Topics on the Ecological Economics of Coastal Zones:

Linking Land Uses, Marine Eutrophication, and Fisheries

Sandra Silva Paulsen
Faculty of Natural Resources and Agricultural Sciences
Department of Economics
Uppsala

Doctoral thesis
Swedish University of Agricultural Sciences
Uppsala 2007

Acta Universitatis Agriculturae Sueciae
2007: 73

ISSN 1652-6880
ISBN 978-91-576-7372-5

Tryck: SLU Service/Repro, Uppsala 2007

«On ne fait jamais attention à ce qui a été fait;
on ne voit que ce qui reste à faire.»
[Marie Curie]

To Therese and Gabriella, life-guards when the sea was stormy like never before
To Giovana and Daniel, more than good enough reasons for enduring

Abstract

Paulsen, S. S. 2007. *Topics on the Ecological Economics of Coastal Zones: Linking Land Uses, Marine Eutrophication, and Fisheries*. Doctor's dissertation.
ISSN: 1652-6880, ISBN: 978-91-576-7372-5

This thesis attempts to integrate ecology and economics into a basis for public decision making concerning environmental resources and problems in coastal zones. It consists of an introduction and four papers that can be read independently of each other. The applications relate to economic valuation of environmental changes, incentives to wetland construction as a means to mitigate eutrophication in the presence of uncertainty and different information structures, and the use of ecological data on habitat structure and fish populations to show the economic importance of coastal habitats in supporting fisheries.

Paper I attempts to economically value changes in shallow soft bottoms along the west coast of Sweden in terms of their impact on plaice fisheries in Kattegat and Skagerrak. The study presents a bioeconomic dynamic model that links the quality of the habitat to changes in the plaice population and connects fish recruitment with fisheries profits over time, suggesting a shadow price for plaice nursery grounds.

Paper II shows, through a statistical analysis of the results of a survey applied to eel fishermen on the west coast of Sweden, that habitat loss has a significantly negative effect on eel catches.

Paper III discusses the issue of how uncertainty affects the decision of a landowner to convert agriculturally productive land into wetlands and shows that, even though land conversion might result from a risk averse farmer trying to diversify her investment options, the possibility of receiving more information in the future leads to either a delay in the farmer's decision to restore wetlands or to the requirement of a higher subsidy for the decision to be made, even when it is not irreversible. Public policies to encourage wetland construction should take these aspects into consideration.

Paper IV presents an interdisciplinary approach where ecological data on habitat structure and fish populations are combined with results from economic valuation case studies to assess and describe effects of habitat disturbance on the Swedish west coast. The results have important implications for coastal zone management, since they show both ecologically and economically how coastal habitats support fisheries.

Keywords: bioeconomic modeling, coastal zones, ecological economics, economic valuation, eutrophication, GAMS, habitat changes, Swedish west coast, wetlands.

Author's address: Sandra Paulsen, Båtbyggargatan 60, 120 68 Stockholm, Sweden, sandra.paulsen@gmail.com

Preface

Once upon a time there was a young environmental economist who dreamed about doing work on the Atlantic forest in the South of the state of Bahia, Brazil. This young economist thought she had gotten a lot from life, she had had a supportive family, a good education, all opportunities one can have in life. She thought one day she would get a Ph.D. degree and go back to Itabuna, Bahia, to "pay it forward", becoming a Professor at the University of Santa Cruz and giving a very small indirect contribution to sustainable development in the Grapiúna region…

Well, things were not really like that and, as usual, life makes other plans for us. But the Ph.D. program is about to come to an end. I do not know how much "effective working time" this thesis has taken and I still cannot believe that this entire struggle is about to finish. What I once planned as five years of academic adventure ended up being much larger, longer and broader. But such is life and I never forget Diane Ackerman's quote: "I don't want to get to the end of my life and find that I just lived the length of it. I want to have lived the width of it as well." That is how I came to this point. And I would like to thank people I met on my way who made this journey worth traveling.

First of all I want to express my gratitude to Karl-Göran Mäler. When I met him ten years ago in Chile, I understood that I had much more to learn by going back to the academic world and pursuing my old dream of getting a doctoral exam. With his lectures in Tomé, Karl-Göran made me remember my times as a young PET student at the ECO-UnB. For me, economics has always been a fine science and a great tool for understanding, interpreting and influencing reality. Thanks, Karl-Göran, for helping me back on track. I also have to thank Karl-Göran for inviting me to come to Sweden. I still remember myself, driving through the W-3 Avenue in Brasília and trying to answer the phone ringing. It was Karl-Göran asking me: "So, do you want to come here to get a Ph.D. degree or not?". I had not thought that the opportunity was still open. And I took it! Then, there were all those years at The Beijer Institute. Karl-Göran became my supervisor, my friend, my father, my kid's grand-father, my mushroom picking master, my guide through Swedish places and forests, habits and celebrations. Not an easy task for him. Not an easy task for me either. But we both survived. Thanks, Karl-Göran, for suggesting, discussing, challenging, commenting, teaching, guiding, scaring, supporting, inspiring, frightening, encouraging, laughing, and joking. Thanks for giving me the best of you. I know I was not up to your expectations, but be sure I too gave the best of me under the circumstances.

Then there is Tore Söderqvist… What to say? I am a blessed person. Somehow in my life I have met the right people at the right moment. Tore is one of those people. Always humble and kind, generous and efficient, it was Tore who offered me the opportunity to join the FISHCASE project that financed the writing of three of the papers in this dissertation. And, in the end, it was Tore who conducted me through the obstacles and gave me time, hope, ideas, and advice. Tore read numerous versions, discussed possibilities, understood and accepted my limits,

helped me through when I was about to give up. When the debt it too big, we say in the Northeast of Brazil: Deus lhe pague! That is all I can say. Thank you Tore.

