the Mondego estuary environmental quality carried out during the last two decades, covering the system's most important quality elements [water quality, hydraulics and sediments dynamics, plankton communities (phyto, zoo, and ichtyoplankton), as well as the term evolution of the benthic communities (intertidal and subtidal), and finally the changes in macrophytes' beds (Zostera noltii) and green macroalgae distribution in relation to morphological alterations) allowed us to clearly understand the ongoing processes:

a) Despite all the changes introduced in the natural river course, data available illustrate that the estuary did not exhibit noticeable eutrophication symptoms until the early 1990s.

b) The interruption of the communication between the two arms caused a rapid deterioration of ecological conditions in the south arm. The combined effect of increased water residence time and nutrients concentration became major driving forces in the south arm, causing the emergence of clear eutrophication symptoms. The occurrence of large seasonal macroalgal blooms (mostly Ulva spp.) has been reported. As a pattern, although we could observe some inter-annual variations as a function of hydrological conditions (e.g. Martins et al., 2001), Ulva spp. biomass tended to increase from early winter (February/March) up to July, when an algae crash usually occurred. A second but much less important algae biomass peak could be observed in September followed by a decrease up to the winter. Concomitantly, the area occupied by Zostera noltii beds, which represented the richest habitat with regard to productivity and biodiversity, as well as Z. nolii biomass in the areas where it remained, suffered a severe reduction especially from 1991 to 1997 (the area occupied decreased from 150 000 m2 in 1986 to 200 m2 in 1997. Presumably, such reduction resulted from competition with Ulva, as a function of different strategies of macroalgae and macrophytes to uptake nutrients.

c) Such shift in the benthic primary producers affected the structure and functioning of the biological communities, including the species composition. Through time such modifications induced the emergence of a new selected trophic structure (Figures 3, and 4), which has been profusely analysed in abundant literature (e.g. Marques et al., 2003; Patrício & Marques, 2006).

d) This trend reversed into a certain extent from 1998, after the decrease in the freshwater discharge proceeding from the Pranto River sluice and the limited re-establishment of the communication between the two arms. In fact, the area occupied by the macrophytes community partially recovered (Figure 2: B; C) and green macroalgae (Ulva spp.) blooms ceased.

e) Taking into account the criteria used in classifying the nutrient levels in transitional waters, it became clear that the system water quality did not show any noticeable improvement. The environmental quality deterioration in the south arm of the estuary should therefore be mostly related with the increase of water residence time (48 to 50 hours since the interruption of the communication), which became incompatible to an efficient water renewal. Moreover, hydrodynamic modelling elucidated that a full re-establishment of the communication between the two arms could drive to an improvement of the system ecological quality by allowing the circulation of a much larger volume of water in the south arm, decreasing the residence time and increasing the transport capacity.

As a consequence, measures involving an ample re-establishment of the communication between the two estuarine channels were proposed (Marques et al., 2005) and subsequently applied. Such intervention, as a matter of fact fully compliant with the new European Marine Strategy, was undertaken during the spring of 2006 and concluded the 6 of May. This created a rare opportunity of obtaining inestimable new knowledge, both theoretical and empirical, by investigating the system's response through a comprehensive comparison of the former and present situations, taking into account the most relevant ecological quality elements. Moreover, from the applied (management) point of view, it is essential to assess into what extent the system's new ecological quality status, resulting from the new physical conditions, will comply with European directives (e.g. the Nitrates and Urban Residual Waters directives, the European Water Framework Directive, and the OSPAR convention, at present considered encompassed under the umbrella of the new European Marine Strategy).

NOTE: To overcome information gaps, a limited sampling programme (presently ongoing) has been continued by the IMAR – Coimbra Interdisciplinary Centre research team after the re-establishment of the upstream connection between the two arms of the estuary, using modest resources and focusing on water quality elements, benthic macrofauna (intertidal and subtidal), plankton, and fish.

LITERATURE CITED

Hauxwell, J. & Valiela I. 2004. Effects of nutrient loading on shallow seagrass-dominated coastal systems: patterns and processes. In s. Nielsen, G. Banta and M. Pedersen (eds.), Estuarine Nutrient Cycling: The influence of Primary Producers, 59-92.

