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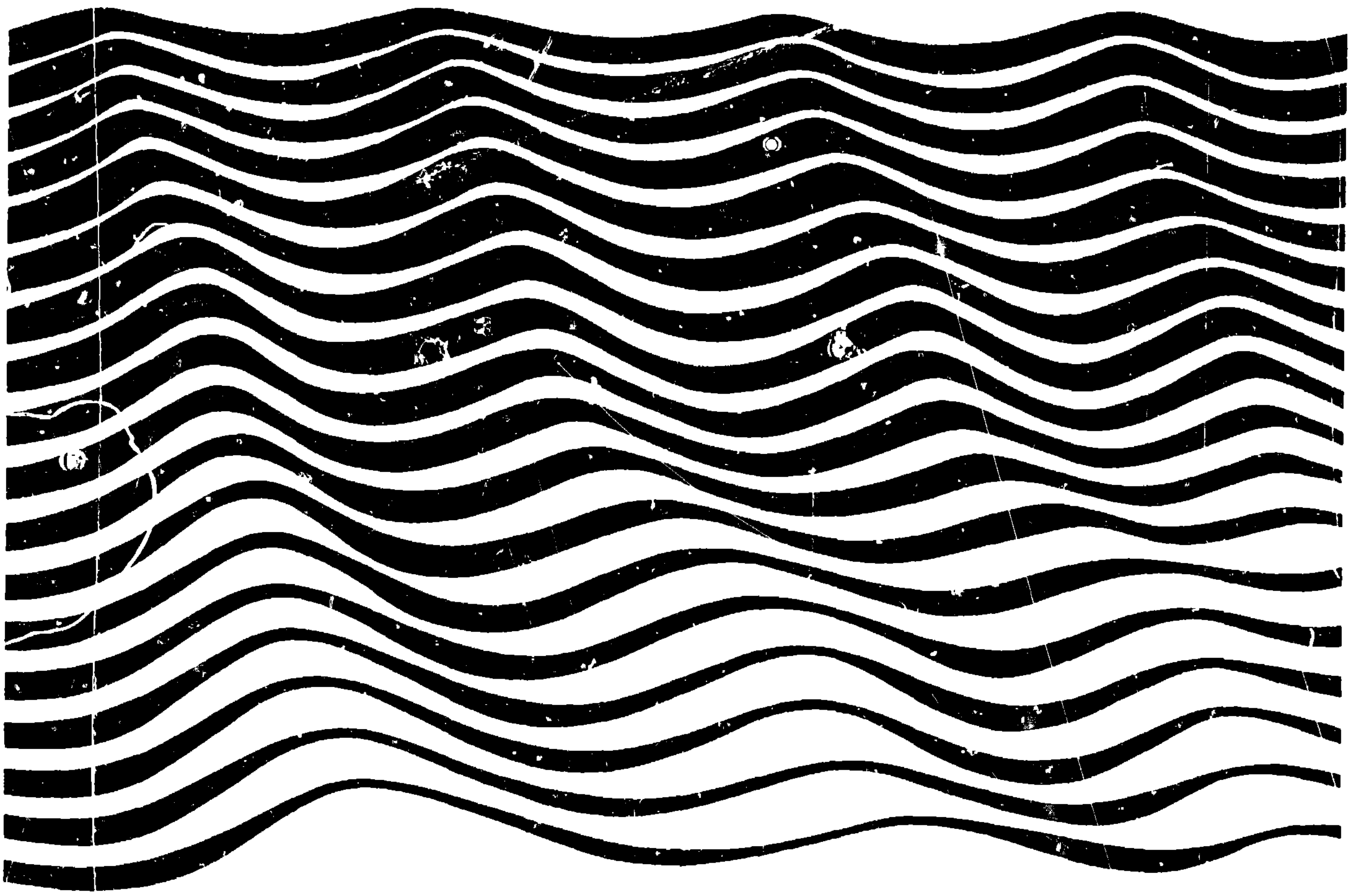
Coastal off-shore ecosystems relationships

Final Report of
SCOR/IABO/Unesco
Working Group 65
Texel, Netherlands,
September 1983



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35	Determination of chlorophyll in seawater. Report of intercalibration tests sponsored by SCOR and carried out by C.J. Lorenzen and S.W. Jeffrey, CSIRO Cronulla, N.S.W., Australia, September-October 1978	1980	—
36	The practical salinity scale 1978 and the international equation of state of seawater 1980. Tenth report of the Joint Panel on Oceanographic Tables and Standards, (JPOTS). Sidney, B.C., Canada, 1-5 September 1980. Sponsored by Unesco, ICES, SCOR, IAPSO. Available in Ar, Ch, F, R, S	1981	WG 10

(*Примечание:* Этот доклад (текст идентичен) был первоначально издан только на английском языке под заголовком *Tenth report of the Joint Panel on Oceanographic Tables and Standards* (Десятый доклад Объединенной группы по океанографическим таблицам и стандартам)). Имеется на арабском, испанском, китайском, русском и французском языках.

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38	Background papers and supporting data on the International Equation of State of Seawater 1980.	1981	WH 10
39	International Oceanographic Tables, Vol. 3	1981	WG 10
40	International Oceanographic Tables, Vol. 4. (To be published)	1982	WG 10
41	Ocean-Atmosphere Materials exchange (OAMEX) Report of SCOR Working Group 44, Unesco, Paris, 14-16 November 1979	1982	WG 44
42	Carbon dioxide sub-group of the joint panel on oceanographic tables and standards. Report of a meeting Miami, Florida, 21-23 September 1981 sponsored by Unesco, ICES, SCOR, IAPSO	1983	—
43	International Symposium on Coastal lagoons Bordeaux, France, 8-14 September 1981 Available in F and S	1982	—
44	Algorithms for computation of fundamental properties of seawater. Endorsed by Unesco/SCOR/ICES/IAPSO Joint Panel on Oceanographic Tables and Standards and SCOR Working Group 51.	1983	—
45	The International System of Units (SI) in Oceanography Report of IAPSO Working Group on Symbols, Units and Nomenclature in Physical Oceanography. (SUN)	1985	—
46	Opportunities and problems in satellite measurements of the sea Report of SCOR Working Group 70	1986	—
47	Research on coastal marine systems Report of the third meeting of the Unesco/SCOR/IABO consultative panel on coastal systems October, 1984	1986	

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PREFACE

This series, the *Unesco Technical Papers in Marine Science*, is produced by the Unesco Division of Marine Sciences as a means of informing the scientific community of recent advances in oceanographic research and on recommended research programmes and methods.

The texts in this series are prepared in co-operation with non-governmental scientific organizations. Many of the texts result from research activities of the Scientific Committee on Oceanic Research (SCOR) and are submitted to Unesco for printing following final approval by SCOR of the relevant working group report.

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ABSTRACT

This report contains the results of the work of the SCOR/IABO/Unesco Working Group number 65 on "Coastal offshore ecosystems relationships", established in 1980 by the Scientific Committee on Oceanic Research (SCOR) at the suggestion of Unesco and in co-operation with Unesco and the International Association of Biological Oceanography (IABO). The terms of reference were: (1) to review and compare the energetics of coastal (littoral and estuarine) and offshore pelagic and benthic populations, and (2) 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.

As is shown herein, the Working Group recognized the great diversity found in the coastal zone, which could lead to local differences in the relationships between coastal and offshore ecosystems. Various aspects of the coastal and offshore ecosystems and of their relationships were reviewed. Examples of these aspects are: classification, nutrient exchange, transport of organic matter, animal populations, productivity, and effects of disturbances by man. Also discussed were the magnitude and importance of the exchanges at the coastal-offshore boundary, in particular the inputs from the coastal to the offshore areas. It was generally concluded that little is known about the interaction between the nearshore and offshore areas. Several recommendations were made concerning the subjects reviewed. A workshop was recommended to review the state-of-the-art in this domain, to discuss the progress of research accomplished by an expanded group of experts, and to propose and stimulate multi-disciplinary research for the next decade.

RESUME

Le présent rapport décrit les résultats des études du Groupe de travail SCOR/AIOB/Unesco (numéro 65) sur les "Relations entre écosystèmes côtiers et océaniques" créé en 1980 par le Comité scientifique de la recherche océanique (SCOR) sur proposition de l'Unesco et en coopération avec elle et avec l'Association internationale d'océanographie biologique (AIOB). Le mandat du Groupe était le suivant : (1) étudier et comparer l'énergétique des populations pélagiques et benthiques près des côtes (littoral et estuaires) et au large et (2) proposer une méthodologie pour les recherches visant à mieux connaître les phénomènes de conversion de l'énergie qui se produisent entre les populations pélagiques migratoires et les populations benthiques des côtes et du large, et définir les travaux complémentaires qu'il y a lieu d'entreprendre.

Ainsi que le montre le rapport, le Groupe de travail a reconnu la grande diversité de la zone côtière, qui pourrait entraîner une différenciation locale des relations entre les écosystèmes côtiers et océaniques. Divers aspects de ces écosystèmes et de leurs relations ont été examinés, par exemple : leur classification, les échanges de substances nutritives, le transport de matières organiques, les populations animales, la productivité, et les effets des perturbations causées par l'homme. Ont également été étudiées l'ampleur et l'importance des échanges qui s'opèrent à la limite entre les zones côtière et océanique et en particulier les apports de la première à la seconde. La conclusion générale est que l'on sait peu de choses des interactions entre les deux zones. Plusieurs recommandations ont été formulées sur les questions examinées. Il a été recommandé d'organiser un atelier pour faire le bilan des connaissances en la matière, échanger des vues sur l'état d'avancement des recherches effectuées par un groupe d'experts élargi, formuler des propositions et stimuler les initiatives en ce qui concerne les recherches multidisciplinaires à entreprendre au cours de la prochaine décennie.