A third person to thank is Ing-Marie Gren. She accepted me as her student in the Ph.D. program at Ultuna, arranged financing for me to write my first paper and present it at a conference in Colombia and for finishing the writing of this thesis. Ing-Marie has also given me comments and suggestions, and several hours of interesting conversations on the way to Uppsala in her car. It is a pity that I ended up 'finding' her almost at the end of the road. Better late than never, though. Thanks, Ing-Marie, for being there with a flashlight when I could not see the end of the tunnel.

Sometimes those who are not at the center of the story can be as important for its development as the main actors. Thomas Sterner, you do not know what it meant to me to be able to be in Gothenburg, taking courses, enjoying the stimulating academic atmosphere there, making all the friends that I have there, feeling at home at EEU! You have always been in my mind, all the time. Every time we meet, you take the time to listen to me, give me advice and tips. Thank you for been such an inspired and inspiring professor and human being. Thank you for approaching me and offering me your support years ago in Washington, D.C., and thank you for always – both spiritually and in practical respects – welcoming me to the Environmental Economics Unit.

I would like to thank Nicolo Gligo and Francisco Brzovic, once upon a time at UN-ECLAC, now at University of Chile and FAO. After Nicolo's enthusiastic presentation at a course in 1989, I went to the ECLAC library and, during two months, dedicated myself to reading and learning about the links between economics and the environment. Then, I became conscious that all that stuff about externalities really meant a lot more! A whole new world opened up for me. Pancho Brzovic is the one who called my attention, some years later, to that workshop that was planned in Concepción, organized by some Beijer Institute that I had no idea about. Then, there is Steven Shultz who talked me into applying to the Environmental Economics course at the EEU-University of Gothenburg, and there is SIDA, the Swedish International Development Cooperation Agency, which financed my time in Gothenburg.

I would also like to thank Jörgen Weibull, María Sáez-Martí, John Hassler, Astri Muren and Harry Flam. In different ways, they have supported me at various moments of this journey, with a word of approval or incentive, some minutes of attention, some comments on a paper, some extra macro lessons, whatever. It has been important for me to have had them as teachers or simply to have met them.

Another thank you note goes to my colleagues at the FISHCASE project and co-authors, Patrik Rönnbäck, Leif Pihl, Håkan Wennhage and Johan Stål. It was really nice working with you! And to Sara Aniyar, my roommate for so many years at Beijer. Ingela Ternström, I was almost forgetting you! How come? Without you, for sure, this book would never exist. Thank you for caring.

I would also like to express my gratitude to people at the Department of Scandinavian Languages at Stockholm University. To overcome part of the difficulties in my Ph.D. studies, I paradoxically decided to study more, a parallel student life, another kind of challenge, and other learning experiences. It was a risky strategy, but studying Swedish, Danish, and Norwegian with you opened new doors for me and helped me adapt to this whole new environment. Thank you all!

There is still a long list of people for me to say thanks to. For the sake of space, the gratefulness will come partly in collective expressions, but you all know who you are. To the colleagues and friends at The Beijer Institute of Ecological Economics and at KVA; those from the Stockholm School of Economics (Handels), especially Pirjo Furtenbach and Ritva Kiviharju; from the Institute for International Economic Studies and from Stockholm University, especially Christina Lönnblad, who revised this manuscript, and Miriam Samuelsson; those from the Environmental Economics Unit at the School of Economics and Statistics at Gothenburg University; those from SLU, with a special note to Mitesh Kataria and Berit Klingspor from the Department of Economics, and Monica Thunberg, from the Faculty of Natural Resources and Agricultural Sciences, for their kindness and efficient help; to the colleagues and friends from IPEA-Brasília, from the late CIDU at the Catholic University, and from the Women Studies Center-CEM in Santiago, Chile.

There are still some other people whom I have met throughout this path and who, in the end, are the ones to blame for my endurance. Each of you deserves a whole paragraph, but I will keep it short.

No words can express the contributions that Claudio Delano Nery, Carmen Ayuy, Alda Dantas and Mats Lejmyr have made to my life. Thank you for listening and pointing to the lighthouse.

On the friends front, just to mention a few, I would like to thank: Admir Targino and Patricia, Agatha Murgoci, Alberto Naranjo, Aldona and Rafal Dlugosz, Alejandra Donoso, Allen Blackman, Ana Beramendi and Leandro, Anders Fredriksson, Anna Sundbaum, Anne-Sophie Crépin, Annika Andreasson, Astrid Auraldsson, Astrid Nuñez, Birger Nilsson, Birgit Strikholm, Caterina Mendicino, Chloé Le Coq, Christina Leijonhufvud, Christine Idevall, Clarice Strauss, David D'Angelo, Daria Finocchiaro, Diane Almeras, Eduardo Núñez and Ruby, Elena Paltseva, Emanuel and Carina Kohlscheen , Ficre Zehaie, Florian Waldow, Giovanni Favara, Gisela Waisman, Henrik Scharin, Ira Yascara, Isaías Coelho, Jenny Roessler, Jessica Andersson, Jorge Borras, Katarina Renström, Lais Abramo and Alvaro Díaz, Lena Nekby, Licia Edvardsson, Lissu Lappalainen, Mhano Silvha, Maria Mendieta, Martine Visser, Max Troell, Miriam Huitric, Moema Ramalho, Nasima Chowdhury, Natalie Labuschagne, Oscar Chao, Patricia and Erik Holmberg, Pernilla Sjöquist Rafiqui, Razack Lokina, Renato Baumann, Roland Nilsson, Ronaldo Brandão, Shawn Mendes, Talayeh Behfar, Thomas Hahn, Verónica Silva, Virginia Queijo von Heideken, Wilfred Nyangena, Wisdom Akpalu and Wandrille Micaux.

On the “feels like family in Sweden” side I have to thank Damián Migueles and Natalia Cruz, my “son” José Maurício Prado Jr., and my “sisters” Raquel Gaspar (and the Medeiros family in Portugal), Siv Maria Rabnor and Therese Lindahl.

