Lecture Notes on Coastal and Estuarine Studies

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Bengt-Owe Jansson (Ed.)

Coastal-Offshore Ecosystem Interactions

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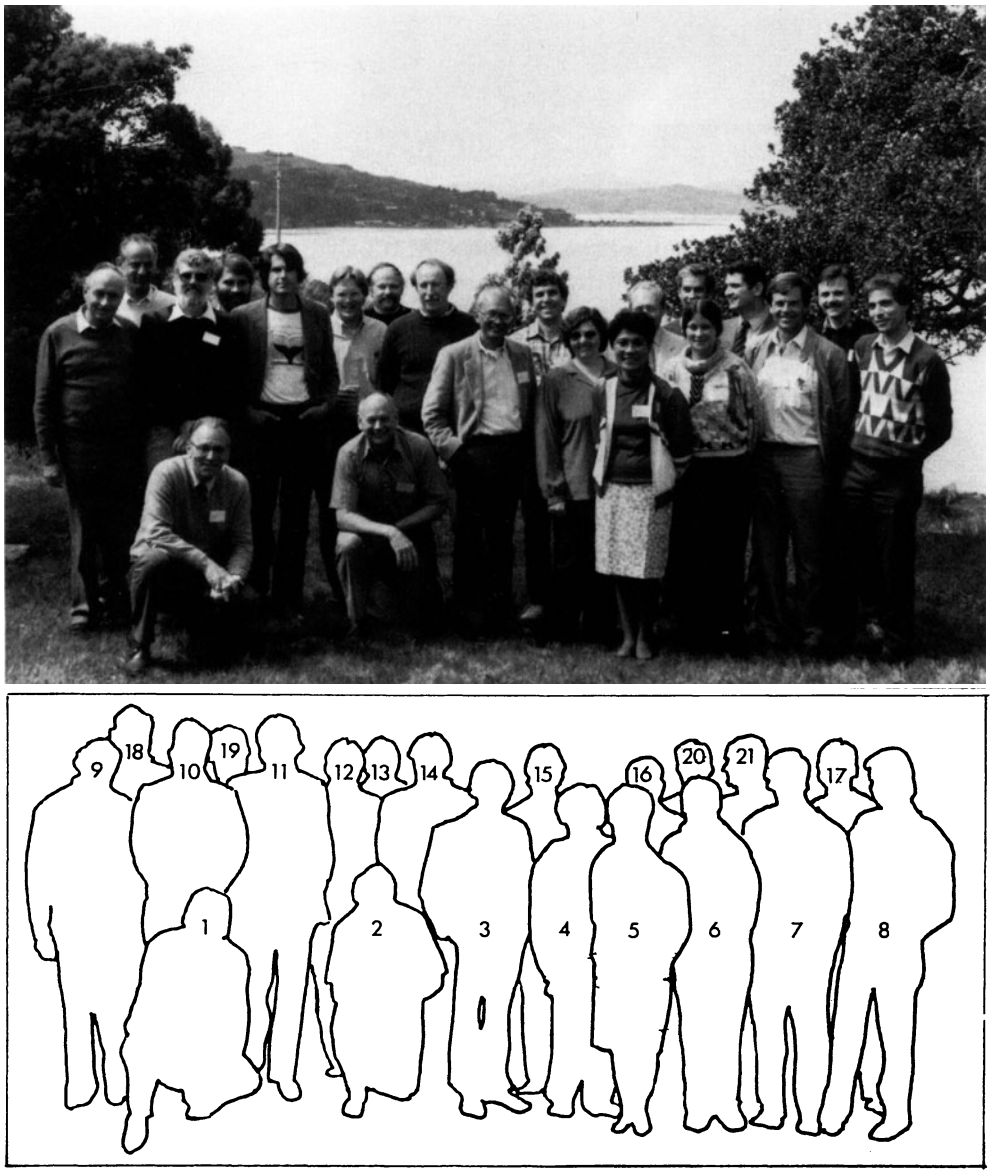

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Not pictured: David Peterson, Peter Rothlisberg, Gary Sharp.