RESUMEN ANALITICO

En el presente informe figuran los resultados de la labor del Grupo de Trabajo N° 65 SCOR/IABO/Unesco sobre "Relaciones de los ecosistemas costeros marítimos" creado en 1980 por el Comité Científico de Investigaciones Oceánicas (SCOR) por sugerencia de la Unesco y en cooperación con la Unesco y la Asociación Internacional de Oceanografía Biológica (IABO). El Grupo de Trabajo tenía como mandato: 1) examinar y comparar los aspectos energéticos de las poblaciones costeras (de los litorales y los estuarios) y las poblaciones marinas pelágicas y bénticas, y 2) sugerir métodos apropiados para acrecentar los conocimientos relativos a la conversión de energía entre las poblaciones costeras y las poblaciones marinas pelágicas migratorias y bénticas y definir las investigaciones futuras necesarias.

En el informe se señala que el Grupo de Trabajo reconoció la gran diversidad encontrada en la zona costera que podía provocar diferencias locales en las relaciones entre los ecosistemas costeros y marinos. Se examinaron diversos aspectos de los ecosistemas costeros y marinos y sus relaciones recíprocas. Figuran entre esos aspectos: la clasificación, el intercambio de nutrientes, el transporte de materia orgánica, las poblaciones animales, la productividad y los efectos de las perturbaciones provocadas por el hombre. También se examinaron la magnitud e importancia de los intercambios en la zona límite costera-marina, en especial los aportes que transitan de la zona costera a la zona marina. En general, se llegó a la conclusión de que no se poseen muchos conocimientos sobre la interacción entre las zonas próximas a la costa y las zonas marinas. Se formularon varias recomendaciones relativas a los temas considerados. Se recomendó celebrar una reunión de trabajo para examinar el estado de los conocimientos en esta materia, así como los progresos de las investigaciones realizadas por un grupo ampliado de expertos, y proponer y estimular investigaciones multidisciplinarias en el decenio venidero.

РЕЗЮМЕ

В этом докладе содержатся результаты деятельности Рабочей группы № 65 СКОР/МАБО/ЮНЕСКО по "Взаимосвязям береговых и прибрежных экосистем", созданной в 1980 году Научным комитетом по океанографическим исследованиям (СКОР) по предложению ЮНЕСКО и в сотрудничестве с ЮНЕСКО и Международной ассоциацией биологической океанографии (МАБО). Круг ее ведения включает следующее: (1) проводить обследование и сравнение энергетики береговых (побережных и эстуарийных) и прибрежных пелагических и бентических популяций и (2) предлагать методы расширения знаний о передаче энергии между береговыми и прибрежными пелагическими мигрирующими и бентическими популяциями, а также определять характер необходимых дальнейших исследований.

Как показывается в этом документе, Рабочая группа констатировала огромное разнообразие, обнаруженное в береговой зоне, которое может привести к местным различиям во взаимосвязях между береговыми и прибрежными экосистемами. Были рассмотрены различные аспекты береговых и прибрежных экосистем и их взаимосвязей. Примерами таких аспектов являются следующие: классификация, питательный обмен, перенос органических веществ, животные популяции, продуктивность и последствия вмешательства человека. Обсуждались также размеры и значение обменов в береговой-прибрежной пограничной зоне, в частности переносы с береговых в прибрежные районы. По общему заключению было констатировано, что имеется недостаточно знаний о взаимодействии между прилегающими к берегу и удаленными прибрежными районами моря. По рассматриваемым вопросам было предложено несколько рекомендаций. Было рекомендовано провести учебно-практический семинар для обзора достигнутого уровня в этой области, обсуждения результатов осуществляемых расширенной группой экспертов научных исследований и для выработки предложений и стимулирования многодисциплинарных исследований на следующее десятилетие.

خلاصـة

يتضمن هذا التقرير نتائج أعمال فريق العمل المشترك بين سكور/ ايابو/اليونسكو رقم ٦٥ عن "العلاقات بين النظم الايكولوجية لأعالى البحار" الذى أنشأته اللجنة العلمية لبحوث المحيطات (سكور) عام ١٩٨٠ بناء على اقتراح من اليونسكو وبالتعاون مع اليونسكو والرابطة الدولية للأوقيانوغرافيا البيولوجية (ايابو) • وكانت اختصاصات الفريق هى : (١) استعراض ومقارنة طاقات المناطق الساحلية (الشاطئية والخليجية) ومناطق أعالى البحار من الموارد الحية فى عرض البحار وفى القاع، و(٢) اقتراح طرائق لتعزيز المعرفة بشأن تحول الطاقة بين حيوانات عرض البحر والقاع فى المناطق الساحلية وأعالى البحار، وتحديد ما يحتاج اليه من بحوث لاحقة •

ولقد تبين فريق العمل، كما هو موضح هنا، التنوع الكبير الذى اكتشف بالمنطقة الساحلية بما قد يؤدى الى اختلافات محلية فى العلاقات بين النظم الايكولوجية الساحلية والنظم الايكولوجية لأعالى البحار • وجرى استعراض مختلف جوانب النظم الايكولوجية الساحلية والنظم الايكولوجية لأعالى البحار والعلاقات بينها، ومن هذه الجوانب على سبيل المثال : التصنيف، وتبادل المواد المغذية، ونقل المادة العضوية، والرصيد الحيوانى، والانتاجية، وتأثير الاضطرابات التى يسببها الانسان • كما جرت مناقشة حجم التبادل فى منطقة الحد الفاصل بين المناطق الساحلية وأعالى البحار، وخاصة ما تحيله المناطق الساحلية الى أعالى البحار • وقد خلص بوجه عام الى أنه لا يعرف سوى القليل عن التفاعل بين المناطق القريبة من الساحل وأعالى البحار • وقدمت عدة توصيات بشأن الموضوعات التى جرى استعراضها • وأوصى بتنظيم حلقة عمل لاستعراض المعرفة الراهنة فى هذا المجال ومناقشة سير البحوث التى يضطلع بها فريق موسع من الخبراء وتقديم المقترحات لحفز البحوث المتعددة التخصصات فى العقد المقبل •

摘　　要

本报告载有海洋研究科学委员会（SCOR）／国际生物海洋学协会（IABO）／教科文组织（UNESCO）关于《沿海与近海生态系统的关系》的第65工作组的工作成果。该工作组是1980年根据教科文组织的建议并在教科文组织与国际生物海洋学协会（IABO）的合作下，由海洋研究科学委员会（SCOR）建立的，其职权范围是：(1)审查和比较沿海（海岸和河口）和近海水层生物种群与底栖种群的能学，和(2)提出增进有关沿海与近海水层生物洄游和底栖种群之间能量变换的知识的方法，以及确定需要进行的深入研究。

如本报告所示，工作组认识到沿海地带存在的巨大多样性，这种多样性可能导致沿海与近海生态系统之间关系上的各种地区差异。本文讨论了沿海与近海生态系统及其关系的各个方面。这些方面有：分类、营养交换、有机质的迁移、动物种群、生产力以及人类干扰的影响。还讨论了沿海——近海边界处交换的量度和重要性，特别是沿海地区对近海地区的输入。总的结论是，对近岸地区和近海地区的相互作用了解甚微。就所讨论的题目提出了几项建议。建议举办一期讲习班研究这一领域的现状，讨论由扩大了的专家小组所完成的研究之进展情况，以及提出并促进下个十年的多学科研究。

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1. INTRODUCTION

During the past decades scientific studies of inshore (coastal) ecosystèms have been greatly intensified. The fact that many of these systems came under human stress, for instance through engineering works, land reclamation or pollution, stimulated research in the coastal areas. A variety of ideas has been generated about the functioning of coastal ecosystems including the way in which they may affect bordering open sea areas. However, up till the present no generally accepted views exist on the importance of the inshore areas for neighbouring shelf seas and on the mutual dependence of coastal and offshore ecosystems in terms of exchange of organic and inorganic substances or organisms. As human pressure on coastal zones is spreading on a world-wide scale there is an urgent need for a critical review of the properties of coastal ecosystems and of their relationships with bordering offshore areas, both for scientific reasons and for future management.

In 1980 SCOR, in close collaboration with UNESCO and IABO, initiated the formation of its 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 on Texel (The Netherlands) from 12-15 September 1983. The membership of the W.G. and participation in the meetings was as follows:

	September 1981	September 1982
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. Full information on the members is provided in Annex I.

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, covering 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), are appended in Annex III.

These accounts, 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. These aspects, to be considered in the next section of this report, are:

(i) Coastal-offshore classification;

(ii) Nutrient exchange between coastal and offshore systems;

(iii) Transport of organic matter across the coastal/offshore boundary;

(iv) Coastal-offshore relations in animal populations;

(v) Productivity in coastal and offshore systems;

(vi) Effects of man-made disturbances.

In the third section of this report gaps in our knowledge and recommendations for future research, as recognised during discussions, will be formulated. Finally, in the last section a proposal is made for a workshop, in which the subject of W.G. 65 can be considered by a larger meeting with a wider range of expertise and experience.

2. SUMMARY OF ASPECTS CONSIDERED

For each of six aspects recognised to be of general interest in coastal-offshore relationships, a state of the art review has been prepared by members of W.G. 65. These reviews are appended in full in Annex II and are presented here in a summary form.