On the family front, my gratitude forever to my relatives on both sides, who always supported me and gave me energy. A special thank you goes to my parents, Silvio and Nivea, and my brothers Ricardo and Rogério, to my grandmother Noêmia, and to my cousin Suylan. Thank you all for your permanent support and unconditional love! Giovana has helped me all the time, being much more than “just” a daughter, a “life-partner”. To Daniel I owe hours of motherhood, but I have already started catching up before it is too late. Still a thank you note to Juan Carlos Lerda, who has been a good and supportive “ex” throughout these years, and to Daniela, caring for me at a distance.

Jacob, we met in the middle of all this. It has not been easy, but at least I promise no more dissertations in the future. Thank you for your loving support, your sense of humor, and your invincible optimism. Let’s go on with our life projects! May “the force” be with us!

…But the story of the environmental economist who wanted to save the Atlantic Forest and the Rio Cachoeira is not over yet… O futuro a Deus pertence. Obrigada, Senhor!

Stockholm, summer 2007

Contents

Appendix

Papers I-IV

The thesis is based on the following articles, which are referred to by their Roman numerals:

I. Paulsen, S.S. Valuation of coastal habitats sustaining plaice fisheries. (Manuscript)
II. Paulsen, S.S. Economic impacts of coastal habitat change on eel fisheries: A fishermen's knowledge based survey. (Manuscript)
III. Paulsen, S.S. Investment in Wetlands for Pollution Abatement under Uncertainty. (Manuscript)
IV. Stål, J., Paulsen, S., Pihl, L., Rönnbäck, P., Söderqvist, T., Wennhage, H. Coastal habitat support to fish and fisheries on the Swedish west coast. (Submitted to *Ocean & Coastal Management*, February 2007)

1. Introduction

This thesis puts together four papers dealing with environmental resources and problems in coastal zones. The introduction makes a general presentation of the problems that called the author's attention and are dealt with in the papers. In a non-exhaustive literature review, the reader gets an overview of the ecological economics of coastal ecosystems and some examples of how to integrate ecology and economics into a meaningful basis for public decision making.

2. Ecological economics

Thirty-five years after the United Nations Conference on the Human Environment, on 5-16 June 1972 in Stockholm, Sweden, and almost forty years after Herman Daly published his "On Economics as a Life Science", there are still controversies about how ecology and economics are related to each other, and what an economist has to say about, for example, eutrophication processes or the extinction of a species. Being an environmental or ecological economist myself, I still have to explain to some of my colleagues in other areas of economics why I read books on ecology or why I go to conferences where sometimes a majority of natural scientists meet to discuss fish population dynamics or ecosystem services. And one can feel some irritation in the air among some natural scientists still fearing that all that economists want is to assign monetary values to invaluable services from nature.

But the fact is that interconnections between the economy and the environment have been the subject of a growing literature in the last few decades and most books in the field of environmental economics start with an introductory chapter explaining the first two laws of thermodynamics and discussing different perspectives on sustainability, economic growth and environmental and natural resources, or ecological economics (cf., for example, Hanley, Shogren and White, 1997; Perman, Ma and McGilvray, 1996). Also books by natural scientists, for example Daily and Ellison (2002), try to unveil the links between the conservation of the ecosystems and the economy.

In spite of a general agreement about the virtues of sustainable development[1], different perspectives about economic development and environmental and natural resources co-exist. Making a complex issue into a simple one, following Perman, Ma and McGilvray (1996), it is possible to classify these different views into three different categories:

a) environmental pessimists, stressing problems of carrying-capacity and the limits to continuous economic growth;

b) economic optimists who trust relative price changes, technological progress and substitution effects to counteract environmental degradation;

[1] According to the well-known definition in the Bruntland Report (UN, 1987), "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

c) “the consensus opinion among orthodox environmental economists”[2], stressing the existence of market failures and the need for environmental policy to enforce sustainability.

A fourth perspective, to which this thesis subscribes, is the one of ecological economics. Ecological economics “is a growing research field with roots in many sciences. It links together ecologists and economists points of view about mankind, society and nature”[3]. As has been shown in the literature[4], it is not only problems with social and economic institutions and market failures that explain the difficulties in following a sustainable path in our development as societies. Nature itself, its dynamics and its complexities, must be taken into consideration.

The point of departure of this thesis is the idea that only by bringing together ecology and economics can we contribute to the improvement of the state of the environment and the current and future well-being of people on the planet. This collection of papers attempts to contribute to the literature on the ecological economics of coastal zone environmental problems. In order to make this contribution, this thesis provides examples of how to integrate ecological and economic data in an interdisciplinary approach to build information as a foundation for sound decision-making in coastal zones, considering the diversity of actors and the scope of the problems studied.

3. The importance of coastal ecosystems

According to the Millenium Ecosystem Assessment (MEA, 2005), 40% of the world population live within 100 kilometers of the coast, thus representing a pressure on coastal resources and contributing to the rapid environmental change that has been observed in these ecosystems in the last few decades. But what are coastal ecosystems and why are they so important?

From the simple “area where land, water and air meet” (Carter, 2001, p. 1) to a characterization of coastal zones “in terms of inter-related physical, bio-chemical and socio-economic systems with particular processes and functions” (Turner et. al., 1998, p. 269), different definitions show the difficulties in capturing the complexity of coastal systems.

The importance of coastal zones is related to the high number and territorial areas of the biomes encompassed by the concept; to the variety of ecosystem functions, goods and services provided by coastal systems[5]; to the number and vast scope of different economic activities dependent on these areas; and to the variety and seriousness of environmental challenges encountered (The European Commission, 2000).

---

[2] Perman, Ma and McGilvray (1996), p. 20.
[3] In the words of Söderqvist, Hammer and Gren (2004), p. 11.
[4] See, for example, Mäler (1974), Dasgupta (1982), Arrow et. al (1995), Perrings et. al. (1995), Levin et. al. (1998), Arrow et. al. (2000), and Dasgupta and Mäler (2003).
[5] For a typology of ecosystem functions, goods and services, cf. de Groot et. al. (2002)

In fact, coastal systems include estuaries, marshes, salt ponds, and lagoons; mangrove areas; intertidal habitats, deltas, beaches, and dunes; coral reefs and atolls; kelp forests; seagrass meadows; semi-encloses seas; and other benthic communities like rock and shell reefs, mud flats, and so on.