SCOR WORKING GROUP 65 CONFERENCE 1986

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ABSTRACT

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Interactions between coastal and offshore ecosystems are considered, focusing on four aspects. 1. Water exchange, crucial for most couplings is classified for two types of system: shallow coastal areas and narrow, deep shelf areas. 2. Mass balance studies of tidal flats, salt marshes, mangroves, fjord systems and coral reefs give a strong indication of recirculation of nutrients and suggest that imported organic material mostly remains in the nearshore areas. 3. Active transport is demonstrated for fish and crustacean species occupying coastal nurseries. Both crab and shrimp larvae are vertical migrators which by reacting to fine-tuned hydrodynamics are retained in favourable adult habitats. 4. Numerical modelling as a means of synthesizing relevant physical and biological processes is analyzed for several existing ecosystem models and recommendations for suitable techniques are made.

Evaluation of present evidence shows that:
a) on a global scale and of the scale of years to decades, outwelling is quantitatively insignificant in the biogeochemistry or productivity of the sea b) productivity of many coastal systems are determined in the short term more by recycling than by inputs, though the relationship between the two remains to be determined c) "information flows" in the form of oceanic populations using the coastal areas as nursery grounds are important.

BACKGROUND AND ACKNOWLEDGEMENTS

In 1980 the Scientific Committee on Oceanic Reseach, in close collaboration with UNESCO and IABO, initiated the formation of SCOR Working Group 65 (Coastal-offshore ecosystems relationships) with the following terms of reference:

(i) to review and compare the energetics of coastal (littoral and estuarine) and offshore pelagic and benthic populations.

(ii) to suggest methods for improving knowledge of energy conversion between coastal and offshore pelagic migratory and benthic populations and to determine what further research is needed.

In consultation with IABO the Working Group decided to concern itself primarily with differences in the energetics of coastal and offshore ecosystems and with significant energy and material fluxes between such systems. These fluxes could include the exchange of organic material and plant-nutrients between the two systems. In addition it was recognized that fluxes might exist which are probably insignificant in terms of energy exchange, but are important in terms of quality and should therefore be considered. Such fluxes could include e.g. migrations of (juvenile) crustacea and fish from the coastal zone to offshore populations as well as fluxes of pollutants.

The Working Group, established in the course of 1980, had two meetings, the first in Bordeaux (France) from 5-7 September 1981 in conjunction with the International Symposium on Coastal Lagoons, 8-13 September 1981), the second at Texel (The Netherlands) from 12-15 September 1983. The membership of the W.G. and participants in the meetings were as follows:

	September 1981	September 1983
B.O. Jansson (Sweden)	x	x
B. Kjerfve (USA)		x
P. Lasserre (France)	x	
A.D. McIntyre (UK) secretary	x	x
R.C. Newell (UK)	x	
S.W. Nixon (USA)	x	x
M.M. Pamatmat (USA)	x	x
B. Zeitzschel (FRG)	x	x
J.J. Zijlstra (The Netherlands) chairman	x	x

B. Kjerfve was coopted by the W.G. after its first meeting to provide expertise on physical processes involved in the coastal-offshore relationships.

The group recognized the great diversity of the coastal zone, which might lead to local differences in the relationship between coastal and offshore ecosystems. It was therefore decided to exchange documented accounts of the situation with which each of the members was most familiar. These accounts covered areas as different as San Francisco Bay, North Inlet (South Carolina, USA), the Bermuda platform, a southern Benguela kelp community (South-Africa), sandy beaches in western Scotland, a Baltic coastal-offshore system and the Wadden Sea (The Netherlands).

These reports together with exchange of views during meetings and by correspondence, assisted in focussing attention on six aspects, which appear to be of general interest for all coastal-offshore situations (with the possible exception of tropical areas, for which no information was presented) and provide a background for the relationship between the two ecosystems.

1) coastal/offshore boundaries and water exchange.
2) nutrient exchange between coastal and offshore systems.
3) transport of matter across the coastal/offshore boundary.
4) coastal-offshore relations in terms of animal populations.
5) relative biological productivity in coastal and offshore systems.
6) effects of man-made disturbances.