2.1 Coastal-offshore classification (Annex 2-1)

To study the properties of coastal and offshore ecosystems and their relationship a definition is required. It appears that the boundaries between these systems are highly dynamic and fluctuate with time due to variability in river discharge, wave climate, wind stress or far-field forcing.

In coastal areas usually three regions can be distinguished: a. the estuarine-riverine zone, b. the estuarine mixing zone, c. the nearshore zone, which are separated mainly on geomorphological and hydrographical (salinity) criteria. The estuarine-riverine zone and the estuarine mixing zone most often show strong salinity gradients, which are weak in the nearshore zone. The latter is usually characterised by high turbidity and high nutrient concentrations. The offshore boundary of the nearshore zone often consists of a sharp front, sometimes defined by a steep density change or a tidal front. In other cases, in the absence of either river discharge or tides, the seaward limit of the coastal (nearshore) region can be defined by the location of the coastal boundary jet, which is a semi-permanent feature of most coasts.

It should be recognised that local conditions may vary greatly from this idealized model, although the exceptions can still be incorporated.

2.2 Nutrient exchange between coastal and offshore systems (Annex 2-2)

Although nutrients in the sea have been studied for many years it was not until the 1920-1930's that analytical techniques were sufficiently accurate to determine low concentrations and not until more recently that satisfactory measurements of ammonia could be made. In spite of the importance of nutrients for the ecosystem and in spite of our analytical ability we are far from a full understanding of the processes responsible for inputs, outputs and transformations that determine the concentrations of nutrients observed. In considering whether coastal areas act as sources or sinks for nutrients, the evidence available is of an indirect nature, and stems from a mass-balance approach or is obtained from mixing diagrams, using salinity as a conservative factor. Consideration of information from these or other sources tends to indicate that coastal areas, in particular estuaries, cannot be regarded in general as significant sources of nutrients for offshore areas, notwithstanding the usually high nutrient levels encountered in the coastal zones. Much of the material contributed from the land to inshore areas probably moves parallel to the coast in a narrow band of turbid coastal water or is retained in estuarine regions. However, good estimates of coastal retention of nutrients require knowledge of sediment accretion (burial) rates and of other factors, such as denitrification, which cannot be easily measured.

2.3 Transport of organic matter across the coastal/offshore boundary (Annex 2-3)

Up to the early 1970's the idea of a significant export of organic matter, produced in highly productive salt-marshes or kelp beds, from coastal areas to offshore ecosystems was commonly accepted. However, it has since been realised that assessing the transport of organic matter over the coastal/offshore boundary offers many difficulties in addition to showing large seasonal variability. In principle two approaches can be applied, i.e.

the direct flux measurement and mass balance calculations, in which for each region the organic input and local production is balanced by various consumption and loss processes.

Studies in some estuarine systems of the east coast of the United States with the first method tend to indicate that the magnitude of "outwelling" of organic matter in these areas is much smaller than was formerly supposed. Recent studies suggest that export from marshes or kelp-beds (see Annex 3-4) is of little real importance to the carbon balance of nearshore or offshore ecosystems. In fact some data have been presented indicating import of particulate organic matter to marshes or to estuarine areas like the Wadden Sea (Annex 3-7).

However, in view of the difficulties encountered in measuring the flux of particulate organic carbon either directly or by indirect methods, more and in particular more complete observations, covering a whole season, are urgently required to settle this dispute.

2.4 Coastal-offshore relations in animal populations (Annex 2-4)

There is good information indicating a significant exchange of faunal elements, in particular active nekton such as larger crustacea and fish, over the coastal-offshore boundary. The evidence is not restricted to some well-studied areas in e.g. North-America, Europe and Australia, but includes also some tropical situations. It seems likely that for the most abundant species, involved in the coastal-offshore exchange, migration is essential for their life-cycle. However, in most cases the importance and background of the migrations is insufficiently recorded and poorly understood. A numerically important part of the fauna, participating in coastal-offshore migrations, appears to be of major commercial interest. For some areas it has been suggested that a large part of the commercial catches in both the coastal and offshore area depends on species taking part in coastal-offshore migration. The form, in which the coastal-offshore dependence in a species occurs, may vary, as some species exploit the coastal zone as spawning grounds and others as nursery areas. The most common form is the one, in which the spawning grounds and adult habitat is in the offshore area, and the nursery in the coastal region.

Although the dependence of offshore fish resources from coastal nurseries has often been claimed to protect coastal areas, few studies are available to indicate the extent and nature of that dependence.

2.5 Productivity in coastal and offshore areas (Annex 2-5)

It is often stated that the productivity of near-shore and particularly estuarine regions is higher at all trophic levels than in the adjacent offshore areas.

The coastal areas no doubt show a higher diversity in potential energy (freshwater input, tides, waves etc.) and in habitats (mudflats, kelp forests, seagrass meadows, saltmarshes and a planktonic system) than the offshore region, where only the plankton system is well-developped. Moreover, the geographically smaller distance between the producer and respiration unit in well-mixed, unstratified coastal areas facilitates the recycling of nutrients, whereas in offshore regions recycling of nutrients is often hampered by stratification.

However, the realisation of the high potential energy in coastal regions is usually achieved in macrophytes, which have a limited value as a direct food source for animal life. Primary production of small scale producers in the water column (phytoplankton) is often limited in coastal waters by light reduction due to high turbidity. By contrast, phytoplankton production in offshore areas, which form there the main source of primary energy, is generally limited by nutrients.

In this situation the W.G. expressed its reservations on the generally accepted idea, that in most cases coastal areas are more productive than offshore regions.

2.6 Effects of man-made disturbances (Annex 2-6)

The group discussed such man-made disturbances as oil and gas exploitation, aggregate extraction, dredging, dumping, coastal discharges (including thermal discharges), ocean energy exploitation and the range of engineering activities associated with coastal development. The management of these disturbances was briefly reviewed, and the system of international, national and local arrangements for controlling and monitoring was recognized.

It was noted that many of the disturbances identified were of a point-source nature and their adverse effects localized, but that in some cases, particularly in the field of major engineering alterations, far-field effects along the coastal zone in terms of, for example, stability of beaches and distributions of flora and fauna could be significant. Further, in view of the working group's conclusions that there are links between onshore and offshore (although they are difficult to quantify and the coupling is usually not strong), it was considered that before decisions are made about the siting of activities controlled by man, knowledge of the relevant hydrodynamics should be acquired, and that to this must be added an understanding of ecological processes in the region.

While we felt it important to quantify the flux between the near- and offshore zone we decided not to formulate a specific recommendation at present in view of the many relevant initiatives currently underway in the field of pollution, and in particular because the problem of coastal fluxes of contaminants was being specifically addressed by the ICES-Workshop in Nantes in the spring of 1984.

3. CONCLUSIONS

The main conclusions in relation to the aspects considered in chapter 2, were:

(1) In the past many discussions about coastal-offshore interactions addressed in fact the exchange over the estuarine-nearshore boundary. Little is known about the interactions between the nearshore and offshore areas, as defined in Annex II-1.

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

(3) "Outwelling" of organic matter from coastal, in particular estuarine, areas to nearly offshore regions is probably much smaller than formerly postulated. In fact, in some cases

there are indications of an import of organic matter into coastal regions.

(4) Migration of nekton, in particular larger crustacea and fish, over the coastal-offshore boundary is well-established for various, often commercially important, species. However, the importance and background of the exchange is insufficiently recorded and understood.

(5) Notwithstanding higher nutrient levels, a higher nutrient recycling, a higher potential energy and higher habitat diversity coastal ecosystems may not be always 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 extremely local effects. Impacts on coastal-offshore interactions can be expected in particular at the mouth of large river systems or in areas, bordering highly urbanised regions.

4. RESEARCH RECOMMENDATIONS

a. Nutrients

- The ideal framework within which to evaluate the exchange between estuarine, nearshore, and offshore systems is the annual mass balance. In spite of the difficulties involved in efforts to obtain annual budgets of nutrients and organic carbon, the working group recommends that multidisciplinary, integrated research programmes be developed in different types of estuarine and nearshore ecosystems to provide estimates (with associated error terms) of the annual inputs and outputs of nitrogen, phosphorus and silica. It is extremely important for these efforts that the research team include chemical, biological, and physical oceanographers as well as sedimentologists who work together to obtain simultaneous estimates of nutrient inputs, primary production, nutrient regeneration, denitrification, long-term sediment accretion and composition and exchange with near-shore waters.

- The major ways in which estuarine and nearshore areas may serve as nutrient sinks include denitrification and burial in sediments. Both processes are, however, difficult to measure. The working group therefore recommends that efforts be made to intercalibrate the various methods used to measure each process (for example $^{15}NO_3$ uptake, acetylene blockage, N_2O enrichment, NO_3 enrichment, N_2 pore water profiles, N_2 flux, etc. and bathymetric changes, ^{14}C dates, ^{210}Pb, etc.) and, if necessary, to develop new techniques for the measurement of these processes.
- As part of the mass-balance studies direct flux measurements across carefully chosen transects or system boundaries should be carried out. It is critical that such work involve a multidisciplinary team with attention to the problem of water transport and spatial and temporal variability in constituent concentrations in order to optimize the information gained within the constraint of a practical level of effort and instrumentation.

b. Organic matter

- The various recommendations made on nutrients apply to the study of organic matter transport. Both direct flux measurements and mass balance calculations are important and should be undertaken together in different nearshore-offshore systems. Each approach is subject to many sources of errors leading to uncertainties that are difficult to quantify. The best way to evaluate the reliability of the final estimate of annual transport is to compare values obtained by both means.
- One evident mechanism of transport of photosynthetically active matter is the drift seawards by upwelling-induced plankton blooms at the coast. In addition to the well-known, large scale upwelling events at the westcoasts of the large continents there are minor, intermittent events at higher latitudes which are little known. We recommend an inventory of known cases possibly as a topic of the recommended workshop (see section 4), followed by multidisciplinary research programmes in selected geographical areas. Emphasis should be put not only on the horizontal transport but also on the sedi-

mentati... processes, the "unloading" of the patch during the horizontal displacement. The successful performance of such an investigation would need not only a high diversity of scientists but also a whole array of instruments from remote sensing platforms to drifting sediment traps.