Economic activities like fisheries, fish farming, residential housing, transport, tourism and leisure, industrial manufacturing, power generation, all take place in coastal areas and depend on the goods and services provided by them.

Coastal systems provide direct and indirect goods and services. Coastal ecosystem goods are, for example, food; raw materials like fiber, timber and fuel; and genetic, medical and ornamental resources. Coastal ecosystem functions and services include, among other things, freshwater storage and retention, nutrient cycling, climate regulation, waste processing, flood and storm protection, habitat and nursery for different species, and recreational, cultural, amenity and aesthetics services (Wilson et. al, 2004; Turner et. al., 2000; Rönnbäck, 1999; MEA, 2005).

Estuaries, marshes and freshwater wetlands; nearshore marine areas; and seagrass beds or meadows are the subtypes of coastal systems that constitute the focus of this thesis. The first are responsible for the mixing of nutrients and maintaining freshwater flows, with wetland areas being declared areas for conservation in the whole of the European Union. Nearshore marine areas are nursery grounds for different species including plaice. Seagrass meadows are highly productive areas and important nursery grounds for juveniles of commercial fish like cod and whiting (Baden et. al., 2003). Seagrass is also the favorite habitat of the European eel, whose stocks have decreased alarmingly in the last few decades (Dekker, 2003).

In what concerns environmental problems affecting coastal systems, the array goes from water and air pollution (Rosenberg et. al., 1990; Elmgren, 2001; Wulff et. al., 2001) to overfishing (Pauly et. al, 2005; Worm et. al., 2006) and the impacts of aquaculture (Naylor et. al., 2000); from the introduction of invasive species through ballast water discharge from ships (Johnson et. al., 2001; also mentioned by Shogren and Tschirhart, 2005) to habitat loss and coastal degradation (Baden et. al., 2003).

According to the Millenium Ecosystem Assessment (2005), even though most of the Earth's surface (around 70%) is covered by oceans and seas, it is exactly the coastal boundary zone of the so-called marine systems that is the most productive part of the world ocean, accounting for 90% of total fish catches.

Overfishing is one of the most pervasive problems in the world's oceans, with unknown consequences (Pauly et. al., 2005). The resulting loss of marine biodiversity affects the ability of marine ecosystems to provide goods and services (Worm et. al., 2006). But it is not only by directly extracting fish that human activities produce resource collapse. Climate change and habitat loss are among the hypothetical causes of the decline in, for example, global eel stocks (Dekker, 2004).

The relation between different coastal subsystems and the oceans is clear, with most activities performed in coastal areas directly affecting the marine environment and its inhabitants. One of the main features of coastal systems is the strong linkages among its separate subsystems, with water as a mediator. And one of the strongest links between coastal subsystems is the one between areas acting as nursery grounds for fish species. In fact, even fish species that live in the high sea might spend part of their life-time in coastal habitats. When these nursery areas are affected by anthropogenic or even "natural" factors, fisheries outside the nursery area can also be significantly affected, as is the case of plaice on the Swedish west coast (MEA, 2005; Pihl et. al., 2005).

Juvenile plaice that settle in areas of Kattegat and Skagerrak are affected by the presence of algae, whose mats cover the areas where they spend their first summer. The growth of these algae is favored by eutrophication, which takes us to the next section of this introduction.

4. The land use – environment link, marine eutrophication and coastal zone management

Among the different connections between coastal and marine systems, the link between coastal areas and land is also very important for understanding the environmental challenges posed to these systems. Changes in land use, such as deforestation, urban development and the development of coastal zones affect the ocean and coastal habitats, directly or through the mediation of fresh water.

The connections between land and sea[6] are summarized in the following Table 1. Rivers and other water flows transport sediment, nutrients and pollutants to the coastal zones and the ocean. Marine eutrophication is the name given by ecologists to the process through which nutrients such as nitrogen and phosphorus are discharged or transported into the sea in an amount and a speed affecting the original functions of the ecosystem.[7] The increased load of nutrients and organic matter increases the production of algae and other forms of plant life. The increased production can even benefit fish populations, but the essence of an eutrophication process is the disturbance in the balance of organisms and different life forms. The presence of algae affects the water quality, resulting in increasing turbidity.

[6] The links between land and sea are the objective of the Land-Ocean Interactions in the Coastal Zone (LOICZ) Project of the International Geosphere-Biosphere Programme (http://www.igbp.kva.se), which also tries to develop economic models to link economic activities and resulting coastal system states. Cf. Talaue-McManus, Smith and Buddemeier, 2003.

[7] http://www.mare.su.se/ENG/eng-om/eng-om-eutrofiering.html

This thesis, dealing with eutrophication, its effects on fish population and fisheries, and mitigation policies, fits in the lower left corner of Table 1.

Table 1. Natural and Anthropogenic Factors linking Land and Sea

Factor	Land to Sea	Sea to Land
Natural	River discharge Groundwater Sediment Nutrients and minerals Humics and organics Storm debris Earthquake debris Volcanic debris	Energy and debris from hurricanes Cold water and nutrients from upwelling Wave action Salt and salt aerosols Sand Nutrients through carcasses, guano
Anthropogenic	Sediment Nutrients and organic matter from agriculture and sewage Coliform, bacteria Herbicides and pesticides Heavy metals Oil and chemicals	Oil and chemical spills Chronic input of oil and chemicals Sewage from ships Ballast water with exotic organisms Debris from ships Brackish infiltrations of groundwater reservoirs by water extraction

Source: MEA (2005)

Eutrophication is one of the most important causes of coastal ecosystem degradation in Sweden (Elofsson et. al., 2003; Troell et. al., 2005). Different studies show that it directly affects fish populations, as in the case of plaice, and indirectly, as in the case of the European eel. In fact, the loss of seagrass (*Zostera marina*) habitats in Sweden has been linked to the loss of water quality, turbidity, and eutrophication (Pihl et. al., 2006). Paper II in this thesis attempts to show to what extent eel fisheries on the Swedish west coast are affected by this habitat loss. Wetlands are important as nutrient sinks and also because of the other ecosystem services they provide (the appendix of Paper III presents a general overview of the main features and the importance of wetland systems). Changing land uses and promoting wetlands restoration and construction have received attention in the public policy realm as cost-effective means of increasing the retention of nutrients and mitigating eutrophication processes (Gren, 1995; Byström, 2000; Carlsson et. al., 2003).

