Porcupine Newsletter

Volume 4 Number 5

JUNE 1989

ISSN 0309 - 3085

- 87 -

CONTENTS

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Roger Bamber, Hon. Editor
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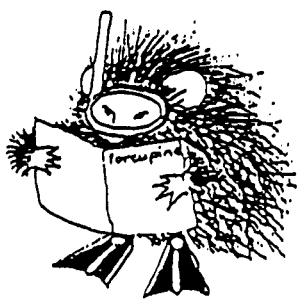
STOP PRESS: Autumn Meeting is on October 28th & 29th; see p.97.
Prospective contributors: Members are waiting to read your notes, letters, requests, reviews, new records, and especially Articles.



PORCUPINE

Hon Secretary
Dr Martin Sheader

Hon Treasurer
Dr Antony Jensen

Department of Oceanography, The University
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EDITORIAL

Some Members have informed me of mistaken delivery of their PN 4(4), and notice of the Lancaster Spring Meeting apparently did not reach all Members, possibly owing to errors in the Membership list at that time. Apologies are duly tendered to all so inconvenienced; if Members are genuinely missing a NEWSLETTER, please let me know,and I will supply accordingly.

With this NEWSLETTER readers will receive the Contents and Index to Genera for PN Volume 3, on the same format as that for Vol.2 (no objections having been received). I hope that Members find it as useful as the Hon. Ed. does (why else would he spend so much time doing it?). The number of genera quoted is up to 700-odd! Is someone making them up??

Regarding the new Membership List - could new members please let us know of their "interests" (see categories on the List, or others as appropriate) - when recruiting at the AGM, I did not have the Membership forms, which would have gleaned the relevant information. The Hon. Treasurer pointed out at AGM that the majority of Members now pay by Banker's Order; thanks to those that do (it makes life so much easier), and to those that don't - forms are available from Hon. Treas. or Hon. Ed.. Could all Members, including new recruits, who newly opt for banker's order payment please inform the Hon. Treasurer. We were glad to pick up 3 new members *in situ* at the AGM.

On 23rd May, The Marine Forum for Environmental Issues had an informal meeting with the Environment Minister, Mrs Virginia Bottomley, at her request to meet representatives of relevant NGO's, that they may introduce their organisations, explaining structure, aims and work and put relevant questions. Written questions were submitted in advance by the Hon. Secretary, after discussions with various Council Members; these will receive written replies from the Minister in due course. The Hon. Editor attended the meeting on behalf of PORCUPINE; other organisations represented included MCS, ACOPS, Cetacean Group, RSPB, Greenpeace, CEGB, WWF. Concern was expressed on behalf of the Members over recent reductions in governmental support for pure marine biological research, particularly in the fields of systematics, taxonomy and biogeography, and regarding long-term studies, particularly in the light of the recent removal of support for the Continuous Plankton Recorder Survey. (Bob Williams informed us further at the Spring Meeting that the CPRS is being funded for a while longer, though too late to save the full research team).

This issue includes reports from the Lancaster Spring Meeting; it is hoped to publish the reports from the remaining presentations in the next issue, due as soon as possible.

Roger Bamber, Hon.Ed.

SOME 'RARE' SHELLS FROM DYFED

by Shelagh Smith
Woodleigh, Townhead, Hayton, Carlisle, Cumbria CA4 9JH

During the past winter I have been pottering about on the sandy shores of Dyfed (entertaining and educating grandchildren) where this season there have been some more interesting shell wrecks than usual and much shellsand washed up. In all, about 120 species of mollusc were found, few of which were more or less alive or contained remains of soft parts. Those mentioned below were all dead, although, apart from *Jordaniella truncatula*, all were fresh. The full details have duly been sent to Dennis Seaward for his Conchological Society records. Some species do not appear in the maps for Sea Area 21 in Seaward (1982), although they have in most instances been previously, if seldom, recorded.

Dennis Seaward has informed me that, of my Broadhaven records [51°36·5'N 04°55·2'W; 31 December 1988], the old record for Area 21 of *Jordaniella nivosa* (Montagu 1803) goes back to Jeffreys (1867) (Ilfracombe) and Marshall (1899) from the Tenby area. *Jordaniella truncatula* (Jeffreys 1850) was also an old record, now upgraded. *Odostomia turrita* Hanley 1844 has also been recorded, living, by Julia Nunn (I have also found it at Manorbier [51°38·4'N 04°48·3'W; 24 September 1987]). *Rhomboidella prideauxi* (Leach 1815) is a new record for Area 21.

Amongst my records for Tenby [51°40·0'N 04°42·0'W; 30 January 1989], *Odostomia acuta* Jeffreys 1848 was previously recorded by Marshall (1899), and *Mangelia brachystoma* (Philippi 1844) by Marshall (1913); *Oenopota rufa* (Montagu 1803) has been recorded recently from the Severn Estuary by Boyden *et al.* (1977), but *Rissoa lilacina* Récluz 1843 and *Antalis entalis* (L. 1758) appear to be new to Area 21. From Saundersfoot [51°42·4'N 04°42·5'W; 10 and 20 February 1989] *Retusa umbilicata* (Montagu 1803) is also new.

All nomenclature is after Smith in Howson (1987).

References

Boyden C.R., Crothers J.H., Little C. & Mettam C., 1977. The intertidal invertebrate fauna of the Severn Estuary. Field Studies, 4; 477-554.

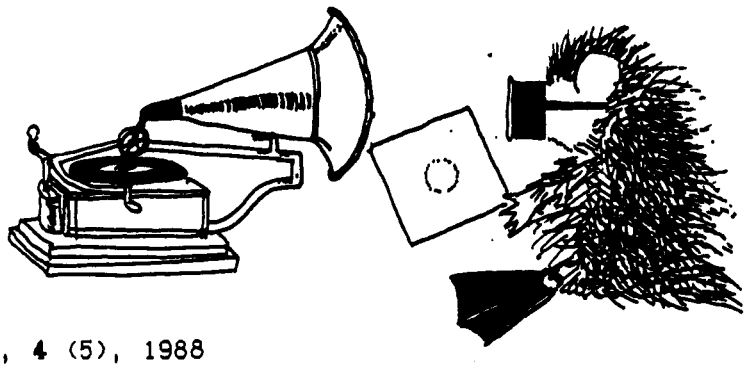
Jeffreys J.G., 1867. British Conchology, Vol. IV. London (p.117).

Marshall J.T., 1899. Additions to 'British Conchology'. J. conch. Lond., 9; pp.224 & 232.

Marshall J.T., 1913. Additions to 'British Conchology'. J. conch. Lond., 13; p.303.

Seaward D. (Ed.), 1982. Sea Area Atlas of the Marine Molluscs of Britain and Ireland. Nature Conservancy Council.

Smith S.M. in Howson C.M. (Ed.), 1987. Directory of the British Marine Fauna and Flora. Marine Conservation Society.



POLYBIUS HENSLOWII: AN IONIC ENIGMA?

by A.P.M. Lockwood & J.A. Riegel

Dept. of Oceanography, The University, Southampton SO9 5NH and c/o Dept. of Zoology, University of Cambridge.

Back in the 1950's, Robertson (1953) drew attention to the apparent correlation between the general level of activity of various species of crab and the magnesium concentration of the blood. The more sluggish the species, the greater the likelihood of a high magnesium level in the haemolymph. Following up this concept, Walters & Uglow (1981) have shown that the heart rate of crab species can similarly be related to the concentration of magnesium in the extracellular fluid. Earlier, Katz (1936) had found a depressant effect of magnesium at the neuromuscular junction, with complete neuromuscular block in *Carcinus* at bathing fluid levels of magnesium of 2½ times the normal blood level. Furthermore, raising the haemolymph level of magnesium artificially in *Panulirus* and *Maia* leads to smaller contractions of muscle than normal (Waterman, 1941). A converse effect at the neuromuscular junction was found by Boardman & Collier (1946) on decreasing the magnesium level in the bathing medium for *Carcinus* muscle.

Magnesium could potentially act in various ways to interfere with neuromuscular transmission and muscle response, (a) by blocking channels used by calcium ions in the process of activation of transmitter release, (b) by affecting the permeability of the post-synaptic membrane, and (c) by influencing the calcium activation of the contractile process (R.J. Walker, pers. comm.).

It is uncertain what the relative importance of such mechanisms may be but there is evidence that at least some crabs take steps to regulate the magnesium in the haemolymph by concentrating this ion in the urine (Webb, 1940; Lockwood & Riegel, 1969). Both withdrawal of water in the excretory system (Riegel *et al.*, 1974) and active secretion of magnesium into the urine (Holliday, 1980) are involved in this concentration.