Marques, J. C., S. N. Nielsen, M. A. Pardal & S. E. Jørgensen, 2003. Impact of eutrophication and river management within a framework of ecosystem theories. Ecological Modelling 166 (1-2): 147-168.

Marques, J. C., H. Teixeira, J. Patrício & J. M. Neto, 2005. Avaliação do impacto das obras de interrupção da ligação entre os dois braços do estuário do Mondego na qualidade ecológica do sistema. Propostas de solução. IMAR, Relatório Técnico, 99 p.

Martins, I., M. A. Pardal, A. I. Lillebø, M. R. Flindt & J. C. Marques, 2001. Hydrodynamics as a major factor controlling the occurrence of green macroalgae blooms in a eutrophic estuary: A case study on the influence of precipitation and river management. Estuarine Coastal and Shelf Science, 52: 165-177.

Patrício, J. & J. C. Marques, 2006. Mass balanced models of the food web in three areas along a gradient of eutrophication symptoms in the south arm of the Mondego estuary (Portugal). Ecological Modelling 197: 21-34.

8.4. Resultados e Repercussões
8.4. Results and Repercussions

Divulgação de Resultados (descrição)
Diffusion of Results (description)

As usual in the research group involved in this project proposal, scientific results will be published in international scientific journals (SCI), which often will be anticipated by its presentation in scientific meetings, for the most part at international level.

Moreover, at the end of the project, a simple and public-friendly brochure will be prepared comparing the ecological status of the Mondego estuary before and after the application of restoration measures in 2006 to decrease eutrophication symptoms.

Finally, a Workshop will be organised on the behalf of IMAR – Institute of Marine Research, in cooperation with national and local authorities, as well as regional stakeholders, as in previous occasions. The objective is obviously not strictly scientific, rather aiming at disclosing practical results to a wider audience. This type of action is of large interest, not exactly for marketing or popularity, but because by informing the public, in practice it helps in implementing results.

Repercussões (descrição)
Repercussions (description)

The most interesting and original feature of the project has to do with the peculiar scientific opportunity created by the artificial re-establishment of an ample communication between the north and south arms of the Mondego estuary, completed in May 2006. The idea was to improve water circulation and decrease water residence time in the south arm, aiming at decreasing eutrophication symptoms (occurrence of Ulva blooms) and recover the declining Zostera beds. Following the system's response after such intervention is therefore a must.

SCIENTIFIC REPERCUSSIONS

Following the system's response in the new conditions will, first of all, allow the validation of previously developed and calibrated hydrodynamic circulation and water quality models, providing an important added value in terms of management tools.

Additionally, existent ecological steady state models of macroalgae growth and controlling factors and trophic chain mass balanced models will be improved - calibrated and validated - using new sets of empirical data. Together with new field observations, such models will be further used to analyse the biological communities' response to changes induced in the system, allowing the validation of ideas and concepts on the Mondego estuary system functioning, built during a decade, which will be an obvious added value.

Finally, regarding the implementation of European Directives, the study of the performance of different ecological indicators and their combined use in capturing ongoing ecological quality changes will provide theoretical advances and practical knowledge on a) estuarine system's recovery and resilience, and b) the choice of the most adequate indicators to deal with such kind of scenarios.

SOCIO-ECONOMIC REPERCUSSIONS

The project core business does not comprehend socio-economic issues. Nevertheless, the project will have obvious socio-economic implications and repercussions. Actually, previous studies allowed concluding that even a 50% reduction of nutrient loading into the estuary would represent a decrease of only 2% in phytoplankton primary production, and would have no evident effect on macroalgae (Marques et al., 2004). Thus, even a significant reduction in nutrients discharge would not bring, a priori, a noticeable improvement in the estuary south arm trophic condition. Since massive reductions of nutrients loading cannot easily be obtained just by improving agricultural practices, other ways of dealing with eutrophication symptoms must be found to avoid severe socio-economic impacts, and assessing its effectiveness demands a rigorous following.

Results from the proposed project will allow validating the solution implemented in the Mondego, and will help finding the best possible trade-off between improving the system's environmental quality to the required levels and the sustainable safeguard of people's way of living. A fruitful interaction with decision makers in the past years illustrates it.