The increasing understanding of the existence of complex connections between human and natural systems in the coastal areas has contributed to the growing importance of what in the literature is called Integrated Coastal Zone Management

(ICZM) (cf., for example, Sorensen, 1993; Bower and Turner, 1998; Ducrotoy and Pullen, 1999; Talaue-McManus et. al., 2003; Christie, 2005).

As in the summarized and at the same time comprehensive definition by Cicin-Sain and Knecht (1998), cited by Christie (2005, p. 209), "ICM (Integrated Coastal Management) is a process by which rational decisions are made concerning conservation and sustainable use of coastal and ocean resources and space. The process is designed to overcome the fragmentation inherent in single-sector management approaches (fishing operations, oil and gas development, etc.), in the splits in jurisdiction among different levels of government, and in the land-water interface."

This kind of approach has increasingly been put into practice internationally, encompassing the use of marine protected areas, land-use control, zoning and permit systems and fisheries management (Christie, 2005; Done and Reichelt, 1998), probably because there are studies showing the positive net benefits of adopting this kind of approach to coastal management (for example, Bower and Turner, 1998).

But the success of ICZM also depends on the integration of natural scientists' knowledge into the institutional decision-making process that goes on at the different levels of government dealing with coastal problems. This issue is dealt with in the next section.

5. Integrating ecological knowledge into economic analysis

Increasing knowledge about the complexities of coastal ecosystems helps identifying both the ecological and the anthropogenic factors affecting their structural and functional characteristics. The question that remains here is how to integrate this knowledge into economic analysis.

As Shogren, Parkhurst and Settle (2003) remind us, the integration of economic and ecological sciences can work at different levels: "the technical integration of models, the policy integration of methods, and the political integration of mindsets" (p. 233).

Economic valuation is one – and probably the most popular – way of integrating ecological knowledge into economic analysis. Turner et. al. (2003) present a comprehensive review of the literature on environmental valuation of ecosystem services. In the words of Schuijt, "economic valuation of ecosystems places a monetary value on the effects of changes in the environment. Valuation processes can play a particularly important role in highlighting the economic importance of ecosystems in addition to their ecological and socio-cultural importance and it also helps to formulate economic arguments for the sustainable management of ecosystems." (Schuijt, 2003, p. 1)

In fact, the literature shows (cf., for example, Knowler et. al., 2003; Ledoux and Turner, 2002), also in the case of Sweden, (Sundberg and Söderqvist, 2004), that there has been an increasing interest in bringing together ecological knowledge and economic analysis for public policy purposes through valuation exercises. Different valuation studies have also confirmed that it might be worth making efforts to avoid ecosystem degradation; Gren et al., 1997; Lynne, 1981; Knowler et. al., 2003 are examples of such studies dealing with marine issues.

Modeling is another way of integrating economic analysis and ecosystem science. As described by Drechsler and Wätzold (2007) in their editorial article to a whole issue of *Ecological Economics* on this subject, both economics and ecology make use of models to analyze reality, but it is not at all clear how to use bioecological models for concrete policy advice when they do not incorporate economic, social, political and institutional aspects. At the same time, economic models may also be useless in terms of leading to the right policies when they do not include current ecological knowledge about the dynamics and complexity of ecosystems. Progress is being made, though, in what concerns integrating ecology and economics through modeling (see, for example, Crépin, 2002; Dasgupta and Mäler, 2003; Hall and Behl, 2006).

This thesis gives examples of ways of contributing to this integration at the technical/theoretical/modeling level. The papers presented here deal with valuation (papers I, II, and IV), with building bioeconomic simulation models in cooperation with ecologists (papers I and IV), and with including ecological uncertainty and irreversibility into economic thinking (paper III), in order to help in the integration of methods and mindsets mentioned by Shogren at. al.

6. The contribution of this thesis

Sweden, the country in focus in this thesis, has 3218 Km of coastline harboring different conflicts of interests regarding the use of coastal ecosystem goods and services, which include "highly tangible natural resources such as fish for commercial or recreational fisheries, or less tangible services such as fish recruitment opportunities provided by marine habitats, or environmental amenities such as recreation opportunities, bathing water quality and attractive areas for housing" (Söderqvist et. al., 2005, s. 169).

As previously mentioned, the papers in this thesis deal with different aspects of coastal zone environmental problems. The first paper is about the effects of ecosystem changes affecting plaice recruitment in the areas of Kattegat and Skagerrak on plaice fisheries and tries to value these changes in economic terms. The second paper discusses the economic impacts of the reduction of seagrass meadows on the Swedish west coast on eel fisheries. The third paper deals with economic incentives to wetland construction and how uncertainty and information availability affect the farmer's decision to invest in wetland recovery as a means of mitigating eutrophication. The fourth paper is a synthesis of the results of a research project that was a joint effort of ecologists and economists to describe effects of habitat disturbances on the Swedish west coast and assess the economic impact of these environmental changes.

In a sense, the papers collected here show two sides of the same coin: actual estimates of the costs caused by eutrophication and habitat change, and a discussion of how to give incentives to reduce eutrophication by constructing wetlands. All four papers are policy oriented, but they all use different methodological approaches: while paper I presents the results of a numerical simulation, paper II is an empirical analysis, paper III follows a theoretical approach and paper IV is an illustration of a team transdisciplinary work.