Given the observed effects of magnesium and the tendency noted above for the more active decapod Crustacea to maintain low blood levels of this ion, we might expect that the swimming crabs would follow the same pattern. This is indeed the case for *Liocarcinus* and *Macropipus* (Table 1), but the portunid crab *Polybius henslowii* Leach appears as something of an enigma in relation to other crabs studied, in two respects - (1) the very high level of magnesium found by Walters & Uglow (1981) relative to its activity and (2) the rather large difference between the values measured by these authors and by ourselves. Thus Walters & Uglow obtained blood values for magnesium of 40·08 ± 5·4 mM l^{-1} (SE) compared to our values of 28·4 ± 0·8 mM l^{-1}. We have no reason to doubt the internal consistency of either of these sets of values since there is good agreement between their figures and ours for other species measured (*Carcinus maenas* mean values 16·2 [W&U], 19·1 [R&L]; *Maia squinado* mean values 39·6 [W&U], 42·9 [R&L]). It

TABLE 1. Mean haemolymph magnesium concentrations for some swimming crabs

	mMl	
Liocarcinus puber	18·0	Riegel & Lockwood (unpubl.)
Liocarcinus puber	22·6*	Robertson (1953)
Liocarcinus depurator	21·3	Riegel & Lockwood (unpubl.)
Liocarcinus depurator	26·6*	Robertson (1953)
Macropipus tuberculatus	28·3*	Walters & Uglow (1981)
Polybius henslowii	40·1*	Walters & Uglow (1981)
Polybius henslowii	28·4	This paper.

* - values transformed from original data.

seems probable therefore that there is a systematic difference in the two sets of readings which merits further consideration. Possibly the unusual behaviour pattern of *Polybius* may provide a clue to the difference.

This species, which occurs from *circa* 30°N to 52°N in the eastern Atlantic (Allen, 1968), is known from British waters in the Channel (Bell, 1853), Celtic Sea (Walters & Uglow, 1981), Liverpool Bay, Bristol Channel and Shetland (Ingle, 1980). Appropriately for this journal, it also occurs in the Porcupine Sea Bight where it has been found down to 1245 m (A.L. Rice, pers. comm.). For a distribution map see Clark (1986). In addition to its benthic life, however, this crab has the ability to swim in the surface waters, as Bell (1953), quoting Crouch, aptly describes: "The Nipper Crab, as our fishermen term it, mounts to the surface over the deepest water in pursuit of its prey amongst which are numbered the most active fishes." "We are witness of this curious habit of obtaining food in the summer only .... and it is probable that in colder weather they keep at the bottom in deeper water." Allen (1968) confirms this swimming ability, recording the presence of swarms of the crab near the surface some 1750 m off the bottom near Santander in Spain. He also mentions that such swarming normally occurs mainly in the period from June to August.

A possible explanation for the very high blood levels of magnesium observed by Walters and Uglow might lie with the season-related behavioural difference noted by both Bell and Allen. Walters and Uglow took their crabs in May by trawl whilst ours were sampled in August. Could it be that *Polybius* is a crab that can vary its blood magnesium according to its activity phase? Such a change has been suggested for the freshwater field crab *Oziotelphusa senex senex* which was reported by Sreenivasula Chetty *et al.* (1984) to show a lowering of blood magnesium by some 20 to 25% at dawn and midnight, correlating with periods of raised activity. To the best of our knowledge, however, no such suggestion of a tidal or seasonal systematic change in magnesium has been made for marine species.

Polybius is not the easiest of crabs to obtain on a regular basis, but, if our supposition is well founded, examination of the way in which it controls its magnesium level could well repay study. Also of interest would be the interaction between the permeability of excitable membranes and magnesium in relation to pressure since there must be few crabs which can potentially experience a range of hydrostatic pressure, whilst in the adult stage, from 1 to 120 atmospheres.

We would like to thank the Director and staff of the Marine Biological Association (now PML) for the provision of the animals and facilities used in this study.

References

Allen J.A., 1968. The surface swarming of *Polybius henslowii* (Brachyura: Portunidae). J. mar. biol. Ass. U.K., 48; 107-111.

Bell T., 1853. *A History of the British Stalk-Eyed Crustaceans.* John van Voorst, London.

Boardman D.L. & Collier N.O.J., 1946. The effect of magnesium deficiency on neuromuscular transmission of the shore crab *Carcinus maenas.* J. Physiol., 104; 377-383.

Clark P.F., 1986. *North East Atlantic Crabs: An Atlas of Distribution.* Marine Conservation Society, Ross-on-Wye.

Holliday C.W., 1980. Magnesium transport by the urinary bladder of the crab *Cancer magister.* J. exp. Biol., 85; 187-201.

Ingle R.W., 1980. *British Crabs.* British Museum of Natural History, London.

Katz B., 1936. Neuromuscular transmission in crabs. J. Physiol., 87; 199-220.

Lockwood A.P.M. & Riegel J.A., 1969. The excretion of magnesium by *Carcinus maenas.* J. exp. Biol., 51; 575-589.

Riegel J.A., Lockwood A.P.M., Norfolk J.R.W., Bulleid N.C. & Taylor P.A., 1974. Urinary bladder volume and the reabsorption of water from the urine of crabs. J. exp. Biol., 60; 167-181.

Robertson J.D., 1953. Further studies on ionic regulation in marine invertebrates. J. exp. Biol., 30; 277-296.

Sreenivasula Chetty P.V., Kala Rani D., Chandra Sehhara Reddy & Padmanabha Naidu B., 1984. Circadian variations in the levels of calcium and magnesium of freshwater crab, *Oziotelphusa senex senex*. Geobios (Jodhpur), 11; 25-27.

Walters N.J. & Uglow R.F., 1981. Haemolymph magnesium and relative heart activity of some species of marine decapod crustaceans. J. exp. mar. Biol. Ecol., 55; 255-265.

Waterman T.H., 1941. A comparative study of the effects of ions on the whole nerve and isolated single nerve fibre preparations of crustacean neuromuscular systems. J. cell. comp. Physiol., 18; 109-126.

Webb D.A.. 1940. Ionic regulation in *Carcinus maenas*. Proc. Roy. Soc., Ser. B, 129; 197-136.

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THE MARINE FORUM FOR ENVIRONMENTAL ISSUES

PRESS RELEASE 21 March 1989: MAJOR CHANGES FOR THE MARINE FORUM

As from the beginning of 1989, the Marine Forum became known as the Marine Forum for Environmental Issues. There will be no change in the main objectives of the Forum, which will continue to function as before.

Under the Chairmanship of the Earl of Cranbrook (Deputy Chairman Dr R.C. Earll) a full-time administrator has been appointed, Mrs Swantje-A. Brodie Cooper, who holds a diploma in marine biology from the University of Kiel (West Germany).

The Marine Forum for Environmental Issues, receiving support from the Department of the Environment and the WWF-UK, aims to foster cooperation between the various user groups and marine environmental interests.

The Marine Forum for Environmental Issues is a meeting point for NGO's and other user groups with marine interests involved in the North East Atlantic sea region. It creates opportunities to enable these parties to meet, to voice their concerns, and to discuss their common interest in ensuring that marine environments are managed sustainably.

The Marine Forum for Environmental Issues evolved from the North Sea Forum, which prepared the "North Sea Forum Report, a Brief to U.K. ministers and officials", in the run up to the 2nd Interministerial Conference on the North Sea. Copies of the Report are still available for purchase at £10, from the Marine Forum for Environmental Issues at 80, York Way, London N1 9AG.

THE MARINE FORUM
FOR ENVIRONMENTAL ISSUES

PRESS RELEASE 22 March 1989: STATEMENT ON MARINE INCINERATION

1. The Ministerial Declaration from the Second International Conference on the Protection of the North Sea, November 1987, calls for;

a. marine incineration to be substantially reduced (by not less than 65%) by 1 January 1991;

b. phasing out this practice in the North Sea by 31 December 1994, whilst seeking an agreement to setting the same date for the entire Oslo Convention area;

c. avoiding the export outside the North Sea of waste no longer incinerated there, or harm to other parts of the environment from alternative disposal methods;

d. wastes for marine incinerations to be loaded, preferably, in the country of origin rather than exported for loading elsewhere.

(NB. The Oslo Convention covers the North Eastern Atlantic region, including the North Sea.)

2. The Department of the Environment's Guidance Note on the Ministerial Declaration, dated February 1988, states that "the rules for licensing marine incineration in the U.K. are already tightly drawn, and our industry makes very limited use of this disposal option - less than 5% of the North Sea total. Licensing authorities (in practise MAFF), advised by Her Majesty's Inspectorate of Pollution (HMIP), will seek reductions in the use of this option where practicable, and emphasis will be placed on ensuring that adequate alternative disposal capacity is available by the end of 1994. This is primarily a task for industry, but the Government will encourage the provision of alternative facilities and HMIP is available to advise individual waste generators and disposal authorities in the course of its normal duties."

3. At a meeting of the Marine Forum f.E.I. on 17 January 1989, with the Environment Minister Virginia Bottomley MP present, MAFF stated that the phasing out of this practice within the Oslo Commision (OSCOM) area was not based on scientific evidence of environmental detriment; it was adopted because it was understood that suitable land-based alternatives would exist by 1994. This is not the case world-wide however, and at the London Dumping Convention (LDC) th UK maintained the view that it would not support a global ban on marine incineration unless appropriate alternative means of disposal were available.