- In order to explore the possibility that primary and/or secondary production of the near-shore zone are enhanced by inputs from the estuarine zone, the group recommends that studies be made comparing the standing stock and productivity of plankton and benthos in areas influenced by river-estuarine plumes with that of near-shore areas without such plumes.
- The biological processes leading to production and metabolic losses of organic matter in estuaries need further attention. For example, estimates of marsh grass production from biomass changes are understood to be minimal values but the extent of the underestimate is not known. In the case of benthic mineralization, and regeneration of nutrients, the relative importance of aerobic and anaerobic metabolism and their dynamic relationship are still largely unknown.

c. Fish-invertebrates

Although there is little doubt that coastal-offshore relations exist in many nekton-species, in particular in fish and crustacea, the importance and background of that relationship is insufficiently recorded and understood.

The Working Group recommends, that future work be concentrated on:

- Distributional patterns of juvenile stages in species, for which a coastal nursery has been claimed.
- The habitat selected by such juveniles in the coastal area.
- Modes and mechanisms by which the juveniles enter the coastal area at the end of their larval stage.
- Food selection, food availability and growth of the juveniles in the coastal zone.
- Predation on and mortality of juveniles in various parts of their area of distribution and in various stages of their development.
- Density-dependent factors, affecting growth and mortality of juveniles with the ultimate aim of assessing whether the size

and quality of the coastal area determines the size of offshore nekton populations.

In view of the multitude of species involved it is recommended that the effort is concentrated on some carefully selected species, to detect general principles rather than disperse the attention on many species, for which incomplete data would be collected.

d. Productivity

Future work should be concentrated on:

- Comparison of primary and secondary productivity in estuarine, nearshore and offshore regions along various coasts to assess the causes and conditions inducing variability in productivity.
- Mechanisms and causes of localized upwelling in estuarine and nearshore areas and the relationship to biomass concentration, changes in productivity and impact on the structure of the ecosystem.

5. FUTURE ACTIVITIES

In view of the importance of the subject in the general context of basic science, and also in relation to the management of commercially important species and the need for linking up with on-going initiatives in the field of pollution, the Group felt it was desirable to encourage further examination of the problems discussed in its report. It was agreed to consider the possibilities of a workshop which would review the state of the art, discuss the progress of research in an expanded group of experts and propose and stimulate multi-disciplinary research for the next decade.

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ANNEX 2 . REVIEW OF ASPECTS CONSIDERED

2.1 Coastal-offshore classifications (B. Kjerfve)

Definitions of "estuary" and "coastal zone" are numerous. Whereas a geographical geomorphological definition usually is put forth, this does not prove to be very practical. Estuaries are largely unsteady in their behaviour. Estuarine boundaries fluctuate with time due to variability in river discharge, wave climate, wind stress, or far-field forcing. Thus a dynamical definition would seem more useful and is proposed here.

Estuaries and coastal areas can be considered under three headings: a. the estuarine riverine zone, b. the estuarine mixing zone, and c. the nearshore zone.

The estuarine mixing zone is what most commonly would be referred to as the estuary proper and be taken to be the estuary under the geomorphological classification. The upriver boundary is taken to be the 1 ppt isohaline, which fluctuates upstream or downstream with time mainly due to tidal stage and river flow. The seaward border of this zone is the ebb tidal delta or river mouth bar in the vicinity of the geographical entrance to the system, where the salinity most often is approaching that of ocean salinity (35 ppt). The flood tidal delta and associated tidal flats where they exist are part of the estuarine mixing zone and located inside the geographical entrance. The estuarine mixing zone typically exhibits strong salinity gradients, contains a region of turbidity maximum where fine-grained sediments flocculate, is the zone where gravitational circulation may exist, and experiences reversing tidal currents. Depending the geomorphology, the estuarine mixing zone is sometimes referred to as a lagoon in the case of shallow systems of elliptical shape, and sometimes as a fjord, flård or loch in the case of glacially carved systems.

The estuarine riverine zone is a freshwater region of the coastal system which experiences periodic tidal rise and fall of the river level. In the lower regions of this zone, near the 1 ppt boundary, the currents typically reverse directions due to the tide. The estuarine riverine zone can be quite extensive and extends for several hundred kilometers in the case of the

Amazon. Even in estuarine systems with a mesotidal range, this zone can exceed 100 km in length as in the case of many of the rivers along the U.S. Atlantic coast.

The nearshore zone consists of a region along the coast, usually characterized by high turbidity, high nutrient concentrations, and weak salinity gradients. The width may vary from approx. 1 km away from a river mouth in a tidal inlet to more than 30 km in the case of a river or estuarine plume. The offshore boundary of this nearshore zone often consists of a sharp front, sometimes defined by a steep density jump, sometimes by a tidal front, signifying the seaward extent of tidal excursion of turbid coastal waters. In the absence of either river discharge or tides, the seaward limit of this nearshore region can best be defined by the location of the core of the coastal boundary jet. This jet is a semi-permanent feature of most coasts, is largely wind-driven, and may exist approximately 5-40 km from the coastline. It should be recognized that this seaward boundary of the nearshore zone is a dynamic boundary which changes location over time due to the variability in dynamic forcing. This boundary constitutes the dividing line between the nearshore and offshore coastal ocean.

It should be recognized that local conditions may vary greatly from this idealized model. However, the exceptions can still be incorporated. A given system may not contain all of the discussed regions. For example, many coastal lagoons in semiarid or arid regions have little freshwater input. The mixing zone may then be hypersaline and the riverine zone totally missing. On a major river such as the Amazon, the mixing zone is compressed to a small fraction of the stage of the riverine and nearshore zones. Tideless systems, e.g. Baltic fjärds, will lack a riverine zone and the nearshore zones defined by the coastal jet. Certain lagoons, particularly in Australia and South Africa, close off at the entrance on account of high wave energy and sediment deposition. Such systems can remain closed off for years at the time, then obviously limiting the possibility for estuarine offshore exchange.

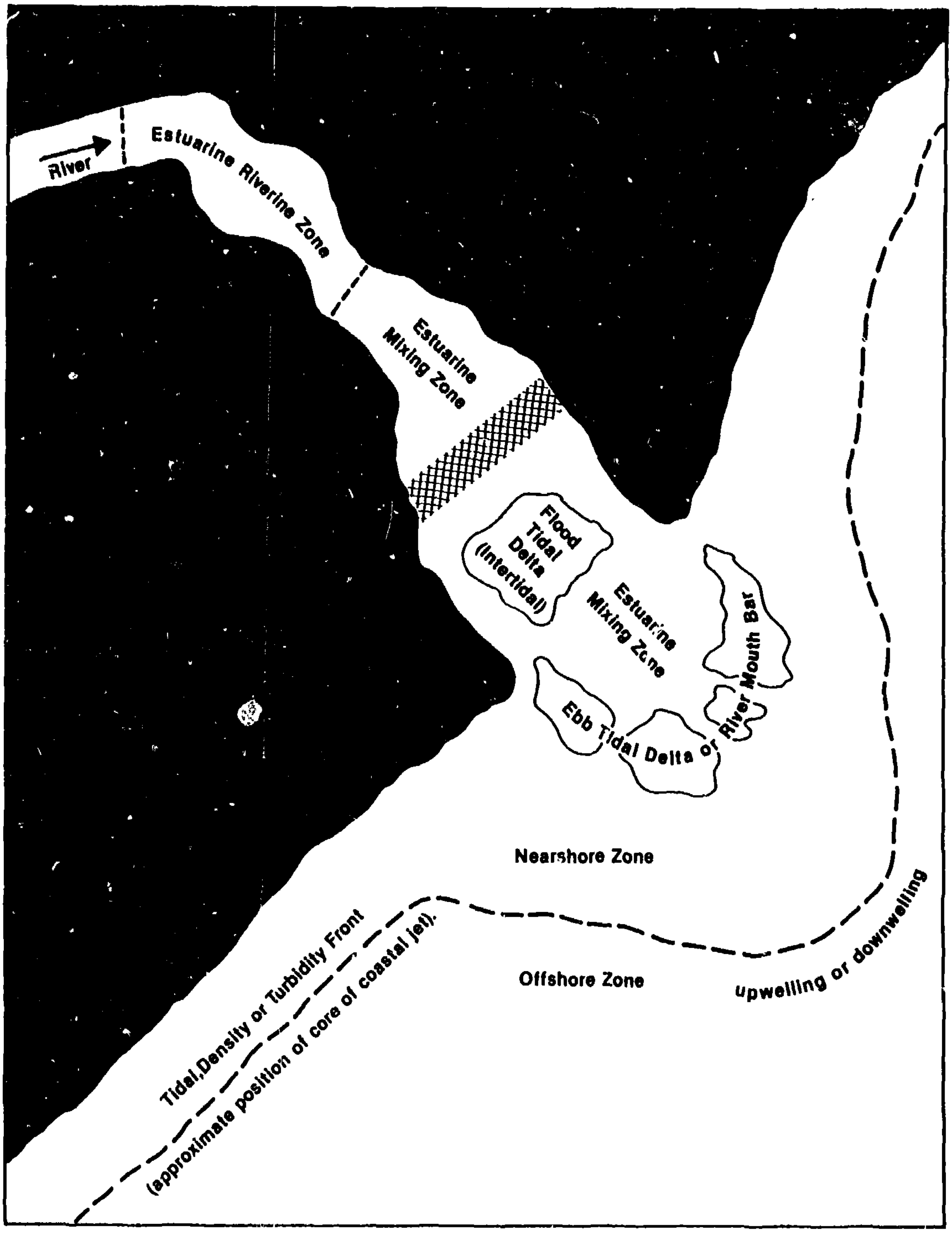

Fig. 1. Definition of the estuarine, nearshore and offshore zones.