8.5. Regionalização
8.5. Regionalization

Região Region	Percentagem Percent

Norte	0
Centro	100
Lisboa e Vale do Tejo	0
Alentejo	0
Algarve	0
Região Autónoma dos Açores	0
Região Autónoma da Madeira	0

Descrição
Description

RESULTS, MADE POSSIBLE BY THE COOPERATION BETWEEN RESEARCH TEAMS WITH COMPLEMENTARY EXPERTISES, WILL HAVE DIRECT SOCIO-ECONOMIC RELEVANCE FOR THE CENTRAL REGION OF PORTUGAL, where the Mondego River basin in located. Let us see why.

The Mondego River catchment area (approximately 6670 Km2) is the largest one entirely regulated by Portuguese authorities, including as main tributaries the rivers Dão, Ançã and Foja, in the right bank, and the rivers Alva, Ceira, Cernache, Ega, Arunca, and Pranto, in the left one. An alluvial plain of 15 000 ha downstream from Coimbra consists of good agricultural land, and improving the use of its soils was one of the major reasons for the interventions that took place in the system, especially since the 1960s, which aimed at controlling floods, develop the uses of water resources, and produce electric power. Although the original planning was only partially accomplished, river regularisation became a fact and several dams ("Aguieira", "Raiva" and "Açude de Coimbra", in the Mondego, and "Fronhas", in the Alva River) were built, changing considerably the Mondego River hydrological regimen.

Presently, directly and/or indirectly, about half a million people take profit in their day by day life from the reorganized catchment area resources, regarding potable water supply, industrial activities, agriculture irrigation, aquaculture, salt-works, tourism, etc.

Eutrophication of water bodies - the Mondego is no exception - is in general associated to excess of nutrients, and became a major concern in the European Union. Its abatement is presently a priority of the European Commission environmental policy. In this context, eutrophication indices evaluating nutrient concentrations in the water were developed (e. g. OSPAR index), and this approach proved to be efficient in driving improvements in lakes and in artificial reservoirs with very simple hydrodynamics. There are in fact many successful examples of better agricultural practices and more efficient urban waste water treatment which have resulted into the decease of eutrophication.

Nevertheless, in estuaries, eutrophication processes are a much more complicated problem (see European Marine Strategy). The hydrodynamic complexity of such systems is the main reason for that, and may cause a) the sudden appearance of eutrophication symptoms without a clear modification of the nutrient loads, and b) does not permit to build a correlation between loads and the trophic state of the system. This is exactly the case in the Mondego estuary.

To deal with such problems and comply with European Directives, decision makers may be forced to apply radical solutions, with high socio-economic costs, or try to implement mitigation measures to decrease or eliminate eutrophication symptoms. THIS PROJECT PROPOSES TO ANALYSE IN DETAIL AND VALIDATE A SOLUTION APPLIED IN THE MONDEGO ESTUARY which falls in the second category, PROVIDING SCIENTIFIC SUPPORT IN FULFILLING PORTUGUESE NATIONAL COMMITMENTS.

8.6. Tarefas
8.6. Tasks

Lista de tarefas (9)
Task list (9)

Designação da tarefa Task denomination	Data de início Start date	Data de fim End date	Pessoas * mês Person * months
Water quality survey	01-01-2007	31-01-2009	40

Benthos response survey	04-01-2007	03-04-2009	113
Plankton response survey	04-01-2007	03-04-2009	58
Fish response survey	04-01-2007	03-04-2009	33
Characterization of sources of nutrients...	01-02-2007	31-07-2009	29
Modelling hydrodynamics and water qualit...	01-07-2007	31-12-2009	49
Food web models development regarding th...	01-07-2008	31-12-2009	20
Evaluation of ecological quality changes...	01-01-2009	31-12-2009	18
Assessing the compliance of the system's...	01-01-2009	31-12-2009	23

(Os detalhes de cada tarefa estão disponíveis clicando na designação correspondente)
(Details for each task are available by clicking on the corresponding denomination)