4. The Minister herself emphasized in her speech that following the 1987 North Sea conference, remaining licenses for dumping of waste at sea are being reviewed by the Fisheries Departments in consultation with the HMIP and the industries concerned to examine whether there are practicable disposal options for the waste on land. Five licenses for the incineration of waste have already been terminated and alternatives for the remaining eight are being actively pursued by MAFF, HMIP and their licensees.

5. At a Meeting of the Marine Forum on 12 April 1988 participants received a presentation from Dr John Parker of Lanstar on present practices for marine incineration, and together discussed options and problems following the Declaration of the Second International Conference on the North Sea. The MF subsequently produced a first statement on this issue, now substituted by the present statement.

6. The Forum then initiated correspondence with the following companies undertaking the incineration of hazardous waste; Kommunikemi (Denmark), Cleanaway and Rechem (UK).

It seems that the following classes of waste (as described in the first MF statement) can be incinerated adequately at land-based facilities;

i. Highly chlorinated wastes (up to 50% chlorine) although having poor combustion qualities, can be destroyed in the incinerator by either blending them with other wastes (Kommunikemi, Cleanaway, Rechem) or injecting them directly into the hottest zones of the incinerator (Rechem). By storing the highly chlorinated waste separately and then blending it down to a maximum of 2% chlorine, corrosion problems are avoided (Kommunikemi).

ii. Fluoridated wastes produce highly corrosive gases, but can be incinerated on land by using e.g. a semi-dry scrubber system or wet air oxidation (Kommunikemi),

iii. Iodinated wastes can cause plume discoloration if not blended (Kommunikemi, Cleanaway, Rechem), whilst brominated wastes in the presence of organo-sulphur compounds with the minimum of chlorine and using alkaline scrubber, can be destroyed by incineration on land (Kommunikemi, Cleanaway, Rechem),

iv. Organo-phosphorus compounds yield oxides of phosphorus on combustion which stabilise the water vapour in the emission producing a visual plume. But suitable gas cleaning equipments exist for the extraction of oxides (Cleanaway, Rechem), although even without oxide particles in the flue gas a visible plume can be formed, due to climatic conditions (Kommunikemi),

v. Odorous compounds (usually sulphur based, e.g. mercaptans) are acceptable at land based incineration sites, if ventilation with activated carbon-filters, totally closed systems and specially designed feeding tanks to the incinerator are used (Kommunikemi, Cleanaway),

7. There may be approx. 1·500 t per annum arising from UK sources, for which a careful and critical examination (e.g. composition) is needed to form a basis for a both safe and environmentally sound treatment decision.

CONCLUSION

8. New evidence gathered by the Marine Forum for Environmental Issues through its recent correspondence to the leading incinerator companies Cleanaway, Kommunikemi and Rechem seems to indicate that the major part of expected arisings of hazardous waste, potentially sent for marine incineration, can be treated by existing technology. If at all, the problems seem to be on the volumetric load and incinerator capacity side, rather than on the chemical nature of the waste.

Sea incineration prices are generally lower than those levied by land-based facilities, and, as such, sea incineration represents a cost-saving option. It would be difficult to defend the use of marine incineration on the basis of the lack of land-based capability. New incineration plants are being constructed and it seems likely that the phasing out of marine incineration could be achieved in time to meet the timetable identified in the ministerial resolution.

Where there is no immediate solution, further research is needed to find other methods of treatment for especially difficult categories of waste and, if possible, convert them to a form safe for permanent disposal.

NOTE: List of Signatory [sic] to the Document

The following individuals and organisations support the MF's 'Marine Incineration Statement':

Dr M.V. Angel, Association of Sea Fisheries Committees, British Ports Federation, The Council for Association for the Protection of Rural Scotland, Dr M.B. Culley (Portsmouth Polytechnic), Devon Wildlife Trust, Dr D.M.J. Dickson, Dr J.D. George, Dr N. Haward, Mr R. Hawkins, Prof. J.N.R. Jeffers, Marine Conservation Society, Prof. I.N. McCave, Mr A. Menez (A.I.M.L.S.), National Federation Fishermen's Organisation, Mr R. Pagett, Dr R.E. Randall, Dr G. Rees (Institution of Environmental Sciences), Sea Fish Industry Authority, Dr D.F. Shaw (Liverpool University), Dr A.D. Tappin, Mr C.J.L. Taylor, Dr C. Tydeman (WWF-UK), Dr L.M. Warren.

AGM Reports

MINUTES OF THE TWELFTH ANNUAL GENERAL MEETING OF PORCUPINE, held at the University of Lancaster, on Sunday 2nd April 1989 at 9.30 am.

David Heppell was in the Chair; 19 Members were present. Apologies for absence were received from the Hon. Secretary and the Hon. Treasurer. The minutes of the Eleventh Annual General Meeting (Published in PORCUPINE NEWSLETTER, Vol.4 No.2) were approved.

Reports of the Hon. Secretary, Hon. Treasurer, and Hon. Editor were presented by Roger Bamber, and approved; the Hon. Records Coordinator's Report was presented by Jonathan Moore, and approved.

Office bearers were elected as follows:

Hon. Secretary	Martin Sheader
Hon. Treasurer	Antony Jensen
Hon. Editor	Roger Bamber
Hon. Records Coordinator	Jonathan Moore

In accordance with Rule of Procedure 5, David Heppell and Dennis Seaward retired from Council, but were available for immediate re-election. The following Members were elected to Council:

Iain Dixon	Ivor Rees
Frank Evans	Ralph Robson
Bill Farnham	Dennis Seaward
Robin Harvey	Shelagh Smith
David Heppell	Brenda Thompson
David Lampard	John Wilson
Jan Light	Fred Woodward

The existing Hon. Auditors, Ralph Robson and Nick Light, were re-elected.

Future meetings were announced at the Trink, 20-22 July 1989. A variety of options for venues and topics, as discussed at the previous day's Council Meeting, was proposed to be passed on the the Hon. Secretary to follow up; the theme of 'mapping' (+recording) was suggested from the floor.

A draft revised Membership list was made available to those present that they may check it for errors. Associated problems with the Newsletter (e.g. Members not receiving their copies) were to be addressed to the Hon. Editor.

The Meeting closed at 10.00 a.m. with the Chair proposing thanks to those involved with the organisation of the Lancaster meeting.

PORCUPINE
RECEIPTS AND PAYMENTS ACCOUNT
for the period 1 April 1988 to 4 March 1989

22.2.87 to 31.3.88			1.4.88 to 4.3.89	
£	£		£	£
		RECEIPTS		
	18	Subscriptions - 1985	-	
	168	- 1986	-	
	315	- 1987	-	
	639	- 1988	107	
	10	- 1989	531	
	-	- 1990	7	
1150	-	- 1991	5	650
-		Advertising Revenue		30
-		Sale of PN Back Numbers		60
250		Donation		-
61		CEGB Display & Tea receipts		-
20		Bank Interest		59
1481		Total Receipts		799
		PAYMENTS		
	341	Newsletter - Printing	188	
	144	- Postage	67	
	35	- Envelopes	-	
	520	Total Newsletter Costs	255	
	27	Delegates' Travel	27	
	28	Speakers' Travel	-	
575	-	Postage and Stationery	8	290
906		**SURPLUS FOR THE PERIOD**		509
		BALANCE BROUGHT FORWARD		1832
926				
		BALANCE CARRIED FORWARD		
	1331	Current Account	550	
1832	501	Deposit Account	1791	2341

Hon. Secretary's Report 1988-1989

During the year 1988-1989 Porcupine held two meetings. The Annual General Meeting was held at the Marine Biology Station, Millport, Isle-of-Cumbrae, on 5th March 1988. The theme of the meeting was broad, covering aspects of marine ecology on the west coast of Scotland. The meeting was well attended despite a ferry strike. May I extend our thanks to John Allen and his staff, who made us all most welcome, and also to Fred Woodward who organised the event. The second meeting was held at Ipswich, based at Ipswich Museum, and organised by Dave Lampard. Initially it was intended to hold a two-day meeting on 'Meiofauna', but this received little support, and the meeting evolved to a Field Meeting, attended by a small but keen group of Members (details published in PN 4 (4)), and centred on shores and lagoons in the Shingle Street / Aldeburgh area of Suffolk.

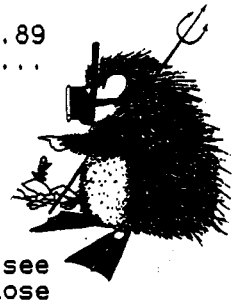
I would like to take this opportunity to thank all those who were involved in the organisation of these meetings, and would also like to make a plea for ideas for topice or venues for future meetings. If anyone is willing to host a meeting, could he/she please contact me.

In 1989 there will be a summer Field Meeting, based at the Dove Marine Laboratory, Cullercoats (Newcastle University) on 20-22 July. Using the M.V. Bernicia, participants will be able to study the biota associated with 'The Trink', a faunistically rich, but under-studied area off the coast of Northumberland.

Membership during the current year has remained steady at around 170. Could I encourage Members to bring PORCUPINE to the attention of colleagues who may have interests within the broad remit of the Society.