2.2 Some observations on nutrient exchanges between coastal and offshore marine waters (S.W. Nixon)

The importance of inorganic nutrients, especially nitrogen, phosphorus and silica, in influencing the productivity of estuarine and coastal marine waters has been recognized since the turn of the century (Brandt 1899, Johnstone 1908). Various mechanisms have been proposed to account for the higher concentrations of nutrients that are commonly found in coastal and inshore waters, including river inputs, anthropogenic inputs from sewage and fertilizer, "onwelling" of enriched deeper offshore waters, "outwelling" from wetlands, nutrient "pumping" from sediments by macrophytes, nutrient trapping by estuarine circulation patterns, and complete recycling from pelagic and benthic communities (see review by Nixon 1981a). Doubtless, a variety of these different processes may operate to a greater or lesser degree in different environments.

In spite of their importance and in spite of the fact that analytical techniques suitable for measuring most of the inorganic forms of nutrients have been available for over 50 years (Riley 1975), we remain far from a full understanding of the processes responsible for the inputs, outputs and transformations that determine the concentrations of nutrients observed. Techniques for the measurement of ammonia and the dissolved and particulate organic forms of nitrogen and phosphorus have become available more recently, and data on the concentrations and seasonal cycles of these forms are only rarely available in sufficient detail to include them in attempts to develop mass balances. The lack of well-constrained nutrient budgets for estuarine and near-shore areas is also due to the difficulties of measuring certain transformations such as denitrification and burial, as well as the exchange of materials due to advection and diffusion across what may often be somewhat arbitrary boundaries between the coastal and offshore areas. As an example of one of the more complete budgets available for a coastal marine system, our present understanding of the annual mass balance for nitrogen in Narragansett Bay is shown in Table 1. It seems clear that the annual input exceeds the measured outputs by about a factor of 4, but the flux of major interest to SCOR Working Group 65, the export to offshore, has not been measured.

While the difficulties of making a direct measurement of the export of nitrogen or other materials have thus far limited us to estimating the total flux by difference, it may also be possible to calculate the export of nitrogen, phosphorus and carbon in organic matter using a simple, but novel, approach. It is well known that the ratio of inorganic nitrogen to inorganic phosphorus in coastal waters is usually much lower than the 16:1 characteristic of much of the open ocean and of the average biomass of marine plankton. In Narragansett Bay, the annual time-weighted mean N/P ratio of the lower West Passage during 1977-1982 averaged 4.2 (M.E. Q. Pilson, MERL data). This ratio cannot be the result of nutrient inputs since these average 14.8 (Nixon 1981b). While denitrification contributes to the lower ratio maintained in the Bay (Seitzinger et al., in press), it may also arise from the uptake and accumulation of nutrients during primary production if the organic matter formed containes N/P in a ratio of 16/1 and some of that organic matter is exported from the system rather than remineralized within it. The amount of export required may be calculated as follows:

I_N = annual input of inorganic nitrogen, m mol m^{-2} y^{-1}

U_N = nitrogen incorporated into organic matter which is exported from the system (offshore, burial, etc.), m mol m^{-2} y^{-1}

DNF = nitrogen lost through denitrification, m mol m^{-2} y^{-1}

R_N = nitrogen left in the water column for export in dissolved form, m mol m^{-2} y^{-1}

The same symbols with subscripts P and C are used for phosphorus and carbon.

Annual inputs of inorganic nitrogen = 978 m mol m^{-2} y^{-1}

Annual inputs of inorganic phosphorus = 66 m mol m^{-2} y^{-1}

Annual denitrification loss = 515 m mol m^{-2} y^{-1}

Annual mean N/P in the Bay = 4.2 (atoms)

$$R_N = I_N - DNF - U_N$$

$$R_P = I_P - U_P$$

$$U_N = 16\ U_P$$

$$R_N = 4.2\ R_P$$

Thus: $I_N - DNF - U_N = 4.2\ R_P$

$$978 - 515 - 16\ U_P = 4.2\ (66 - U_P)$$

$$463 - 16\ U_P = 277.2 - 4.2\ U_P$$

$$U_P = 15.7 \text{ m mol P m}^{-2}\ y^{-1}$$

Thus: $U_N = 251.2$ m mol N m^{-2} y^{-1}

$U_C = 1664.2$ m mol C m^{-2} y^{-1}

$= 19.9$ g C m^{-2} y^{-1}

The stoichiometric calculation suggests that if 20 g C m^{-2} y^{-1} are lost from the Bay, along with the associated nitrogen and phosphorus (assuming Redfield organic matter), the N/P ratio can be maintained at the observed level if the inputs are added at the rate and in the ratio specified. This loss amounts to about 6% of the reported annual primary production measured by ^{14}C uptake. Since the burial of organic nitrogen in Bay sediments is estimated at about 132 m mol m^{-2} y^{-1} (Table 1), the remaining 119 m mol m^{-2} y^{-1} (U_N - burial) may be exported in organic form offshore. This is less than 10% of the difference between the inputs and outputs of nitrogen shown in Table 1. Presumably, the remainder of the nitrogen is exported in dissolved form. If it is assumed that the DON and PN entering the Bay are essentially unreactive, then sedimentation, denitrification, and the export of nitrogen in organic matter appear to account for almost 80% of the input, with the remainder exported in dissolved form. The major sinks for nitrogen in the Bay appear to account for about 650 m mol m^{-2} y^{-1} or some 30% of the total input. Since phosphorus does not exchange with the atmosphere, it is likely that a considerably larger fraction of the input is passed offshore, presumably in dissolved form since the stoichiometric calculation suggests that only some 24% of the PO_4 input or 10% of the total phosphorus input may be lost through the export of organic matter formed in the Bay. Similarly, perhaps 90% or more of the organic carbon fixes in the Bay appears to be remineralized within the system.

Similar calculations could easily be made for other areas in which the nutrient inputs and ambient concentrations are known. The denitrification correction, however, appears to be important, and there are few systems where this flux has been measured.

It is also possible to gain evidence, at least in a qualitative sense, of the extent to which estuaries may serve as sources or sinks of nutrients through the use of mixing diagrams or plots of nutrient concentrations as a function of a conservative tracer such as salinity. Examples from the Delaware River Estuary and the Scheldt Estuary are shown in Figures 1 and 2.

The data from the Delaware are particularly useful since all of the forms of nitrogen were included and it is possible to look at the transport of total nitrogen in the system (Fig. 3). It is evident that the export from the system varies with season and the form of the nutrient being considered. This approach is becoming increasingly popular in estuarine ecology and will doubtless yield interesting results from many systems where the variation in concentration of the fresh and salt water "end members" does not vary widely over time scales that are short relative to the exchange rate of the estuary and where there are strong sources and a well-defined mixing gradient. In systems with a very slow flushing rate, a weak salinity gradient, and varying or multiple inputs, the approach may be less useful.

As far as I am aware, there is no convincing evidence that estuaries themselves serve as sources of nutrients for near-shore or offshore areas. Estuarine wetlands and intertidal areas do not appear to be strong sources of nutrients (Nixon 1980; Nixon and Lee 1983), and a major fraction of the material added to estuaries by rivers and anthropogenic sources appears to be retained. Assessing the degree of retention requires a knowledge of long-term sediment accretion rates and sediment composition and, in the case of nitrogen, of denitrification rates. Neither of these terms is easily measured and there are also considerable uncertainties in our estimates of the inputs to most, if not all, estuarine systems.

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Table 1. Present state of the annual nitrogen budget for Narragansett Bay, Rhode Island. Units are mmol N $m^{-2} y^{-1}$ (From Nixon and Pilson, in press).

Sources	PN	DON	NH_4	$NO_{2,3}$	Total N
Fixation (sediments)[1]	<0.7	0	0	0	<0.7
Precipitation[2]	24		30		54
Runoff[3]					60
Rivers[3]	74	258	236	322	890
Sewage[3]	178	485	365	25	1053
Offshore	?	?	?	?	?
			TOTAL INPUT		>2058
Sinks					
Sedimentation[2]	132	0	0	0	132
Denitrification[2]	0	0	0	515	515
Fisheries[4]	<5	0	0	0	<5
Offshore	?	?	?	?	?
			TOTAL OUTPUT		>652
Recycling					
Micro zooplankton excretion	0	?	?	0	?
Meso zooplankton excretion[5]	0	132	242	0	374
Ctenophore excretion[6]	0	14	16	0	30
Menhaden excretion[7]	0		3	0	3
Benthic flux[3]	0	114	886	0	1000
			TOTAL RECYCLED		>1407
Primary production[3]	3900	?	0	0	3900

[1] From Seitzinger et al. (1978)

[2] Calculated by Seitzinger (1982)

[3] From Nixon (1981a)

[4] Assuming catch is <100 Kg/ha (Nixon 1981b, 'n press a).