Below, abstracts of the four papers present a short description of their contents and their main conclusions. After the abstracts follow some general conclusions from the thesis as a whole.

Paper I – Valuation of coastal habitats sustaining plaice fisheries

This paper presents a model to attempt to economically value changes in shallow soft bottoms along the west coast of Sweden in terms of their impact on plaice fisheries in Kattegat and Skagerrak. An ecological model links the quality of the habitat to changes in the plaice population which, in turn, are likely to be of importance for the opportunities for fishermen to harvest plaice. An economic dynamic model connects fish recruitment with fisheries profits over time, suggesting a shadow price for plaice nursery grounds. Using the results – under the assumptions and restrictions – of the model, the presence of algal mats on the Swedish west coast could "cost" from 30% up to 40% of the total profits of the plaice fishing industry, i.e., between 7.6 and 12.5 billion Danish kroner , depending on the recruitment level and the discount rate used for the simulation.

Paper II – Economic impacts of coastal habitat change on eel fisheries: A fishermen's knowledge based survey

While the link between the decrease in European eel stocks and different anthropogenic factors is still under study, this paper presents new information about eel fishery on the Swedish west coast and shows, through a statistical analysis of the results of a survey applied to eel fishermen, that habitat loss has a significantly negative effect on eel catches. The economic loss derived from the decrease in the availability of eelgrass meadows for the fishing activity is estimated to be equal to 6.4 million Swedish kronor per year and is shown to be comparable in importance to the effect of other disturbances affecting the fishery, such as the damage produced by seals and predation by cormorants, and greater than the problems produced by crabs or fouling of gears. The paper unveils the habitat contribution to the economic activity and suggests that the impact of environmental change on fisheries is significant and should be taken into consideration when designing policies to increase the long-run sustainability of the fishing activity.

Paper III – Investment in Wetlands for Pollution Abatement under Uncertainty

Wetlands have been identified as a cost effective way of abating pollution from agricultural and other human activities. The establishment and restoration of wetlands is one of the policy measures implemented by the Swedish government to reduce excessive nutrient input from non-point sources of pollution that contribute to the eutrophication of the Baltic Sea. This paper discusses the issue of how uncertainty affects the decision of a landowner to convert agriculturally productive land into wetlands. Three issues are dealt with. First, how does uncertainty affect the risk averse farmer's decision as concerns constructing wetlands. Second, what is the effect of different information structures on the level of land conversion carried out. And finally, what is the role played by irreversibility in the decision-making process. Land conversion might result from a risk averse farmer trying to diversify her investment options. The possibility of receiving more information in the future leads to either a delay in the farmer's decision to restore wetlands or to the requirement of a higher subsidy for the decision to be made, even when it is not irreversible. The establishment of a public policy to encourage wetland construction should take these aspects into consideration. The subsidy could be designed as an insurance mechanism and the policy maker should consider the effect of the information availability on the agent's behavior.

Paper IV – Coastal habitat support to fish and fisheries on the Swedish west coast

Swedish coastal habitats provide significant support to the total marine finfish landings in Sweden. The fisheries are dependent on habitat quantity and quality because the fish species being caught are ecologically linked to the habitat and/or because the habitat is used as a location for harvest. Unfortunately, coastal areas are exposed to a variety of threats due to high population densities and high fishing pressure, which have resulted in habitat fragmentation and degradation. In this study, we use an interdisciplinary approach where ecological data on habitat structure and fish populations are combined with results from economic valuation case studies to assess and describe effects of habitat disturbance on the Swedish west coast. The focus is on three major habitats (soft sediment bottoms, seagrass beds and rocky bottoms with macroalgae), five fish species (cod, plaice, eel, mackerel and sea trout) and three types of fisheries (commercial, subsistence and recreational fisheries). We have shown that there exists a strong link between the major coastal habitats, the fish utilizing these habitats and the fisheries on the Swedish west coast. Cod, plaice and eel showed a high to medium association to one or several of the major habitats in the coastal zone. Cod and plaice were highly important in off-shore fisheries whereas eel was a significantly important fish species in coastal fisheries. Conversely, mackerel and sea-trout showed a medium to low dependence on coastal habitats, but were highly important in recreational fisheries. The results have important implications for coastal zone management, since they show both ecologically and economically how coastal habitats support fisheries.

The collection of papers in this thesis had different purposes. First, to make use of an ecological economics approach to analyze coastal zone problems. Second, to give concrete examples of how this fundamental integration between economics and ecology can help providing better information to understand both economic and ecological problems. Third, to provide a better understanding of the links between economic activities in the land and their consequences in the ocean, in terms of eutrophication and its impacts both on biodiversity and ecosystem health, as well as its impacts on other economic activities that depend on goods and services provided by coastal ecosystems. Fourth, to offer an innovative analysis of how information availability, uncertainty and irreversibility might affect private investment decisions that could help mitigate environmental problems in coastal areas.

The papers show that the eutrophication process on the west coast of Sweden has had a negative impact on the fisheries and the fishing activity that takes place in that area; that this impact is likely to affect the fisheries in the future; that ecological knowledge can help building better models to understand these processes and their impacts on the economy; and that better policies should be designed that take the interactions between economic activities and ecosystem dynamics in the Swedish coastal zone into consideration.

7. References

Arrow, K. J. et. al. (1995), "Economic Growth, Carrying Capacity, and the Environment", *Science* 268 (5210):520-521.

Arrow, Kenneth, et. al. (2000), "Managing Ecosystem Resources", *Environmental Science & Technology*, Vol. 34, No. 8:1401-1406.

Baden, S., Gullström, M., Lundén, B., Pihl, L. And Rosenberg, R. (2003), "Vanishing Seagrass (Zostera marina, L.) in Swedish Coastal Waters", *Ambio*, Vol. 32, No. 5, August.

Bockstael, Nancy E. and Elena G. Irwin (2000),"Economics and the land use-environment link", *The International Yearbook of Environmental and Resource Economics 2000/2001: A Survey of Current Issues*, edited by Tom Tietenberg and Henk Folmer, Edward Elgar, 1-54.