It is with sadness that we learned of the death of our Honorary Member Norman Holme on 10th January. Norman was present at the inaugural meeting of PORCUPINE, and acted as Honorary Auditor for many years. He was that rare combination of experienced ecologist and natural historian, and shall be sorely missed.

Martin Sheader
Hon. Secretary 2.4.89



FUTURE MEETINGS

THE SUMMER FIELD MEETING based at the Dove Marine Laboratory (see previous NEWSLETTER): Frank Evans has a working list of those intending to participate in boatwork on the Thursday & Friday, 20 and 21 July: further participants are welcome to attend at the Dove over the weekend, when collected material will be available for sorting, examination, etc. Please let Frank or the Hon. Sec. know of your intentions: in return you will get information on accomodation, etc..

THE AUTUMN MEETING will take place over the weekend of 28 and 29 October, 1989, based at Surrey University (Guildford), on the theme of "Islands" (which must be open to interpretation!), organised by Jan Light. Would all Members (and others) interested in attending please contact Jan (88, Peperharow Road, Godalming, Surrey GU7 2PN), who has details of accomodation, destination, timings, etc.. There are still some gaps in the programme for those wishing to contribute papers, and of course plenty of room for poster displays.

Papers from the Lancaster "Irish Sea" Meeting

MONITORING OF RADIONUCLIDES IN THE IRISH SEA

by Duncan Jackson
Environmental Protection Group, BNFL, Sellafield, Cumbria

Introduction

British Nuclear Fuels plc (BNFL) operates through six sites in the north-west of England and the south-west of Scotland (Springfields, Lancashire; Capenhurst and Risley, Cheshire; Sellafield and Drigg, Cumbria; Chapelcross, Dumfriesshire). Each site discharges material to the environment, which may contain low-level radioactivity, subject to the terms of specific Authorisations. Environmental monitoring is undertaken as appropriate, the objectives of which are:

i to establish radionuclide concentrations in the environment,
ii to determine the most important pathways by which radiation exposure of the public may occur,
iii to estimate (in conjunction with habits surveys and metabolic models) radiation doses received and to demonstrate compliance with statutory limits,
iv to identify areas where further research is required.

The Company prefers to rely on independent advice concerning metabolic data, but does carry out or sponsor research aimed at defining the behaviour of radionuclides in specific environmental conditions.

For the purpose of comparison to statutory limits of company targets, the intent is to establish doses typical of the most highly exposed individuals. This depends on ascertaining maximal values, representative of a small 'critical group', for habits such as consumption of specific foods or occupancy in certain areas. The major pathways identified relevant to discharges from Sellafield are:

- high rate consumption of seafoods (especially fish and shellfish);
- external radiation from exposed intertidal sediments;
- inhalation of material resuspended from coastal areas.

Habits relevant to each pathway are kept under review by MAFF and the Scottish Office, for sites in England and Scotland respectively, with supporting information from NRPB and BNFL.

Dose limits to members of the public

Dose limits are currently under review, but can be summarised as an upper limit of 5 mSv committed effective dose equivalent (CEDE) in any one year, or 70 mSv over a lifetime (approximating to 1 mSv per year on average). More restrictively, the Company is committed to maintaining doses below 0·5 mSv in any year, which is in line with recent recommendations of RWMAC and the NRPB. Notwithstanding this, all doses incurred must be maintained "as low as reasonably achievable" (ALARA). For particular nuclides, organ doses may limit intakes more than CEDE, but the same principle of ALARA applies in all cases.

Routine discharges of radioactivity

i Discharges via the Sellafield Pipeline

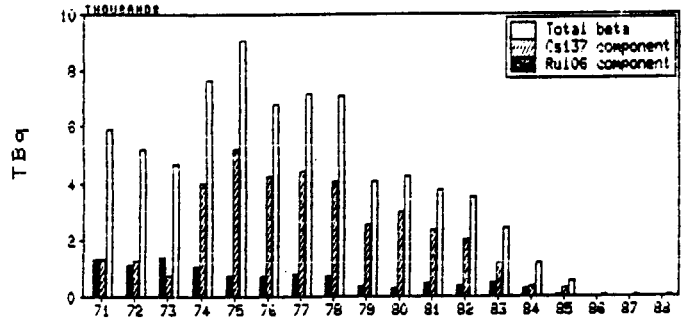
Liquid effluents discharged to sea from Sellafield are collected from two major and two minor streams. One of the major streams is storage pond water from the Magnox decanning plants, which becomes contaminated, principally with isotopes of caesium and strontium from fuel elements. This water is continuously replaced and circulated to the Site Ion Exchange Efffluent Treatment Plant (SIXEP) prior to discharge, and passed through an array of sand filters and clinoptilolite ion exchangers. These remove both particulate activity and specific cations such as caesium and strontium from the aqueous phase. After treatment, the

water is discharged directly to the sea pipelines, with continuous monitoring for radioactivity. Liquid wastes arising from reprocessing operations, and from the Calder Hall Nuclear Power Station and the Northern Research Laboratories (Windscale) of the UKAEA, are diverted where practicable for delay storage via a medium active evaporator and salt evaporator. Remaining low level wastes are discharged via the sea tanks, in which effluent is held for composition to be confirmed prior to discharge.

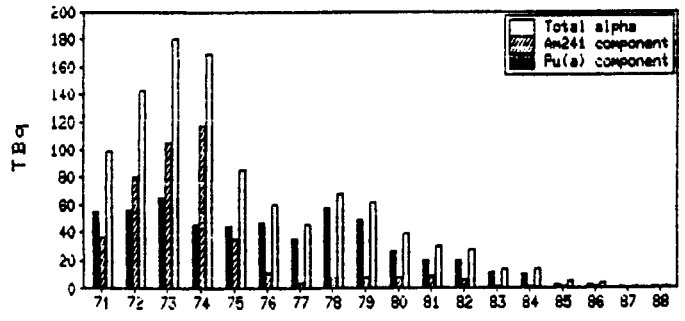
Minor waste streams from surface drainage water and laundry effluent are discharged direct to sea through the pipelines following sampling to determine radioactive content, and account for less than 0·1% of total liquid radioactive discharges.

Discharges of activity from all streams have declined steadily since the mid 1970s (Fig.1), reflecting a combination of reprocessing programmes and the efficiency of treatment plants.

Fig 1. Marine pipeline discharges from Sellafield



a) Beta discharges*



b) Alpha discharges

* For 'total-beta' the approved technique does not detect very low energy emitters (eg ^{241}Pu, ^{99}Tc and ^{3}H).

ii Discharges via the Sellafield Site Sewer

Small amounts of radioactivity arise from surface water drainage into the site sewer, which discharges into the confluence of the Rivers Calder and Ehen, and thence to the sea. Effluent is sampled automatically once per hour, and discharges are equivalent to approximately 0·004 TBq total alpha plus total beta. This is well within limits specified by the Certificate of Authorisation.

iii Discharges via the Drigg Stream

Disposal trenches on the Drigg site are drained currently into a stream which runs off-site to the intertidal region of the R. Irt, and thence to sea. The stream is sampled automatically every hour near the Drigg site boundary, and analysed regularly.

Environmental monitoring programmes

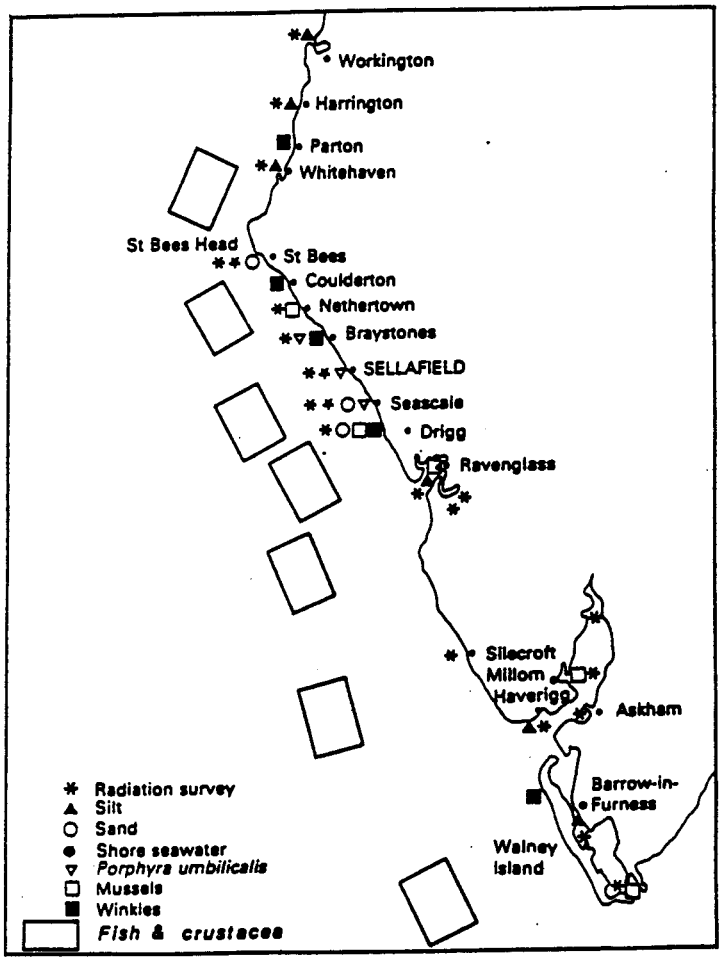
i Monitoring of Foodstuffs

Dose estimates to seafood consumers depend on a number of factors, including:

- concentration of radionuclides in food and quantities consumed;
- transfer of radioactivity to the consumer and dose per unit uptake.