8.7. Referências Bibliográficas
8.7. Bibliographic references

Ano Year	Publicação Publication
2001	Martins, I., M. A. Pardal, A. I. Lillebø, M. R. Flindt & J. C. Marques. Hydrodynamics as a major factor controlling the occurrence of green macroalgae blooms in a eutrophic estuary: A case study on the influence of precipitation and river management. Estuarine Coastal and Shelf Science, 52: 165-177. (www.uc.pt/imar/jcmarques/estcoastshelfsc_52_165_177.pdf)
2003	Marques, J. C., S. N. Nielsen, M. A. Pardal & S. E. Jørgensen. Impact of eutrophication and river management within a framework of ecosystem theories. Ecological Modelling 166 (1-2): 147-168. (www.uc.pt/imar/jcmarques/ecomod_166_147_168.pdf)
2004	Cardoso, P. G., M. A. Pardal, A. I. Lillebø, S. M. Ferreira, D. Raffaelli & J. C. Marques. Dynamic changes in seagrass assemblages under eutrophication and implications for recovery. Journal of Experimental Marine Biology and Ecology 302 (2): 233-248. (www.uc.pt/imar/jcmarques/Cardoso_et_al_2004a.pdf)
2004	Cardoso, P. G., M. A.Pardal, D. Raffaelli, A. Baeta & J. C. Marques. Macroinvertebrate response to different species of macroalgal mats and the role of disturbance history. Journal of Experimental Marine Biology and Ecology, 308 (2): 207-220. (www.uc.pt/imar/jcmarques/jexpmarbioandecol_308_207-220.pdf)
2006	Patrício, J. & J. C. Marques. Mass balanced models of the food web in three areas along a gradient of eutrophication symptoms in the south arm of the Mondego estuary (Portugal). Ecological Modelling, 197: 21-34. (www.uc.pt/imar/jcmarques/Patricio_Marques_06_EM.pdf)

8.8. Artigos Anteriores
8.8. Previous Articles

Ano Year	Artigo (endereço na *Internet* - URL) Paper (Link in the Internet - URL)
2001	www.uc.pt/imar/jcmarques/cabral_et_al_2001.pdf
2000	www.uc.pt/imar/jcmarques/lopesetal_2000.pdf
2005	www.uc.pt/imar/jcmarques/Cardoso_et_al_2005MEPS.pdf
2006	www.uc.pt/imar/jcmarques/marpolbol_52_162-174.pdf
2006	www.uc.pt/imar/jcmarques/Marques_et_alJPR_2006.pdf

9. Ficheiros Anexos
9. Attachments

-

Nome Name	Tamanho Size
Figures - Technical Annex.pdf	324Kb

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A – FIGURES CITED IN THE STATE OF THE ART – Figures 1 to 4