Boesch, Donald et. al., Eutrophication of Swedish Seas, Final Report, Naturvårdsverket, Stockholm, 13 March 2006.

Bower, Blair T. and Turner, K.T. (1998), "Characterising and analyzing benefits from integrated coastal management (ICM)", *Ocean & Coastal Management* 38, pp. 41-66.

Byström, Olof (2000), "The Replacement Value of Wetlands in Sweden", Environmental and Resource Economics 16(4):347-362.

Carlsson, Fredrik, Frykblom, Peter and Liljenstolpe, Carolina (2003), "Valuing wetland attributes: an application of choice experiments", *Ecological Economics,* Vol. 47, No. 1, pp. 95-103

Carter, R.W.G. (2002), *Coastal Environments: An Introduction to the Physical, Ecological and Cultural Systems of Coastlines*, London: Academic Press.

Christie, Patrick (2005), "Is Integrated Coastal Management Sustainable?", *Ocean & Coastal Management* 48, pp. 208-232.

Crépin, Anne Sophie (2002), *Tackling the economics of ecosystems*, Dissertations in Economics 2002:6, Department of Economics, Stockholm University.

Daily, Gretchen and Ellison, Katherine (2002), *The New Economy of Nature: The Quest to Make Conservation Profitable*, Island Press.

Daly, Herman E. (1968), "On Economics as a Life Science", *The Journal of Political Economy*, Vol. 76, No. 3. (May - Jun.), pp. 392-406.

Dasgupta, P. (1982), *The Control of Resources*, Cambridge, MA: Harvard University Press.

Dasgupta, Partha, and Mäler, Karl-Göran (2003), "The Economics of Non-Convex Ecosystems: Introduction", *Environmental and Resource Economics* 26: 499-525.

De Groot, R. S., Wilson, M.A. and Boumans, R.M.J. (2002), "A typology for the classification, description and valuation of ecosystem functions, goods and services", *Ecological Economics* 41, pp. 393-408.

Dekker, W. (2004), *Slipping through our hands – Population dynamics of the European eel*, University of Amsterdam, the Netherlands, 11/10/2004, (http://www.diadfish.org/doc/these%202004/Dekker-Thesis-eel.pdf (retrieved 2006/01/10)).

Dekker, Willem (2003a), "Eel stocks dangerously close to collapse", (http://www.ices.dk/marineworld/eel.asp (retrieved 2005/12/18)).

Done, T.J. and Reichelt, R.E. (1998), "Integrated Coastal Zone and Fisheries Ecosystem Management: Generic Goals and Performance Indices", *Ecological Applications*, Vol. 8, No. 1, Supplement: Ecosystem Management for Sustainable Marine Fisheries, February, pp. S110-S118.

Drechsler, Martin, and Wätzold, Frank (2007), "Ecological-economic modeling for the sustainable use and conservation of biodiversity", *Ecological Economics,* Vol. 62, pp. 203-206.

Ducrotoy, Jean-Paul, and Pullen, Siân (1999), "Integrated Coastal Zone Management: commitments and developments from an International, European, and United Kingdom perspective", *Ocean & Coastal Management* 42, pp. 1-18.

Elmgren, R.,(2001), "Understanding human impact on the Baltic ecosystem: changing views in recent decades", *Ambio*, Vol. 30, No. 4-5, pp. 222-231.

Elofsson, K., Folmer, H., and Gren, I-M. (2003), "Management of eutrophicated coastal ecosystems: a synopsis of the literature with emphasis on theory and methodology", *Ecological Economics*, Vol 47, No. 1, pp. 1-11.

Engström, R., Wadeskog, A. and Finnveden, G. (2007), "Environmental assessment of Swedish agriculture", *Ecological Economics*, Volume 60, Issue 3, 15 January, pp. 550-563

Franzén, Frida, Soutukorva, Åsa and Söderqvist, Tore, *Skagerraks miljö i samhällsekonomisk belysning*, Enveco, Stockholm, 6 november 2006, www.forumskagerrak.com.

Gren, Ing-Marie (1995), "The Value of Investing in Wetlands for Nitrogen Abatement", Beijer Reprint Series No. 47, reprinted from European Review of Agricultural Economics 22:157-172.

Gren, I-M., Söderqvist, T., and Wulff, F. (1997), "Nutrient reductions to the Baltic Sea: ecology, costs and benefits", *Journal of Environmental Management*, Vol. 51, pp. 123-143.

Hall, Darwin C. and Behl, Richard J. (2006), "Integrating economic analysis and the science of climate instability", *Ecological Economics,* Vol.57, pp. 442-465.

Hanley, N., Shogren, J.F. and White, B. (1997), *Environmental Economics in Theory and Practice*, Macmillan.

Johnson, L.E., Ricciardi, A., and Carlton, J.T. (2001), "Overland Dispersal of Aquatic Invasive Species: A Risk Assessment of Transient Recreational Boating", *Ecological Applications*, Vol. 11, No. 6. (Dec.), pp. 1789-1799.

Knowler, D.J., MacGregor, B.W., Bradford, M.J., Peterman, R.M. (2003), "Valuing freshwater salmon habitat on the west coast of Canada", *Journal of Environmental Management*, Vol. 69, pp. 261-273.

Ledoux, L. and Turner, R.K. (2002), "Valuing ocean and coastal resources: a review of practical examples and issues for further action", *Ocean & Coastal Management*, Vol. 45, pp. 583-616.

Levin, S. et. al. (1998), "Resilience in Natural and Socioeconomic Systems", *Environment and Development Economics* 3(2):222-235.