Samples of actual or potential marine foodstuffs are collected regularly from the Cumbrian coastal area (Fig.2), the precise locations being reviewed periodically. In most cases (e.g. fish, crustaceans, molluscs), additional samples are obtained through commercial suppliers, representing the foodstuffs available for general consumption.

Figure 2 Marine environmental monitoring locations



During 1988 the critical group consisted of a number of people in the Cumbrian coastal community consuming fish or shellfish from the Sellafield area at the following rates:

Fish 36·5 kg (based on equal mix of plaice and cod)
Crustaceans 6·0 kg (based on mix of ⅔ crab and ⅓ lobster)
Molluscs 8·3 kg (based on winkles)

For assessment purposes it is assumed that a single group of people consumes all three categories at the above rate.

Generalised gut transfer factors are used for the uptake of radionuclides to the consumer, except for plutonium and americium. Studies by MAFF with human volunteers suggest that a factor of 10^{-4} is appropriate for both plutonium and americium near Sellafield (in place of the more conservative 10^{-3}). Further studies are being undertaken. Meanwhile, NRPB considers that the method for deriving doses to the critical group using a gut transfer factor of 5×10^{-4} will not lead to underestimates.

ii Coastal Radiation Surveys

The amount of time spent by members of the public on intertidal areas of the coastline is reviewed, and gamma dose rates are measured regularly 1 m above the surface at 21 locations. Particular note is made of transient silt patches. Seawater and coastal sediments are sampled also. During immersion in seawater, fishing gear may entrain particulate material, and fishermen handling this gear could be exposed to external radiation. Monthly monitoring is carried out on the BNFL vessel *Seascan*.

iii Inhalation of Resuspended Material

High volume air samplers (drawing air at approximately 50 to 100 m^3 hr^{-1}) are situated in coastal towns and villages to determine the potential inhalation dose from material resuspended from the sea.

Results

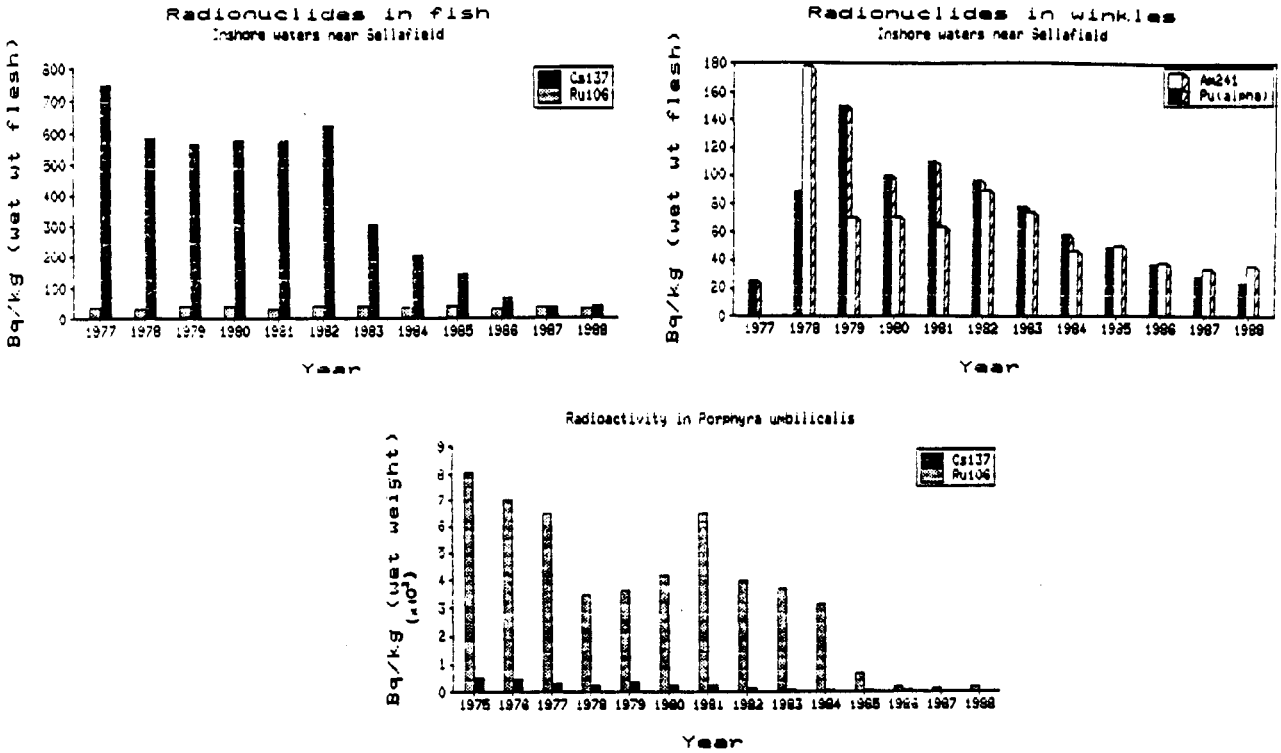
The isotopes of principal concern in the past have been ^{106}Ru (in the edible seaweed *Porphyra umbillicalis*), ^{137}Cs (in fish) and Pu-α and ^{241}Am (in winkles). Concentrations of each of these nuclides have declined substantially over the past few years (Fig.3), and doses to the critical group of fish and shellfish consumers are currently around 0·3 mSv. No allowance is made for immersion of winkles in water overnight to allow for gut clearance, although this practice is widely recommended to reduce the hazards of contamination by sewage and industrial effluents. Allowing for such soaking would reduce the dose estimate to less than 0·2 mSv per year. Typical consumers of fish and shellfish landed commercially at Whitehaven or Fleetwood receive an annual dose of around 0·005 mSv.

Porphyra is no longer harvested from the Cumbrian coast for manufacture into laverbread, but even in the case of a resumption of this industry the critical group dose would be less than 0·05 mSv. Published data for actual laverbread consumption in 1987 indicate a dose to consumers of less than 0·01 mSv.

Mean gamma dose rates over coarse-grained sandy beaches are generally lower than for fine-grained silts and saltmarshes. This reflects the fact that many radionuclides sorb more efficiently to smaller particles. Nonetheless, a general decline in dose rates is observed at all sites (e.g. Fig.4), reflecting decreasing concentrations of radioactivity in silts and sands from West Cumbria. Currently, a hypothetical critical group occupying fishing boats within Whitehaven Harbour, and consuming fish at the elevated rate associated with fishermen, would receive a dose of under 0·2 mSv per year.

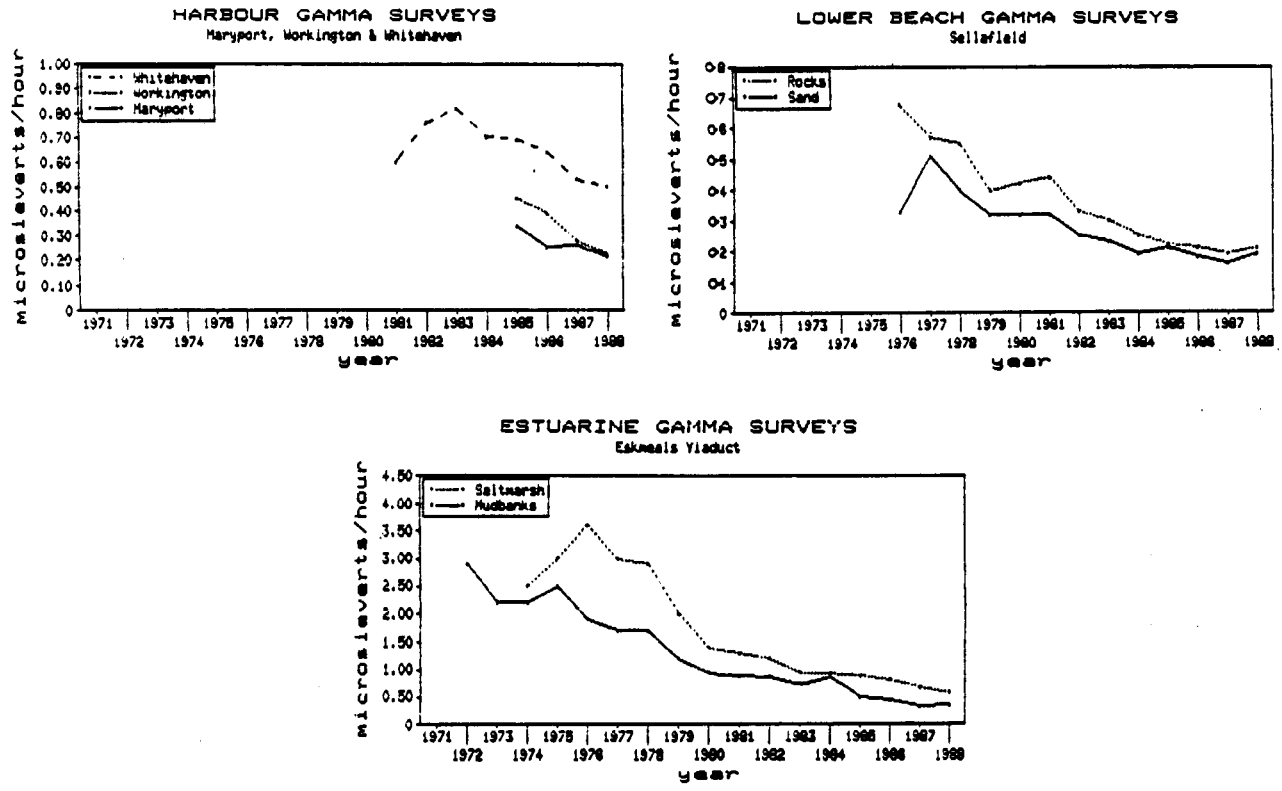
A gradual build-up of radionuclides in the Drigg stream has been observed over the past few years. This is not potable water, and since it would be necessary to drink some 300 litres to incur a radiation dose of 1 mSv the inadvertent ingestion of small quantities would result in a negligible dose. Nonetheless, a series