The discussions within the working-group of these six aspects can be summarized as follows:

1) The boundary between coastal and offshore systems is highly dynamic and varies with river discharge, wave climate, wind stress, and other physical forces or events generated outside the immediate system. As used here, the term coastal includes estuaries and nearshore waters. Little is known about material exchange between nearshore and offshore areas. Studies have been published dealing with exchange between estuaries and adjoining nearshore waters but their results are not conclusive with regard to the exchange between nearshore and offshore waters.

2) It seems doubtful that coastal areas, in particular the estuaries, contribute significantly to the nutrient budget of offshore areas.

3) "Outwelling" of organic matter from coastal estuarine areas to offshore regions is probably much smaller than formerly postulated. In fact, there are indications of net organic matter import by some coastal waters from offshore areas.

4) migrations of nekton, especially large crustaceans and fish, across the coastal-offshore boundary is qualitatively established for commercially important species. Except perhaps for some migratory species like the salmon in some river systems, there are no reliable measurements or estimates of population movements in both directions.

5) Notwithstanding higher nutrient levels, higher rates of nutrient recycling, a higher potential energy and higher habitat diversity, coastal ecosystems may not always be as productive on all trophic levels as is generally postulated in comparison to offshore systems.

6) Most man-made disturbances are from point sources and will have localized effects. Impacts on coastal/offshore interactions can be expected especially at the mouth of large river systems or in areas bordering highly urbanized regions.

The group concluded that it did not seem possible from the kind of existing information to quantitatively evaluate the importance of estuaries, lagoons, mangrove swamps, or coastal waters in general, in the ecological energetics and productivity of offshore waters

To provide a more detailed basis for this possibly controversial conclusion the W.G. 65 proposed to SCOR that a workshop meeting be held to bring scientists together in order to develop an international consensus on gaps in our knowledge, the necessary approach and methodology.

After discussions between SCOR-representatives and members of the W.G.65 (Lasserre, Nixon) the program for the meeting was outlined. SCOR, the United Nations Educational and Scientific Council and San Francisco Bay Foundation were most helpful as co-sponsors of the workshop meeting and in the provision of financial support.

The meeting took place at Paul F. Romberg Tiburon Center for Environmental Studies, San Francisco State University, from April 7-12, 1986. The local arrangements were excellently directed by Prof. Mario Pamatmat who was also of great assistance during the first important

editing phase of the manuscripts. Prof. M. Josselyn and his staff through their hospitality and efforts provided an inspiring background to the meeting.

Mrs Elizabeth Tidmarsh, Executive Secretary of SCOR shares greatly in the realization of this workshop through her constructive handling of the administration. I am also most grateful to Mrs Antoniella Cerri, Springer-Verlag, for her patience and support when editing processes were difficult. Maureen Moir undertook the Herculean task of typing the whole book.

GUIDE TO THE CONTENTS

The intention of this work is to summarize some of the present evidence for the interactions between coastal and offshore ecosystems, and at the same time to reveal gaps in knowledge and to make recommendations for future work. Not every author has chosen the state-of-the-art approach. Some have preferred to concentrate on, from their point of view, crucial problems which need further elucidation. A few give a detailed analysis and synthesis of the coastal/offshore exchange. These differences are probably significant for our knowledge today - it is patchy in both space and depth.

By examining different types of ecosystem it was our hope to scrutinize the generality of the six previously stated aspects of the coastal/offshore relationships. It was not possible, however, to obtain studies of all major systems. In particular, we did not include the tropical systems due mainly to the difficulty of assembling the necessary data.

Water exchange provides the most obvious and direct connection between coastal and offshore areas. Two types of systems and one extra methodological paper describe this type of coupling. DRONKERS discusses water exchange in shallow coastal systems, stressing tide, wind and buoyancy as principal agents. A classification system relating major mixing zones to mixing agents and geomorphological characteristics is presented. MCCLIMANS describes the coastal/offshore water exchange in narrow, deep shelf areas. He concludes that the common density front between coastal and offshore areas is a sufficient dividing line. Thanks to satellite images, the multiple fronts in this border areas can be assessed. Here filaments of highly productive regions are deformed in spirals and mixed through wind action. HORSTMAN advocates satellite remote sensing data from two or more consecutive days for estimating coastal-offshore fluxes with examples from the Baltic Sea.