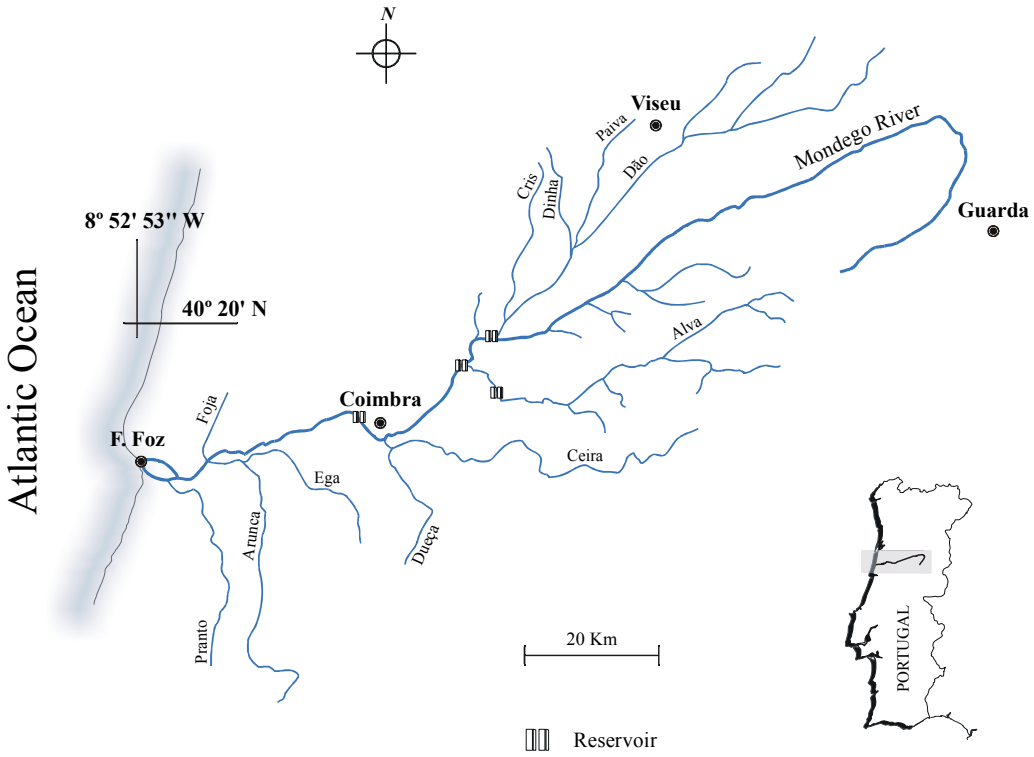

Figure 1: The Mondego river hydrological basin

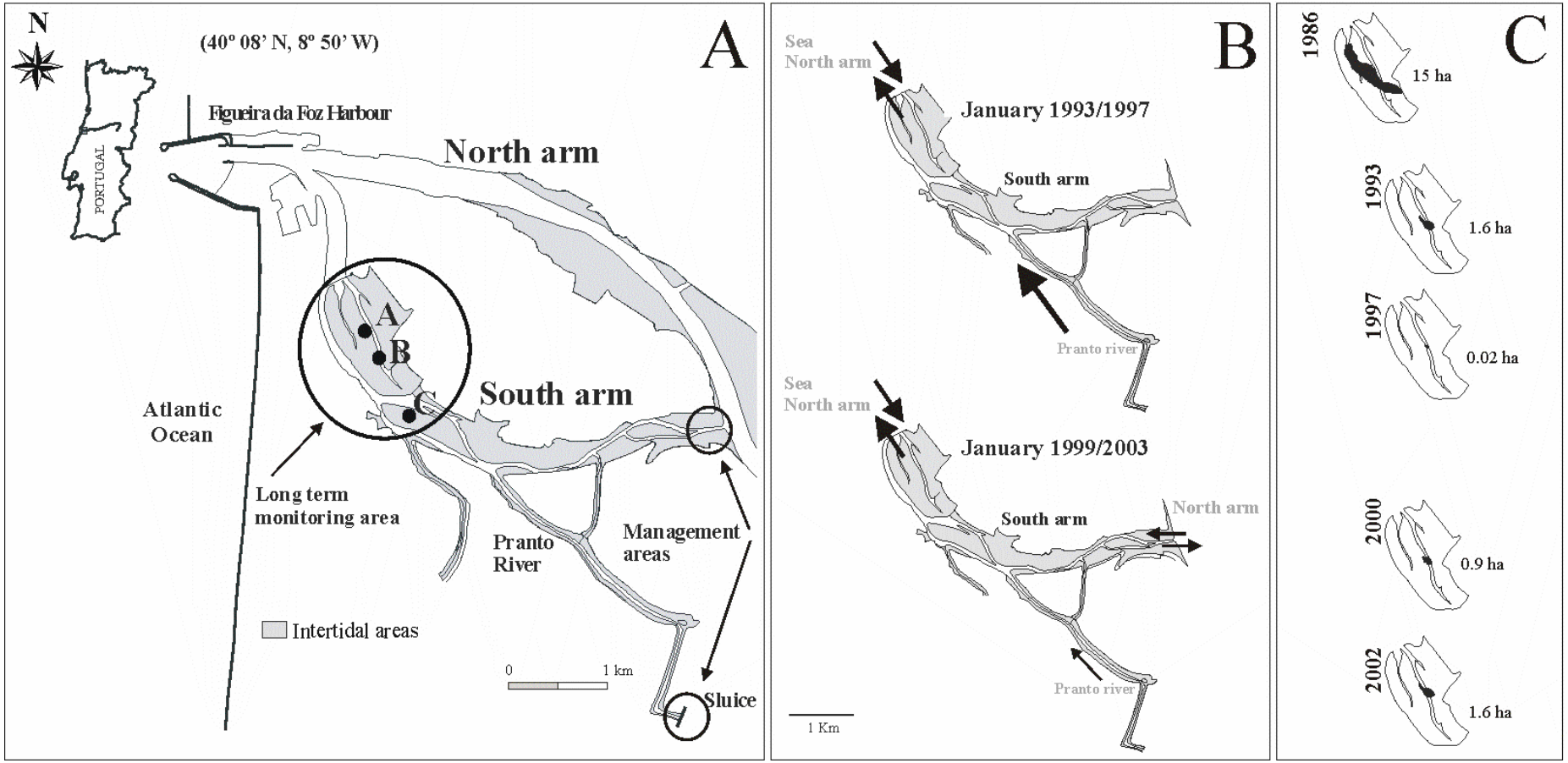

Figure 2: A) The Mondego estuary, with the location of the long term monitoring area (A, B and C) and the areas of management measures were implemented in 1998; B) The main freshwater inputs before the management (1993-1997) and after (1999-2003); C) The evolution of the *Z. noltii* beds (ha) from 1986 to 2002.