[5] Vargo (1976, 1979)

[6] Kremer (1975)

[7] Durbin (1976)

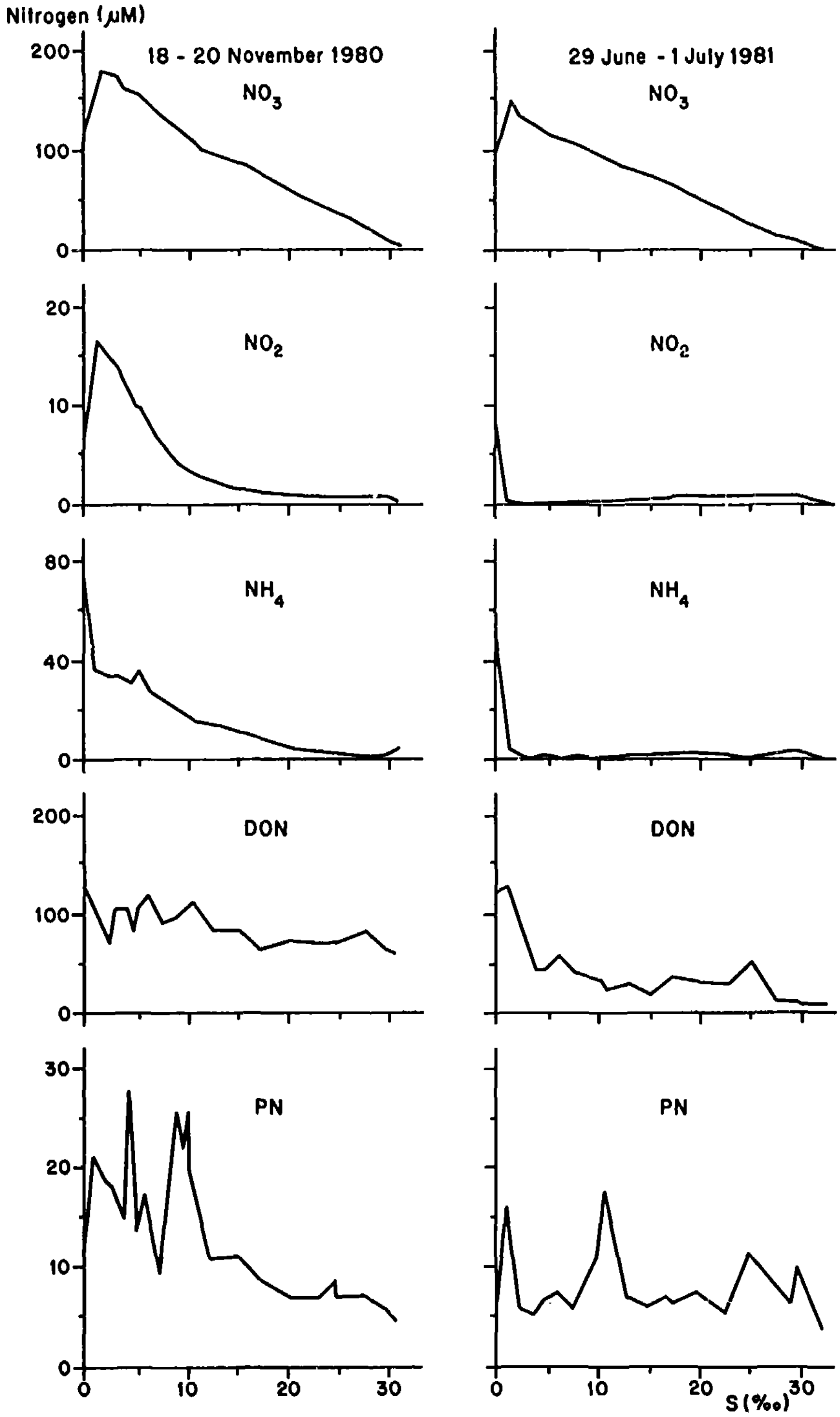

Fig. 2. The concentration of inorganic and organic fixed nitrogen as a function of salinity in Delaware Bay during fall (left panel, 18-20 Nov., 1980) and summer (right panel, 29 June - 1 July 1981). Data from Culberson, Sharp, Church and Lee, pers. comm. (From Nixon and Pilson, in press).

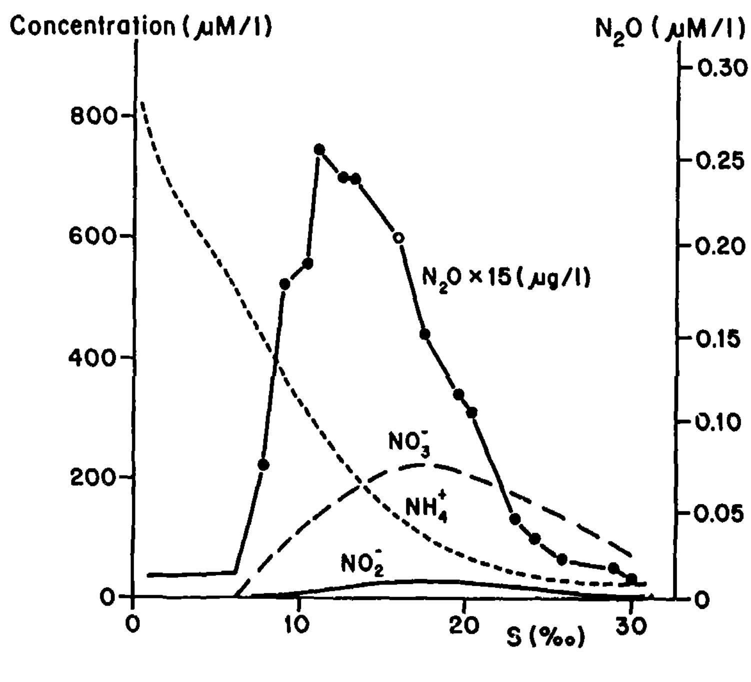

Fig. 3. The distribution of ammonia, nitrite, nitrate and nitrous oxide as a function of salinity in the Scheldt estuary. From Deck (1980). From Nixon and Pilson, in press).

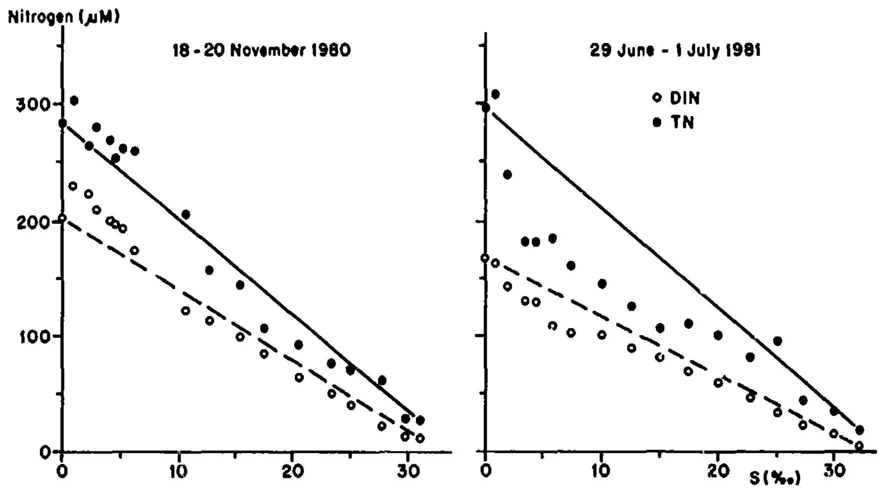

Fig. 4. The concentration of total dissolved inorganic nitrogen (DIN) and total nitrogen (excluding gases) as a function of salinity in the Delaware estuary. Lines are drawn to represent conservative mixing. Data from Culberson, Sharp, Church and Lee, pers. comm. (From Nixon and Pilson, in press).

2.3 Net transport of organic matter between coastal and offshore ecosystems (M.M. Pamatmat)

Besides dissolved nutrients, the seasonal and yearly exchange of total organic matter between coastal and offshore waters should be one indication of their relative importance.

There is widespread notion that coastal waters are important because they are a source not only of primary nutrients but also of organic matter which contribute significantly to fishery production on the continental shelf. For example, the shrimp catch on the shelf has been correlated with the extent of coastal marshes (Turner) implying that the larger their area the greater the amount of detritus transported offshore. If this is generally true, the filling and reclamation of marshes, the cleaning and conversion of mangrove swamps into milkfish ponds, etc. could have adverse affects on offshore fisheries.

The actual transport of organic matter offshore is difficult, if not impossible, to assess from the kind of information presently available on both systems. Estimations derived from concentration gradients and calculated residence times can be misleading because of unknown advection and dispersion of material which take place in both directions in open systems.

For coastal-offshore systems where the need for actual estimates of net transport is indicated this can be approached in two ways.

Direct flux measurement. The instantaneous flux of matter, F(t), across an arbitrary boundary is equal to:

$$F(t) = \iint_A \rho V c \, dA$$

where ρ = density of water

V = velocity normal to cross-section

c = concentration

A = cross-sectional area

or Total Material Flux = Advective Transport + Dispersive Transport

The advective term comprises transport by a) river flows, b) estuarine circulation and c) transport by far-field forcing. Dispersion includes net transport by a) tidal sloshing, b) spatial shear, and c) turbulence.