Mass balance study is a classical tool for quantifying imports and exports of matter. GEARING presents a review of the promising technique of using stable isotope ratios for tracing transport of organic matter. Being more of an independent method, this technique might be used as a rough check on mass balance calculations. POSTMA summarizes the present knowledge for tidal flats stating that local production of organic matter is mostly insufficient, the system running on imports from

outside. An unusually high percentage of this organic matter is metabolized by anaerobic bacteria which are fed through bioturbation. HOPKINSON starts with a critical evaluation of the direct flux and mass balance approaches for estimating the transfer of matter. Through a detailed analysis of five marsh/estuarine systems he then arrives at the overall conclusion that a substantial transfer of estuarine carbon to the nearshore region exists but that the source of "new" allochthonous nutrients cannot be defined on the basis of present information. TWILLEY concludes from studies of mangrove forests, that there is a more conclusive flux from forested wetlands than from salt marshes, partly due to the continuous litterfall in the former. Although present data on nutrients are scarce there are indications that nutrient recycling may vary along a hydrologic continuum. GOMEZ reports from her studies of Philippean mangrove areas that there is a net export of particulate material from the estuary to the open sea coinciding with the peak of litterfall of major mangrove species and the wet period. PEARSON, in his summary of boreal and polar fjord systems, states that boreal well-mixed fjords tend to export considerable amounts of nutrients to adjacent coastal waters whereas stagnant boreal fjords appear to be nutrient sinks. Stratified fjords are probably sinks for both nutrients and carbon throughout the year. SMITH interprets available metabolic data on coral reefs and stresses that reefs are not metabolically different from other shoal-water systems, but have very limited metabolic interaction with the surrounding ocean. Produced new carbon is only slightly higher than the new production of the surrounding plankton communities. PETERSON, HAGER, SCHEMEL and CAYAN take a global view of the riverine C, N, Si and P transport to the coastal ocean. They find that after aphotic and benthic mineralization the "leftovers" for eventual exchange are difficult to quantify by empirical methods. Large-scale onshore fluxes dominate the coastal nutrient budgets and the riverine/estuarine nutrient sources are secondary to the ocean, except locally.

Active transport between coast and ocean is studied through reviews of fish and crustacean case studies. ZIJLSTRA reviews the evidence of migrating fish as a coastal/offshore transport agent. He concludes that the diadromous fish play a minor role, partly due to the deterioration of rivers and estuaries. Fish using the coastal areas as nursery grounds are important, however, utilizing the favourable conditions in these areas such as: high production of food, high temperature in late spring and summer and scarceness of large predators including adults of the same species. Although there is a netflow of biomass from the

coastal to the offshore areas this is important in terms of its quality rather than its quantity. ROTHLISBERG describes the flow of living matter between coast and offshore through the migration patterns of three crustaceans, all commercially important, from different oceanographic regimes and with different larval form and life span. All are active vertical migrators, showing three different larval transport trajectories due to the different hydrodynamic pattern. EPIFANIO shows how three species of crabs have evolved behavioural traits which allow control of horizontal advection with consequent larval retention in areas near favourable adult habitats. These traits can be summarized as: 1) constant maintenance of position deep in the water column; 2) downstream advection of surface-dwelling immature larvae; 3) tidally rhythmic vertical migration of larvae.

Numerical modelling as a tool for synthesizing physical and biological processes was discussed in the last session. UNCLES reviews the currently used techniques for coupling hydrodynamical and ecological models of large tidal estuarine ecosystems. He arrives at the conclusion that the fixed element, tidally-averaged model is the most suitable for ecosystem simulations.

The evidence of the separate reviews and the discussions during the meeting are summarized by the Working Group members. Several recommendations for future research and for suitable methods are made.

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