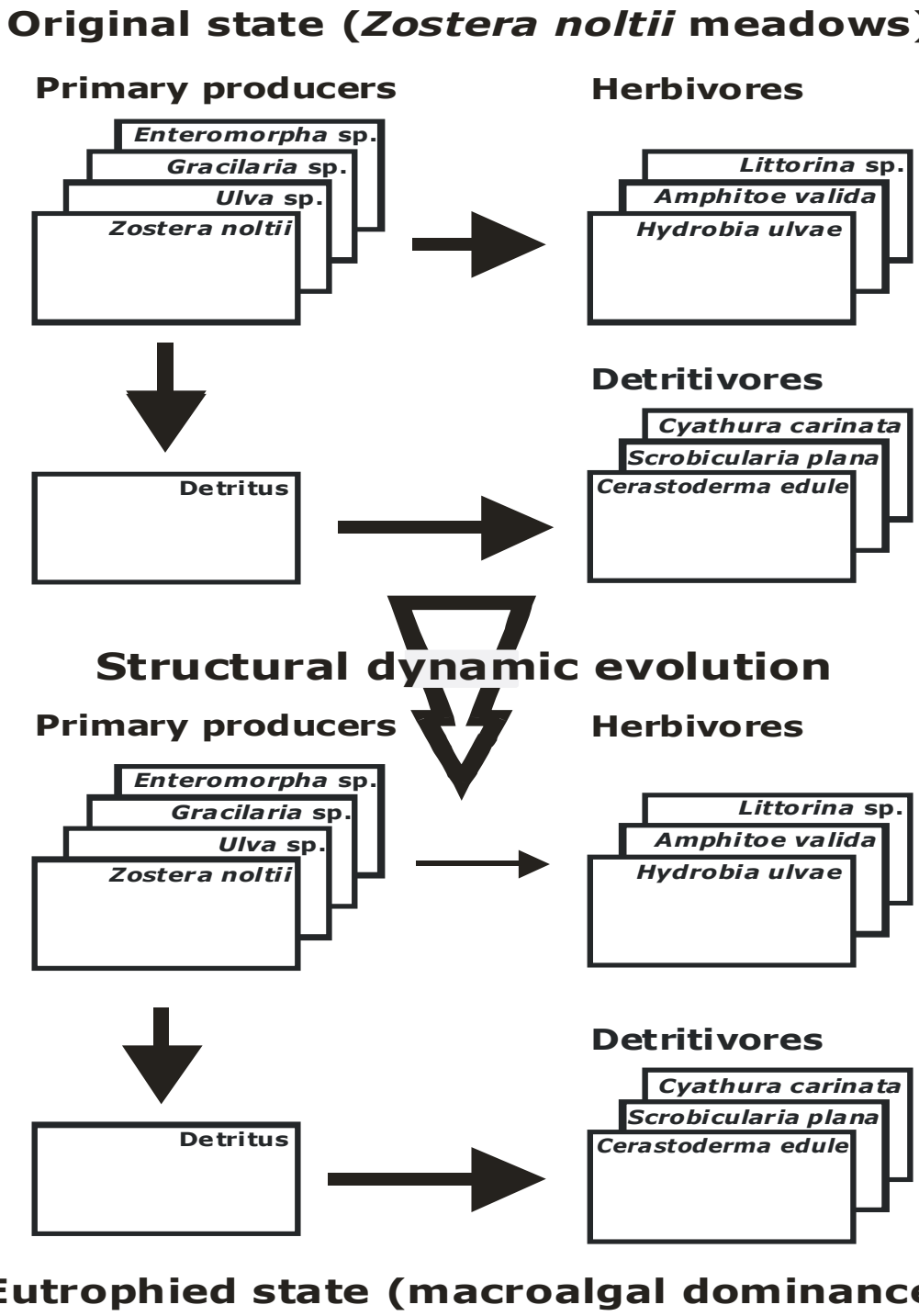

Figure 3: Structural changes in the trophic network in the south arm of the Mondego estuary as a function of the shift in primary producers induced by eutrophication. A – Situation at the *Zostera noltii* beds, at the non eutrophied area, assumed to represent the original state of the system; B – Situation at the most eutrophic area, where macroalgae blooms take place, assumed to represent the new state of the system. Boxes represent species or species aggregations according to their function in the trophic network. White boxes represent the dominant species in each situation, and dark boxes represent species poorly represented. Arrows represent matter fluxes. The width of the arrows reflects the relative importance of the path (see Patrício, J., R. Ulanowicz, M. A. Pardal & J. C. Marques, 