The total exchange between an estuary and the shelf region is presently being measured using this approach, at North Inlet, South Carolina and other locations. The actual work involves simultaneous measurements of current velocities and material concentrations at many cross-sectional stations and several depths in a section, several times per tidal cycle for many tidal cycles. The main problem is that the net flux varies significantly from cycle to cycle which makes it difficult to generalize the annual net flux from measurements over a few tidal cycles.

In dealing with metabolic organic matter it is important to realize that significant changes and metabolic losses can occur between the time that it passes one section of an estuary and exits to the open coast. Hence, it is preferable to pick a section as close to the mouth of the estuary as possible.

The outflow from an estuary is predominantly transported alongshore and its organic load may enter another estuary farther down the coast. Hence, during certain periods the import of organic matter to an estuary could exceed its export. Careful estimation of fluxes of organic matter with both incoming and outflowing water is required to arrive at a meaningful estimate of net annual transport.

Mass balance approach. One alternative to direct flux measurements is an integrative mass balance approach. By this method the organic input and local production of organic matter is balanced by various consumption and loss processes. Part of the organic matter is remineralized, some is buried, and the rest is transported out of the system. The major terms of an organic matter budget are as follows:

$$(P+I) - (R_p-R_b) - M - F - B - E = 0$$

where P = primary production (phytoplankton + macrophytes + benthic microalgae)

I = import (from rivers, local runoff . gravitational flow + sewage)

R_p = pelagic respiration

R_b = benthic mineralization

M = migratory loss (birds, fish, setachians, crustaceans)

F = fisheries yield

B = burial in sediments

E = export offshore

Clearly, the many terms involved and the calculation of the export team by difference have a great influence on the accuracy of its estimate. Some small coastal systems (e.g. see Nixon and Oviatt) are readily amenable to this technique. The larger and more heterogeneous an estuary the more difficult and extensive will be the task.

Current status. Present indications from both direct and indirect approaches applied to the most studied systems are that the net export of organic matter from coastal waters is small in comparison with the other losses. It appears that if there is a large input or large local primary production of organic matter there are correspondingly large losses via decomposition and remineralization. However, it is not inconceivable that certain local conditions could lead to relatively large exports from some systems or compared to those that have been studied. The only way to find out is to perform the necessary measurements.

The estimation of the flux of organic matter between coastal (estuarine) and offshore systems, whether it is done by direct or mass balance determinations, is a difficult and costly undertaking that requires a large multidisciplinary group of scientists. This team should include hydrodynamicists, chemists, sedimentologists, and biologists. The study must be done over a long term and many measurements have to be of close intervals in space and time.

2.4 Coastal-offshore relationships - importance for invertebrates, fish, birds and marine mammals (J.J. Zijlstra)

There is a growing body of information indicating a strong exchange of faunal elements over the coastal-offshore boundary, in particular for larger, active animals (nekton). Most of the information stems from well-studied areas in North-America, Europe, Australia and New Zealand, but some studies in tropical regions suggest a fundamentally similar situation. The coastal-offshore movements of mainly nekton may be of minor interest in terms of transport of organic matter as compared to passive transport processes, but its importance is large in relation to the quality of the systems, affecting both species diversity and the yield of fisheries.

In various cases it has been suggested that the faunal composition of both coastal and offshore ecosystems strongly depends on the exchange between the two regions, in all climatic areas. In coastal zones, in particular in estuaries and lagoons, the migrating nekton often forms the majority of the species present or includes the both in numbers and biomass dominant species. Such migrating species play usually a more moderate role in offshore ecosystems, although their presence extends over the whole continental shelf area. In a few cases (e.g. eels, Anguillidae) species migrating between coastal and offshore ecosystems, go beyond the continental shelf limits and penetrate into the open ocean.

Many species, migrating over the coastal-offshore boundary are top-carnivores and presumably exert a strong influence on the lower part of the ecosystem by their predatory activity, affecting its composition which could be quite different without their presence.

Part of the exchange of faunal elements simply results from dispersion of normally offshore species into the coastal environment during periods, when physical factors as temperature and salinity in that environment form no barrier. Depending on the period of observation the number of such species may be quite high, but with few exceptions their quantitative importance is very limited.

For the most abundant species, concerned in the exchange the migration over the coastal-offshore boundary forms most likely an essential part of their life-cycle. For such animals the loss of either part of their biotopes will probably result in a severe reduction of their population size and possibly in a total disappearance of the species in the affected area.

In a special case of coastal-offshore migrations, those of diadromous species, depending on a migration between fresh water and the sea, their generally observed decline in most parts of the world was usually mainly the result of changes in river systems (hydrodynamic works, pollution), but in some cases similar changes in the estuaries, forming the entrance to the rivers have been partly responsible.

A numerically important part of the fauna, participating in coastal-offshore migrations, is of major commercial interest. Many species of both fish and crustacea, forming the bulk of catches of these groups in coastal areas, depend on the offshore zone for part of their life-cycle (e.g. mullets, penaeid shrimps). At the same time catches in the offshore area, usually in continental shelf areas, also seem to depend for a significant part of species, involved in the coastal-offshore migrations. In the north-Atlantic 65% of the landings of the U.S.-shelf area and 40% of the North Sea landings have been claimed to consist of species, depending in some way on estuaries and coastal regions. In addition, in various offshore tropical areas important fisheries depend on penaeid shrimps, which at least partly have grown up in coastal areas, in particular in estuaries and lagoons. The importance of the coastal area is enhanced in this case, because the highly-priced shrimp forms only a small part of the landings, which are made up by less valuable fish species consumed by local human populations.

The importance of the exchange over the coastal-offshore boundary is probably not limited to nekton, but includes also planktonic organisms and benthic invertebrates. In addition all pelagic birds, belonging for instance to the families Alcidae, Diomedeidae, Procellariidae rely during their breeding season on food resources extracted from coastal, often estuarine areas. In the same way some groups of marine mammals, notably Pinnipedia, use the coastal zone for whelping and raising their offspring, but often rely in part of their life-cycle on offshore resources.

Modes of dependence

a. Nekton. Among the species depending in their life-cycle on both the coastal and offshore systems, fishes (including Agnata, Selachii and Teleosts) represent probably the most important group in terms of species number, biomass and economic value, followed by various groups of crustacea (e.g. lobsters, shrimps, crabs). The exchange over the coastal-offshore boundary is however, of great importance for the conservation of practically all open seabirds and some marine mammal populations. The dependence on the migration between coastal and offshore areas in the nekton may take various forms:

I. Offshore species which visit the coastal zone, including lagoons and estuaries, for spawning. Usually in such cases the area also contributes the main nursery area. The offshore area serves, however, mostly as the main feeding ground and, in temperate waters, as overwintering area. Examples are found in the fish families of the Clupeidae, Scomberesoeidae, Gobidae.

A special case here is represented by the anadromous fish species, spawning in fresh water, with representation in the Acipenseridae, Clupeidae, Salmonidae, Osmeridae, Petromyzontidae, Serranidae. Anadromy tends to decline with latitude.

II. Offshore species of which all adult activities including reproduction are performed in the offshore area, but which exploit the coastal zone, in particular estuaries and lagoons, as nursery. Usually the juveniles enter the coastal area in a late larval or early postlarval stage by largely unknown behavioral mechanisms. The period of presence of the juveniles in the coastal area may vary considerably, from a few months up to some years. This type includes many fish families as Clupeidae, Engraulidae, Sciaenidae, Sparidae, Gadidae, and many flounders (Pleuronectidae, Soleidae, Bothidae, Cynoglosidae). In addition, various crustaceans belong to this group (lobsters, shrimps, crabs).

III. Coastal species, which migrate to the offshore area for spawning and larval development. Usually most of the postlarval juvenile and adult life is spend in the coastal zone, although in the temperate region adults and juveniles may leave the coastal area during the cold season. Important representatives of this group are found in the Mugilidae and Chanidae. A special case of this type is represented by catadromous species (e.g.

Anguillidae).

With few exceptions the offshore spawners (groups II, III), in the fishes have pelagic eggs, whereas inshore spawners (group I) produce sessile, sticky eggs, attached to the bottom or to algae.

The most common type is group II, including many large populations of economically important species, both in fish and crustacea. In group I the anadromous fish species are most important, whereas group III includes species used in aquaculture.

Birds and mammals are mainly included in group I.

b. Plankton and benthos. For some species of plankton, mainly Ctenophora and Medusae, the coastal zone may act as the main area of propagation. In Medusae the polyp-stage of some species is found almost exclusively in this area and species are dispersing from the coastal zone to the offshore area. In various Ctenophores a similar situation has been observed, with juveniles appearing in the coastal zone with a subsequent dispersal to the offshore area.

In a few cases benthic animals have been shown to be dependent on settlement of larval stages in the intertidal area, with a secundary settlement at a later stage in a wider area, including the offshore region.

Conclusions

Although there is little doubt that coastal-offshore relations exist in many nekton-species, in particular in fish and crustacea, the importance and background of that relationship is insufficiently recorded and understood. This statement may not apply to pelagic birds and some marine mammals, which obviously need a terrestrial environment for breeding and whelping. Also, the offshore spawning of some coastal nektonic species may be simply related to the production of pelagic eggs, which do not survive in coastal waters with an unpredictable and greatly variable density of the water.

The majority of fishes and crustacea in coastal environments are juveniles belonging to species of type I or II. In the majority of the cases it is, however, unknown in how far juveniles of the species concerned are restricted to the coastal area or also occur, in lower densities but in larger areas, in the offshore region. Moreover, the distribution of juveniles within the coastal area in open coastal zones or bays, in lagoons, estuaries, beach-zones, tidal areas - is hardly studied for most species.