Lynne, Gary D. et. al. (1981), ”Economic Valuation of March Areas for Marine Production Processes”, Journal of Environmental Economics and Management 8:175-186.
Mäler, Karl-Göran (1974), *Environmental Economics: A Theoretical Inquiry*, Baltimore, Maryland, The Johns Hopkins University Press.
MEA (2005), Chapter 18, “Marine Fisheries Systems”, and Chapter 19, “Coastal Systems”, in: *Ecosystems and Human Well-Being: Current state and trends*, Findings of the Condition and Trends Working Group, Washington, D.C.:Island Press. Retrieved on Mars 12, 2007, from http://www.millenniumassessment.org/en/Condition.aspx
Naylor, R.L. et. al. (2000), “Effect of aquaculture on world fish supplies”, *Nature*, No. 405, pp. 1017-1024 (29 June).
Pauly, Daniel, Watsonm, Reg, and Alder, Jackie (2005), “Global trends in world fisheries: impacts on marine ecosystems and food security”, *Philosophical Transactions of The Royal Society B,* Vol. 360, pp.5-12.
Perrings, C. et al., (eds.) (1995), *Biodiversity Loss: Economic and Ecological Issues*, Cambridge: Cambridge University Press.
Pihl, L. Baden, S., Kautsky, N., Rönnbäck, P., Söderqvist, T., Troell, M., and Wennhage, H. (2006), “Shift in fish assemblage structure due to loss of seagrass *Zostera marina* habitats in Sweden”, *Estuarine, Coastal and Shelf Science,* Vol. 67, Issues 1-2, March, pp. 123-132.
Pihl, L., Modin, J. and Wennhage, H. (2005), “Relating plaice (Pleuronectes platessa) recruitment to deteriorating habitat quality: effects of macroalgal blooms in coastal nursery grounds”, *Can. J. Fish. Aquat. Sci*. 62:1184-1193.
Poizat, Gilles and Baran, Eric (1997), “Fishermen’s knowledge as background information in tropical fish ecology: a quantitative comparison with fish sampling results”, *Environmental Biology of Fishes* Vol 50, pp. 435-449.
Rönnbäck, P. (1999), “The ecological basis for economic value of seafood production supported by mangrove ecosystems”, *Ecological Economics* Vol. 29, 235–252.
Rosenberg, Rutger et. al., “Marine Eutrophication Case Studies in Sweden”, *Ambio,* Vol 19, no. 3, May 1990.
Schaberg, Rex H., et. al. “Ascribing value to ecological processes: an economic view of environmental change“, *Forest Ecology and Management* 114 (1999) 329-338.
Schuijt, Kirsten (2003), Valuation of Water - The process of economic valuation of ecosystems in water management, PhD dissertation, Erasmus University Rotterdam. https://ep.eur.nl/bitstream/1765/1072/1/ESM-dissertatie-2.pdf -
Shogren, J.F., and Tschirhart, J. (2005), “Integrating ecology and economics to address bioinvasions”, *Ecological Economics*, Vol. 52, No. 3., pp. 267-271.
Shogren, J.F., Parkhurst, G.M., and Settle C. (2003), “Integrating economics and ecology to protect nature on private lands: models, methods, and mindsets”, *Environmental Science & Policy*, Vol. 6, pp. 233-242.
Sorensen, J. (1993), “The international proliferation of integrated coastal zone management efforts”, *Ocean & Coastal Management* Vol. 21, pp. 45-80.
Söderqvist, Tore, Eggert, Håkan, Olsson, Björn, and Soutukorva, Åsa (2005), “Economic Valuation for Sustainable Development in the Swedish Coastal Zone”, *Ambio*, Vol. 34, No. 2, March, pp. 167-173.
Söderqvist, Tore, Hammer, Monica and Gren, Ing-Marie (2004), *Samverkan för människa och natur: En introduktion till ekologisk ekonomi*, Lund: Studentlitteratur.
Sundberg, Sara and Söderqvist, Tore (2004), “The economic value of environmental change in Sweden – A survey of studies”, Natuvårdsverket, Report 5360, March.
Talaue-McManus, L., Smith, S.M. and Buddemeier, R.W. (2003), “Biophysical and socio-economic assessments of the coastal zone: the LOICZ approach”, *Ocean & Coastal Management* 46, pp. 323-333.
The European Commission (2000), *An Assessment of the Socio-Economic Costs & Benefits of Integrated Coastal Zone Management*, Final Report prepared by Firn Crichton Roberts Ltd and Graduate School of Environmental Studies, University of Strathclyde, November.

Tol, R.S.J., Klein, R.J.T., Jansen, H.M.A. and Verbruggen, H. (1995), ”Some economic considerations on the importance of proactive integrated coastal zone management”, *Ocean & Coastal Management* 32, No. 1, pp. 39-55.

Troell, M., Pihl, L., Rönnbäck, P., Wennhage, H., Söderqvist, T. and Kautsky, N., “Regime shifts and ecosystem services in Swedish coastal soft bottom habitats: when resilience is undesirable”, *Ecology and Society*, Vol. 10, No. 1, online at http://www.ecologyandsociety.org/vol10/iss1/art30/.

Turner, R.K., Brouwer, R., Georgiou, S., and Bateman, I. J. (2000), “Ecosystem Functions and Services: An Integrated Framework and Case Study for Environmental Valuation”, CSERGE Working Paper GEC 2000-21.

Turner, R.K., Lorenzoni, I., Beaumont, N., Bateman I.J., Langford, I.H., and McDonald, A.L. (1998), ”Coastal Management for Sustainable Devolpment: Analysing Environmental and Socio-Economic Changes on the UK Coast, *The Geographical Journal*, Vol. 164, No. 3, November, pp. 269-281.

Turner, R.K., Paavola, Jouni, Cooper, Philip, Farber, Stephen, Jessamy, Valma, and Georgiou, Stavros (2003), “Valuing nature: lessons learned and future research directions”, *Ecological Economics* 46, pp. 493-510.

United Nations World Commission on Environment and Development (1987), *Our Common Future*, Oxford University Press, Oxford, UK, p.43.

Worm, Boris et. al., “Impacts of Biodiversity Loss on Ocean Ecosystem Services”, *Science* Vol 314, 3 November 2006.