2004. Ascendency as ecological indcator: A case study on estuarine pulse eutrophication. *Estuarine Coastal and Shelf Science*, 60 (1): 23-35).

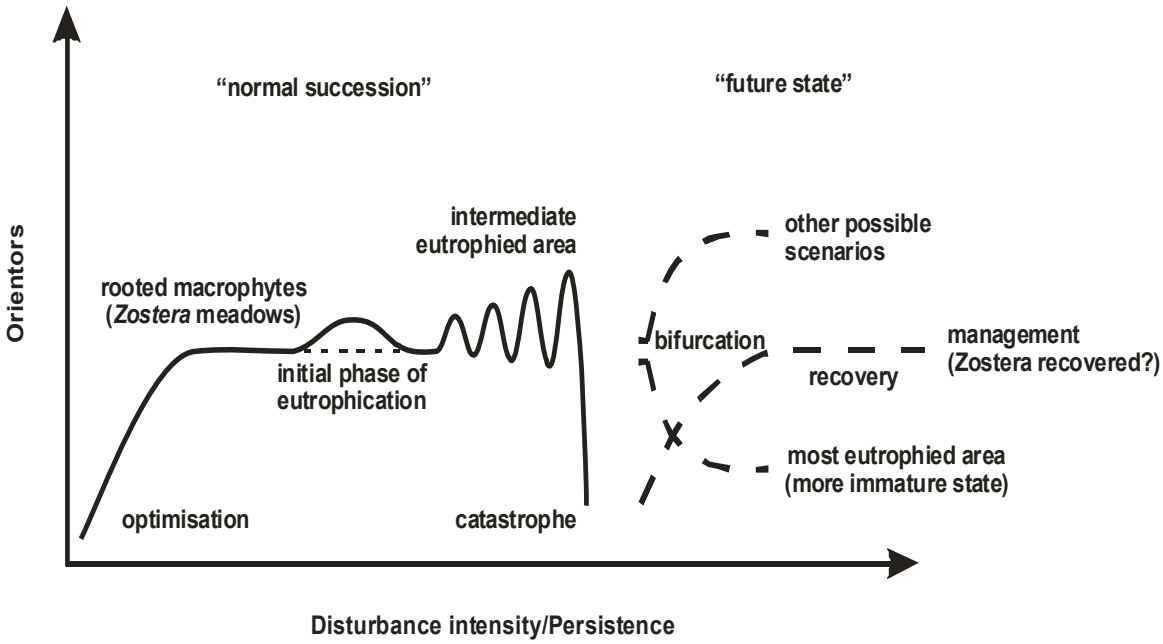

Figure 4: Orientors (e.g. many of the ecological indicators referred in the literature) development during stress. Possible interpretation of changes ongoing in the Mondego estuary in the framework of ecological theory . For details address: a) Marques, J. C., M. A. Pardal, S. N. Nielsen & S. E. Jørgensen, 1997. Analysis of the properties of exergy and biodiversity along an estuarine gradient of eutrophication. *Ecological Modelling*, 102:155-167; b) Marques, J. C., S. N. Nielsen, M. A. Pardal & S. E. Jørgensen, 2003. Impact of eutrophication and river management within a framework of ecosystem theories. *Ecological Modelling* 166 (1-2): 147-168.