There is little information on how late larvae of early post-larvae of species, growing up in the coastal zone, migrate or drift into the area. There is a general lack of understanding why some marine species have developped coastal (freshwater) spawning grounds. Sometimes favourable food conditions for juvenile fish have been mentioned as the important factor, but few studies have been made to substantiate this statement. Alternatively a relative absence of predation is given as the ultimate factor for the development of coastal nurseries in some marine species, but in most cases evidence to support this view is lacking. There have been claims that the extent of the coastal area or that part of the coastal regions, to which the juveniles are limited, determines the size of the offshore populations, but with few exceptions the evidence is lacking. Still, if true such a dependence would be of great importance, because it would allow an assessment of the loss of exploitable offshore resources as a result of man-made changes in the coastal environment. Also, it would provide an explanation how the size of offshore nekton populations is limited by the operation of density-dependent processes in the juvenile stage in the nursery.

2.5 Productivity in coastal and offshore areas (B.O. Jansson)

The coastal areas show a higher diversity of potential energy than the offshore areas. Freshwater input, wind, waves, tides, land elevation and the small water depth which makes boundary mixing an important process sums up to a total which is higher than for the offshore areas. The often large differences in bottom types and structures which vary from mudflats to kelp forests also offer a high diversity in structure with higher possibilities for maintaining different life forms.

Heavier pulses in light and temperature contrast to the offshore and set conditions whereby migrating organisms could get optimal conditions for growth or decrease the maintenance costs during starvation periods by changing habitat.

The geographically smaller distance between the producer unit - the seaweed and phytoplankton - and the respiration unit - the consumer dominated parts - facilitates the recycling of nutrients. For the seaweed and seagrass systems there even often exists a physical contact between the two.

The totally higher amount of potential energy and the better access to nutrient for example through higher mixing rates makes the productivity in the coastal zone, at least when light is not limited, higher than in the offshore area. The channelization is different, however. More particulate matter settles in the coastal area due to less time spent in suspension. Large vertical distances and checking of recirculation by pycnoclines make degradation in the water column more dominating in the offshore area. The potential energy is in the offshore area channelized mostly to small-scaled producer and consumer units which means that the storage capacity per volume is probably smaller than in the coastal area. If this holds also when calculated per unit area is questionable as it depends on water depth and stratification, problems associated with Sverdrup's critical depth. In the coastal area potential energy and critical material is often stored in large-scaled structures with larger turnover times like seaweed and seagrasses, where storages for example nutrients help the organisms survive periods of low nutrient concentrations in the water. The significance of the macrophytes as direct food source for animals is low. As physical structures, offering substrate and space to numerous micro- and macroconsumers, they are important, however.

The more complete degradation in the offshore water column means that less potential energy goes to the benthos, which due to less food and lower temperatures offer less favourable conditions for the upper trophic levels which are of interest for man.

Bearing in mind the clearly different properties of the coastal and offshore areas and the long time period offered to evolution it seems likely that many more organisms than those already studied should rely on both areas for their persistence.

2.6 The relevance of man-made disturbances (A. McIntyre)

Types of disturbance

Oil and gas exploitation. In the 1920s and 1930s, drilling rigs were established in shallow coastal waters in the Gulf of Mexico and later in other such sites in Lake Maricaibo, Nigeria and the Far East. More recently the high price of oil stimulated development further offshore and wells in the North Sea were exploited in the 1970s, followed by extensive investigation of the north polar region of USA and Canada and off the Atlantic coasts of these countries. If the price of oil is maintained or increases, additional exploitation may be expected. The results of this are activity offshore at the sites of the wells; activity on-shore at terminals for reception and export of oil/gas; and associated transport of oil by sea or by pipeline from well to shore. Even in the best regulated operations there can be inputs of oil and associated contaminants at offshore and on the sites, and the enhanced possibility of oil spills at these sites and during transport between them .

Dumping. The dumping (including incineration) of wastes at sea is a wide-spread method of disposal used in particular for sewage sludge and dredge spoils but also for other types of material including T_{102} wastes, pharmaceuticals, and munitions. The effects can be increased water-column turbidity and deposition on the bottom with inert or contaminated material.

Thermal discharges. Most of these are along the coast and are usually related to power generation. They result in a warm water plume and sometimes in enhanced temperatures for short distances round the outfalls. In some cases anti-fouling agents such as chlorine may be added to the environment and there may be entrainment of organisms on intake screens. In temperate zones changes in biological systems do not usually extend much beyond the warm water plume and are not always adverse, but in the tropics there may be concern for animals near their temperature threshold.

Coastal discharges. These have already been referred to in the context of oil and power stations, but there are other types of discharge from a range of industrial and commercial sources. On open coasts these are likely to affect only local areas, but concentrations of land-based discharges in semi-enclosed or estuarine areas can have a cumulative effect and result in a generalised reduction of water quality.

Aggregate extraction. The demand for marine aggregate in western Europe for building began to increase in the 1960s and now about 6 million tonnes of sand and gravel are taken annually from the North Sea. Effects are partly due to the pits and furrows left by the dredgers, which interfere with demersal fishing, and partly to the removal of substrate which is the limited habitat for herring and sandeel spawning.

Dredging. This is a continuing coastal activity common all round the world. Since it involves both the disturbances of settled sediments and their distribution elsewhere, it can have the effect of mobilising contaminants which may have been previously unavailable.

Coastal engineering and development. Land-reclamation (agriculture), industrial and tourist requirements can involve extensive building and alteration in coastal areas, including the construction of hotels, harbours, sea walls and other coastal defences. Those activities can result in significant changes causing erosion or destruction of habitats.

Ocean energy exploitation. There is increasing interest in the possibilities of this, and while it is probably at present nowhere developed on a large enough scale to cause problems, it is at least worth while noting the potential for disturbance. The main relevant technologies are ocean thermal energy conversion (OTEC), marine biomass, wave energy, and tidal energy. The use of marine biomass for energy production is not available on a commercial scale but the promise is likely to be from macro-algae digested anaerobically with the production of methane. Wave ene. /

production has attractive features but would involve long lines of convertors offshore which could disrupt long shore currents, alter sediment aggregation and cause coastal erosion, as well as affecting marine life directly. Tidal energy is already an industrial reality (at La Rance in France) and is being investigated at other sites in various parts of the world. There is not likely to be much pollution risk from a tidal plant, but it would change the existing hydraulic conditions in the area and locally interfere with such activities as navigation, fishing, and mariculture and affect coastal ecology, waste disposal and water drainage. OTEC, which utilizes the temperature difference between warm surface and cold deep water to drive a heat engine that produces power, is probably the best bet of the four techniques, and quite a bit of work is in progress on this. The main effect would be from the withdrawal and discharge of large volumes of water. Effects might be comparable with those discussed for thermal discharge, but the scale would be much greater, and the location offshore.

Management

The various activities listed above are managed and controlled by a range of local, national and international arrangements. At the international level, the global London Dumping Convention (and associated regional conventions such as the Oslo, Barcelona and Helsinki Conventions) control dumping and incineration at sea and provide for monitoring of effects. A comparable treaty, the Paris Convention controls discharges from the land or from offshore structures such as oil platforms. Discharges from ships at sea are controlled by the Inter-Governmental Maritime Organisation (IMO) through a series of Conventions which have been widely ratified. At the national and local levels most countries and local government bodies have a network of legislation and regulations often linked to the international treaties, designed to control the activities listed, and to keep adverse effects to a minimum. There are of course significant black spots, but in general these controls seem to work reasonably well where there is the will to apply them properly. In the North Sea, for example, experience with more than 10 years of oil exploitation is that the marine environment has been able to cope with the inputs it has so far received. For dumping, if the grounds are carefully chosen and the exercise conducted to achieve maximum dispersion (or concentration if that is the management strategy) then damage to the environment is usually minimal. The same applies to coastal discharges, although local problems do arise.

Relevance to the interests of the working group

Most of the disturbances identified here are of a point-source nature, and adverse effects are usually extremely local, so that any significant impact on coastal-offshore interactions would not be expected. Such impacts might arise where coastally contributed contaminants were transported offshore, but this is probably not occurring on a large scale except at the mouths of major river systems or in areas such as the Southern Bight of the North Sea, or in New York Bight where coastal input from large conurbations is significant. This may be the most fruitful topic for farther research.

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17	An intercomparison of some current meters, report on an experiment of Research Vessel Akademic Kurchatov, March-April 1970, by the Working Group on Current Velocity Measurements; sponsored by SCOR, IAPSO, Unesco	1974	WG 21
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22	European sub-regional co-operation in oceanography. Report of Working Group sponsored by the Unesco Scientific Co-operation Bureau for Europe and the Division of Marine Sciences	1975	—
23	An intercomparison of some currents meters, III. Report on an experiment carried out from the Research Vessel Atlantis II. August-September 1972, by the Working Group on Continuous Velocity Measurements: sponsored by SCOR, IAPSO and Unesco	1975	WG 21
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28	Eighth report of the joint panel on oceanographic tables and standards, Woods Hole, U.S.A., sponsored by Unesco, ICES, SCOR, IAPSO	1978	WG 10
29	Committee for the preparation of CLOFETA-Report of the first meeting, Paris, 16-18 January 1978	1979	—
30	Ninth report of the joint panel on oceanographic tables and standards, Unesco, Paris, 11-13 September 1978	1979	—