Figure 3 Radionuclide concentrations in marine foodstuffs



Note: A sample consists of a variable number of organisms (to give 0.5-2 kg of edible material), and may be bulked across several locations.

Figure 4 Beach, estuarine and harbour gamma dose rate surveys near Sellafield



of site improvements are being undertaken to reduce levels of radioactivity.

Conclusions

Results from monitoring indicate clearly that doses to members of the public, arising from Sellafield operations, are well within the UK primary dose limits. Furthermore, both the environmental concentrations and resultant doses have declined continuously since the mid 1970s, following the notable reduction achieved in discharges. For the future it is anticipated that discharges of total beta-activity will remain near constant (at about 100 TBq per year) when the Enhanced Actinide Removal Plant is commissioned in 1992. Thus, whilst doses due to fish consumption (which derive mainly from the β-emitting ^{137}Cs) will stabilise, doses to the limiting critical group of shellfish consumers (due principally to the α-emitting actinides) should decline further, subject to changes in consumption habits.

TABLE 1. AVERAGE ANNUAL RISK OF DEATH IN THE UK

Cause	Risk of death per year
Smoking 10 cigarettes per day	1 in 200
Natural causes, aged 40 years	1 in 850
Accidents on the road	1 in 9,500
Accidents at home	1 in 26,000
Accidents at work	1 in 43,000
Radiation exposure at 0·3 mSv yr^{-1}*	1 in 250,000

* Equivalent to radiation exposure of Sellafield most limiting critical group in 1988.

In order to place these results into perspective, the doses currently incurred due to Sellafield discharges into the Irish Sea can be compared to the 2 mSv arising from natural background radiation as an average over the UK. The natural dose in Cornwall is generally up to 7 mSv, and in some 2000 houses a dose in excess of 50 mSv is estimated due to radon gas. The risk arising due to various common causes is compared to the effect of Sellafield discharges in Table 1. From this it appears that the risk to even the most exposed individual is low both in absolute and comparative terms. This is not taken as an invitation to complacency however, as the industry strives continuously to reduce further its impact on the environment and to improve both radiological and conventional industrial safety.

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NOTICE

THE SCOTTISH MARINE GROUP is to hold its next meeting on Thursday 2nd November 1989 at Stirling University. Contact John Gamble, DAFS, Victoria Road, Aberdeen AB9 8DB.

BENTHIC STUDIES AT DREDGED SPOIL DISPOSAL SITES IN LIVERPOOL BAY

by H.L. Rees, S.M. Rowlatt & E.I.S. Rees*

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Summary of paper presented at the Lancaster Meeting

Studies of the sediments and benthic fauna at dredged spoil disposal sites in Inner Liverpool Bay were conducted between 1974 and 1988.

Spoil arises mainly from maintenance dredging within the Mersey Estuary and its approaches, and consists of sands and muds. The spoil typically contains elevated levels of organic carbon and certain trace metals, relative to background conditions in the locality.

Contrary to expectation, there was no evidence for a widespread area of faunal impoverishment in the immediate vicinity of the spoil ground, even at high disposal rates (several million tonnes per annum) in the early 1970s.

Newly deposited spoil is rapidly recolonised by the larger 'opportunistic' species - notably the polychaetes *Pectinaria* and *Lanice* and the bivalve *Abra* - which are characteristic of soft sediments of the Inner Bay area. As a result, the main effect of spoil disposal appears to be one of enhancement in numbers. This may occur as a result of both larval recruitment and re-distribution of adults. It is also probable that, once established, populations on the periphery of the dumpsite can survive repeated additions of migrating spoil.

High dominance by *Pectinaria* and *Abra* provided a good indication of the presence of muddy spoil. However, similar population structures were also encountered in the transient mud deposits off the Mersey mouth.

Enhanced benthic counts may be a consequence of the stabilizing or nutritional properties of the dispersing spoil. There was no evidence of a chemical inhibitory effect associated with elevated contaminant levels.

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PATTERNS OF ACOUSTIC SCATTERING NEAR THE MARGINS OF STRATIFIED WATER IN THE IRISH SEA

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When the gain controls on ordinary commercial fish-finding echo-sounders are turned up slightly, interference patterns start to show in the water column. If the control settings are left constant while passing between mixed and stratified water masses the patterns will normally be seen to change. This was noticed almost as soon as echo-sounders became available on trawlers after the 1939-45 war, but was largely ignored by most biological oceanographers until the 1980s.

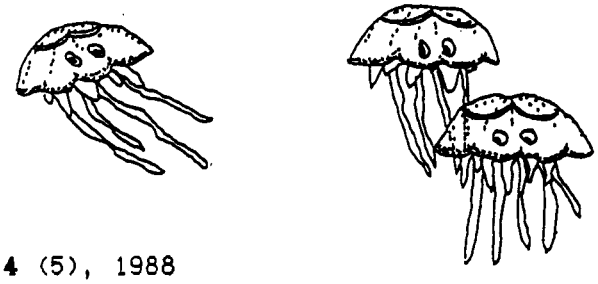
In the Irish Sea and its approaches there are several well known fronts between mixed and stratified water. Since 1980,

numerous acoustic records have been examined from frontal crossings in high summer by the UCNW research vessel *Prince Madog*. For the western Irish Sea front these show a highly replicable sequence of patterns. With experience, echosounding allows the feature and its component parts to be defined more readily from a moving ship than by watching the surface thermograph trace.

The typical sequence, when steaming on a line between Anglesey and Northern Ireland and thus coming from tidally mixed towards stratified water, was for there to be first a gradual increase in diffuse mid-water scattering. On paper traces this resembles the approaching curtains of a rain shower, hence the term "curtain scattering". On the expanded display of a colour sounder, these appear as patches of weak echoes seeming to be spaced about 80-90 m between centres and showing most 20-40 m down. After gradually intensifying, the curtain scattering usually faded abruptly, giving way to a zone with minimal scattering. Often this zone was quite narrow, being less than 0·5 km wide, but it could be more than 8 km wide. Where it is narrow it seems to coincide with the surface temperature minimum that is usually noticed next to a sharp front. After the blank zone some diffuse scattering reappeared, but the pattern soon became organised into one or more definite scattering layers. Very often, several large internal waves were seen in the scattering layers. These were far larger right at the edge of the stratified water than elsewhere, being about 10-12 m from crest to trough and about 180-200 m between crests. Further into the stratified area the internal waves showed as smaller, spaced out, downward pointing crests. Still further northwest into the stratified area the organised scattering at the thermocline either faded out or broke up into an increasingly complex series of layers. The strongest layer seen here was often at 70-80 m depth by day. Together with clouds of echoes that are believed to be decapods, this layer of fish came up at night.

Fronts are maintained as sharp discontinuities by the balance between the intensities of mixing energy and those forces that enhance density stratification. Mixing processes are different where tidal currents flow across a front rather than parallel to it. Anglesey - Northern Ireland transects cross parts of the front where tides flow along the front. Off Dublin, and where St George's Channel meets the Celtic Sea, the fronts are across the tide. In these localities fairly narrow zones of enhanced layered scattering were also seen. They coincided with surface water of intermediate temperature and were roughly the width scale of the difference between spring and neap tidal excursions. Alternate stirring and stabilisation on such a timescale would be expected to foster production in such an area.

The identity of the organisms causing shallow scattering layers in the Irish Sea in mid-summer has yet to be firmly established, but there is enough circumstantial evidence to suggest that medusae and other coelenterates could be major components. Large medusae have often been noticed in large numbers both in nets and at the surface. Casual observations off Anglesey have shown *Rhizostoma* drifting past an anchored ship at mid depth where the density stratification was a 0·5‰ salinity change at the same depth. Estimates of numbers of targets in some fairly pronounced thermocline depth layers showing at 200 KHz have given counts of about 10-15 targets per 100 cubic metres in layers only 2 m thick. Intuitively this seems realistic for *Aurelia* sized medusae.