B – FIGURE CITED IN THE TASKS DESCRIPTION – Figure 5

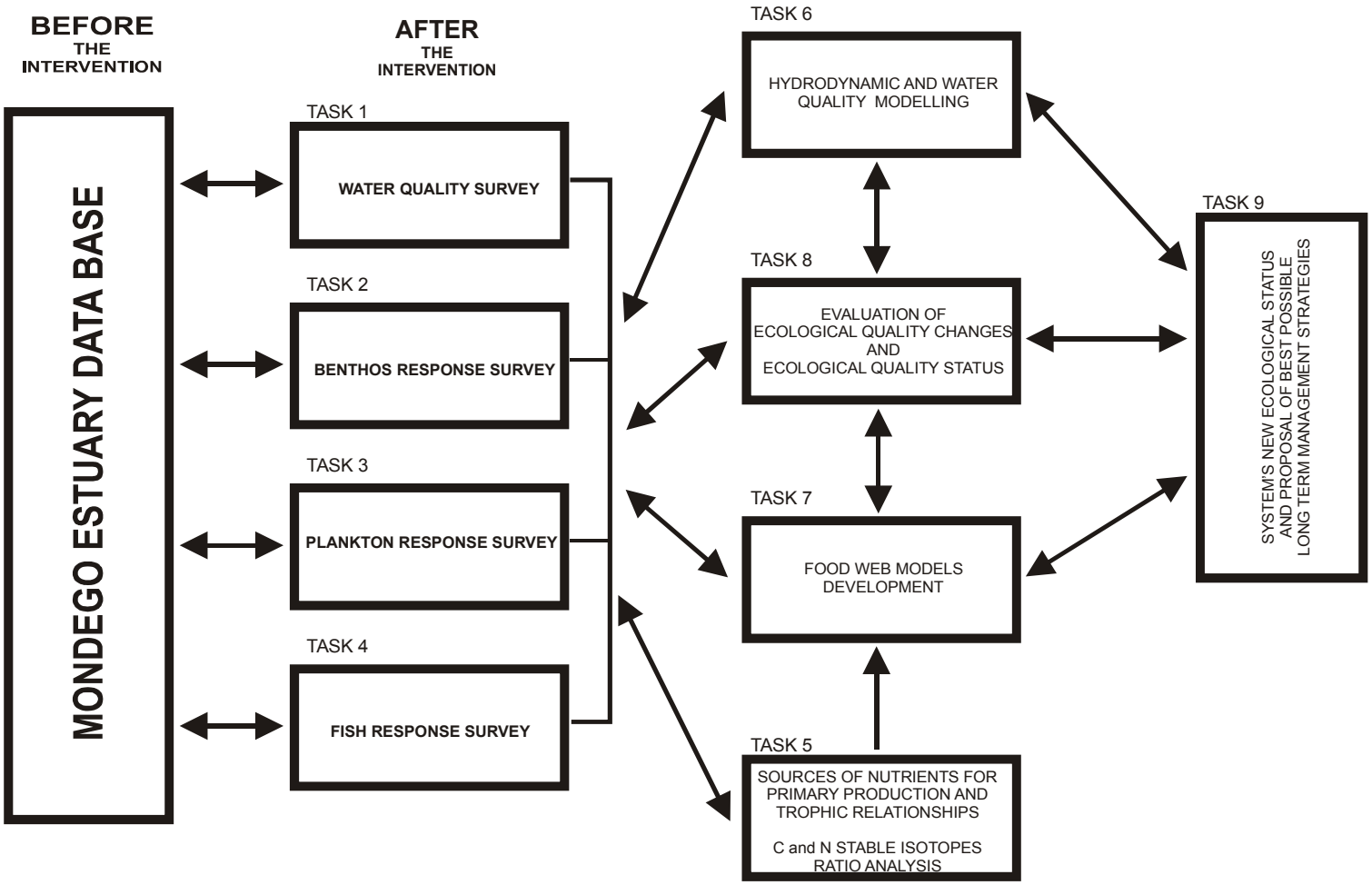

Figure 5: Data availability and tasks interconnection