STRESS ASSESSMENT OF *OSTREA EDULIS*

by S. Hutchinson & L.E. Hawkins

Department of Oceanography, Southampton University SO9 5NH

During the last 30 years, the concepts and measurement of biological stress have developed from Brett's (1958) definition of stress as "a state produced by an environmental or other factor which extends the adaptive responses of an animal beyond the normal range, or which disturbs the normal functioning to such an extent ..... that the chances of survival are significantly reduced". More recently, Bayne (1976, 1985) has defined stress in marine organisms not as the physiological state that represents the response, but as "a measurable alteration of a physiological (or behavioural, biochemical or cytological) steady state which is induced by environmental chance and which renders the individual (or the population or the community) more vulnerable to environmental change".

The ability to recognise stress is essential in understanding the functioning of any biological system and in ecophysiological studies it is necessary to examine a variety of processes that define the adaptability of individuals. The use of experimental procedures that measure the effects of environmental changes that are within the normal range of a population gives some indication of the physiological and biochemical basis for the observed distribution of a species and of its tolerance of naturally occurring changes; this may be broadly described as an approximation of a species' or population's ecological "fitness". For example, the ubiquity of the common mussel *Mytilus edulis* L. is reflected in the stability of its stress indices under the harshest of conditions, whereas the same indices applied to *Ostrea edulis* L. show it to be extremely sensitive to external factors, and as a consequence its distribution is restricted. At the level of the individual, stress indices give expression to an animal's well being or "health" (Bayne *et al.*, 1985).

Stress indices have a number of attributes which make them particularly useful in gauging animals' responses to changing conditions. Firstly, they represent an integration of the innumerable cellular processes that can alter in response to specific external changes, and they can also describe non-specific (generalised) responses reacting to the sum of environmental stinuli. Secondly, stress indexation can be used to detect environmental deterioration from individuals' indices before there are overt effects on the structure of a population or community. Finally, the rapidity of the response of each index will depend on the rate-determining step of the process that is measured; and so, each index represents the summation of stresses acting over the period required to produce a measurable change. Thus, indices can be chosen to show the accumulated effects of a stressor or stressors acting over periods of a few minutes to many months.

The adoption of these methods to study the European flat oyster *Ostrea edulis* arises from the need to explain the distribution and occurrence of outbreaks of the disease bonamiasis, which is caused by the protozoan *Bonamia ostreae* Pichot *et al.*. During the late 1970s and early 1980s *Bonamia* destroyed the commercial exploitation of flat oysters in France, northern Spain and most of the grounds in the Netherlands, forcing a change to the resistant, but less valuable, Pacific oyster *Crassostrea gigas*. In Britain, *Bonamia* was first identified in 1984 after mass mortalities in the Helford River fishery, by which time transfers of stock had spread the disease to the Essex coast and eventually to the Beaulieu River and Poole Harbour. In all the outbreaks there were certain common factors: all the sites were in shallow water, often with some degree of tidal exposure, major mortalities appeared to start in spring and reach a peak in early summer, and the severest losses were from beds with relaid oysters, whereas natural beds in the same area suffered much smaller losses and low levels of infection.

This anecdotal evidence, and the study made by the Fish Diseases Laboratory at Weymouth, clearly suggested that environmental stress was a predisposing factor associated with the disease, and so in May 1987 the present study began with three objectives. These were to characterize the stress responses of *Ostrea edulis*, to identify those environmental variables which induce stress responses, and to develop a protocol for the further investigation of the effects of stress on disease susceptibility. The present investigation has used the stress assessment methods to establish the effects of temperature, salinity and tidal exposure. Particular emphasis has been laid on the detailed examination of these effects which may reveal stress-induced changes in animals' physiology and biochemistry that render them susceptible to pathogens such as *Bonamia*. Three main methods were used to measure stress induced by these variables, and, where possible, laboratory studies were validated by comparison with field samples which were also used to follow the normal seasonal variations in conditions, including the intrinsic metabolic stresses associated with the annual reproductive cycle. The assessment methods used were 'Scope for Growth' measurements, biochemical indices, and specific physiological indices.

Scope for Growth

This is an overall stress index derived from the energy budget proposed by Winberg (1960):

$$C - F = A = R + U + P \quad (1)$$

$$\text{or} \quad P = A - (R + U) \quad (2)$$

where C = energy in food consumed, F = energy lost in faeces and pseudofaeces, A = assimilated energy, R = energy lost in respiration, U = energy lost in nitrogenous excretion, and P = energy incorporated into somatic growth and gamete production ≡ 'Scope for Growth'.

The rearrangement of the basic equation (1) into equation (2) allows P, the 'Scope for Growth' (Warren & Davis, 1967), to be calculated from components which are directly measurable physiological processes which can be converted to energy equivalents (Joules h^{-1}). Animals in favourable conditions will have positive Scope for Growth while those in stressful conditions will have reduced or negative values as metabolic regulatory requirements exceed the input of energy from assimilation (which may also be impaired). Chronic exposure to stress will cause the depletion of energy reserves as these are mobilised to cover the difference between energy input and consumption.

Biochemical Indices

The present study puts into effect the recommendation made by Ivanovici & Wiebe (1981) that adenylic energy charge (AEC) should be used in conjunction with other indices of sublethal stress; this has been dome using additional biochemical indices as well as comparison with Scope for Growth and other independent assays. Figure 1 indicates the close correspondence betwen these indices when applied to oysters acclimated to fixed temperatures. Also, comparisons of laboratory and field samples subjected to the same conditions show no significant differences for each index.

AEC was first proposed as an overall stress index by Atkinson (1968) who suggested that variations in the ratio of the components of the adenyl-phosphate pool reflected the modulations, by external factors, of enzyme activities at key points in the major metabolic pathways that yield energy in the form of high energy adenosine-phosphate bonds. The present study is the first to apply AEC indexation to *Ostrea edulis* and it appears that for this species AEC is sensitive to relatively small changes in external conditions and changes in AEC can be detected within a few minutes. For example, Fig. 2 shows the effects of a range of acclimated salinities on the AECs of oysters from the western Solent; it can be seen that not only do reduced salinities induce a stress response but the apparent optimum salinity is 32‰. The field data

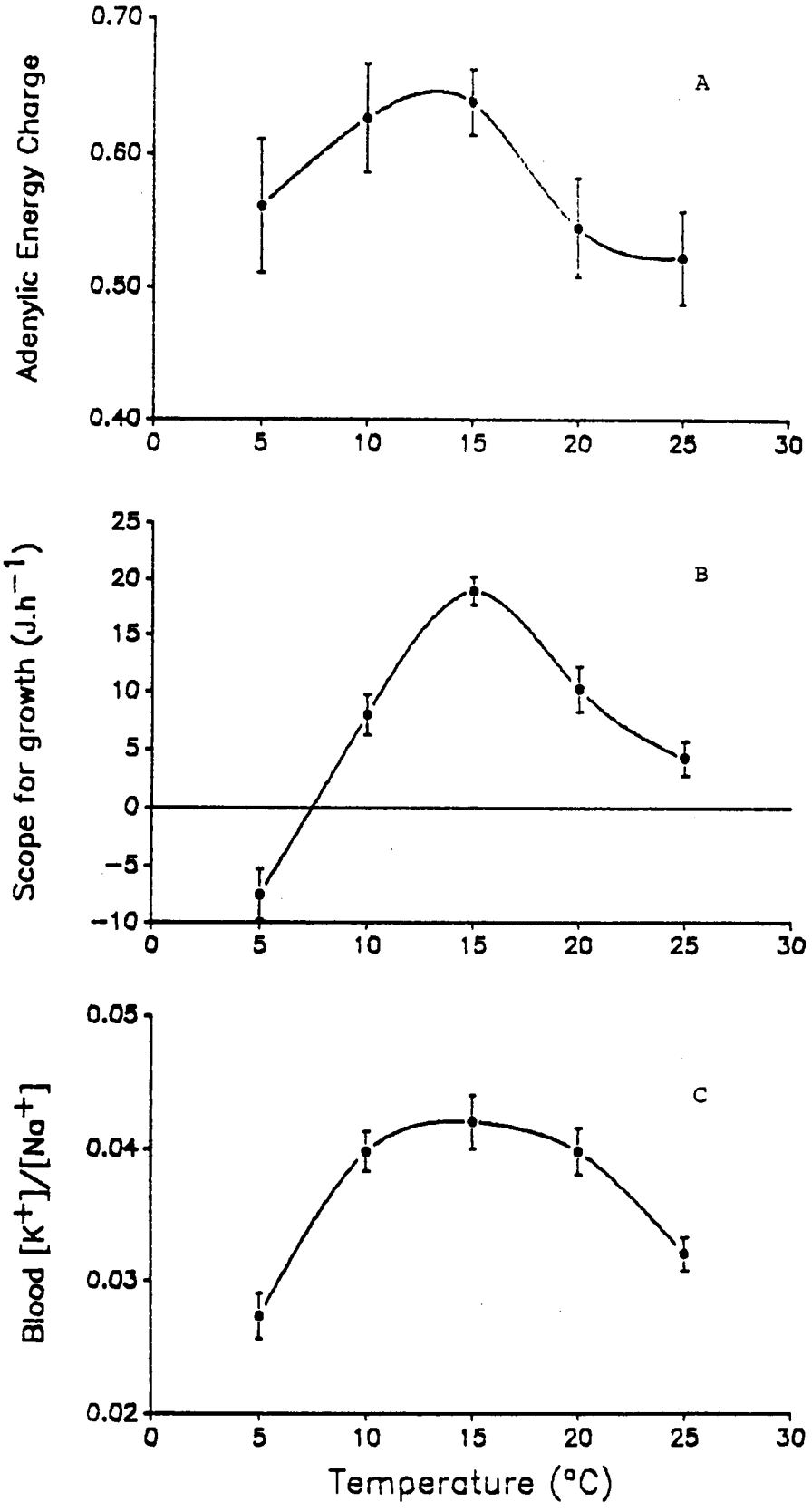


FIGURE 1. Stress indexation of O. edulis exposed to a range of fixed temperatures for 60 days, salinity 34‰. Effects of exposure on (A) adenylate energy charge, B scope for growth, C haemolymph K:Na ratio. N=18; error bars are SD.

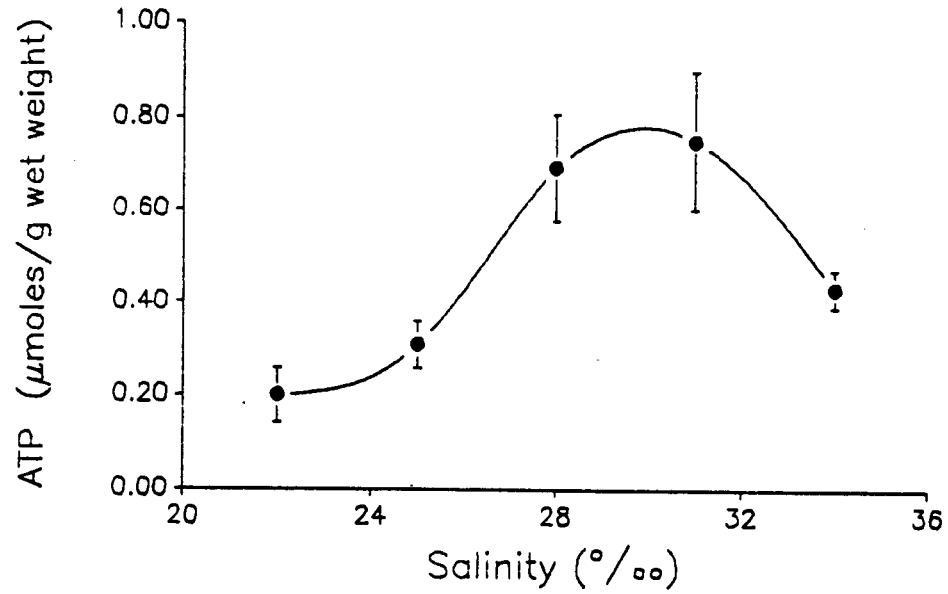


FIGURE 2. Adenylate energy charges of O. edulis exposed to a range of fixed salinities for 60 days, temperature 15°C (N=18 for each point, error bars indicate SD).

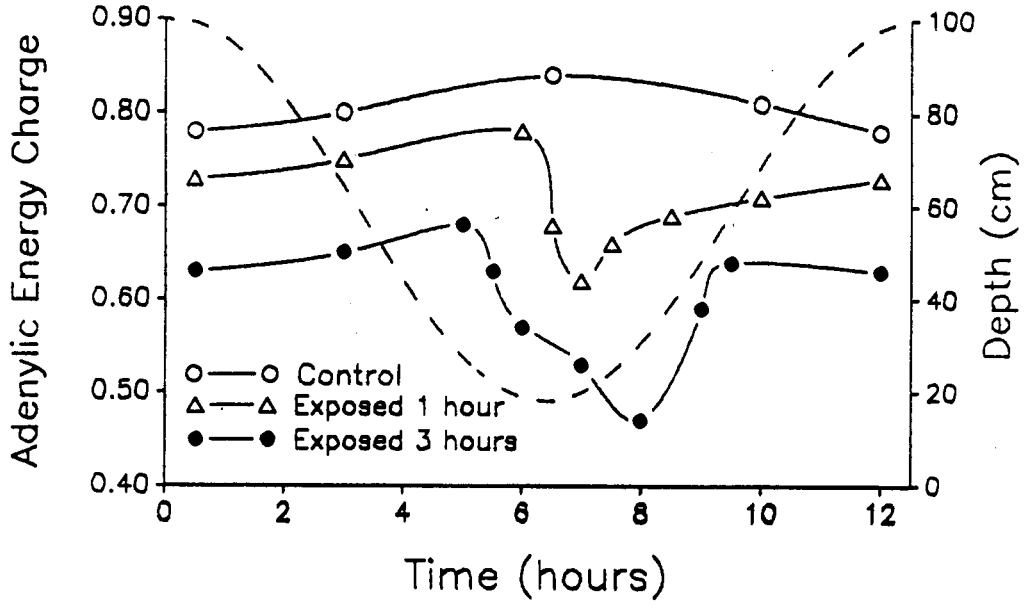


FIGURE 3. Adenylate energy charges of O. edulis acclimated for 12 months to a simulated tidal immersion/exposure cycle of period 12h 25 min. Exposure times indicate period of air exposure per cycle, dashed line indicates water level (N=18 for each point; error bars indicate SD).

from the sampling point show the normal salinity to be in the range 30 to 32‰, suggesting that these oysters are habituated to this slightly reduced salinity. A further example of the sensitivity of AEC to stress in oysters is shown in Figure 3, which shows the change in AEC caused by anaerobic respiration during tidal exposure.

The extension of the biochemical monitoring of stress effects follows the rationale of Atkinson's (1968) key enzyme theory. The concentrations and ratios of number of metabolites at various points on the Embden-Meyerhof route for glycolysis and Krebs' tricarboxylic acid cycle can be used as indicators of changes in the functioning of the enzymes responsible for the transformations between metabolite pools. This approach gives a range of indices whose integrative periods are related to the heirarchy of energy storage products. The most stable metabolites are glycogen and lipids, long term storage products present in large concentrations that change slowly in response to seasonal effects. The progressive loss of long-term storage products caused by chronic stress can be seen in oysters subjected to laboratory-simulated tidal exposure for twelve months (Fig.4): it is apparent that the tissue glycogen content is inversely related to the period of air exposure during the tidal cycle.

The glucose, pyruvate and succinate pools can be considered to be intermediate in the heirarchy of metabolites since, under aerobic conditions, detectable responses occur over a period of hours. Tissue concentrations of lactate under aerobic conditions are small in comparison to other metabolites; however, when *O. edulis* is subjected to anaerobic conditions, e.g. when closed during tidal exposure, the balance of these metabolites is altered: the proportion of lactate is increased whilst the glucose and pyruvate pools are depleted. Succinate does not decrease as, in common with *Crassostrea* spp. (Hammen, 1969), the reduction in oxygen tension does not completely stop the Krebs' cycle, but halts it at succinate, which will accumulate in preference to lactate (Fig.5).

Arginine phosphate can be considered with the intermediate metabolites. Measurements of the relative amounts of arginine phosphate have proved a useful guide to adaptation to environmental stressors; long term acclimation to increased tidal exposure produces an increase in the arginine phosphate pool (Fig.6). This would have the effect of prolonging survival under anaerobic conditions when generation of ATP is limited to that associated with glycolysis, the lactate shunt and the incomplete form of the Krebs' cycle (succinate accumulation). The combination of arginine phosphate measurements with those of adenylate concentration (and therefore AEC) is a novel extension of biochemical stress assessment. The results obtained so far from cycling tidal exposure seem to indicate that increased arginine phosphate concentrations are associated with physiological stress. This increase may be some form of adaptation to cope with regular episodes of stress or prolonged exposure to a stressor. In such situations it is likely that metabolic demands on the adenylate pool cannot be covered by direct contribution from glycolysis and the Krebs' cycle, and so the arginine phosphate pool acts as an additional energy reserve.

The measurement of metabolites in addition to the adenyl phosphates has been particularly useful in this study by revealing metabolic stress effects that could have a significant influence on disease susceptibility; for example, tidal and handling exposure are known to be associated with increased mortality in relaid oysters. During tidal anaerobiosis the rediced oxygen tension and accumulation of succinic and lactic acid as well as waste products produce conditions that are favourable for the proliferation of many potential pathogens, but are likely to reduce haemocyte-mediated defence mechanisms.

Specific Physiological Indices

Methods have been devised for use in this study of semi-quantitative assessment of the effects of stress on the haemocytes

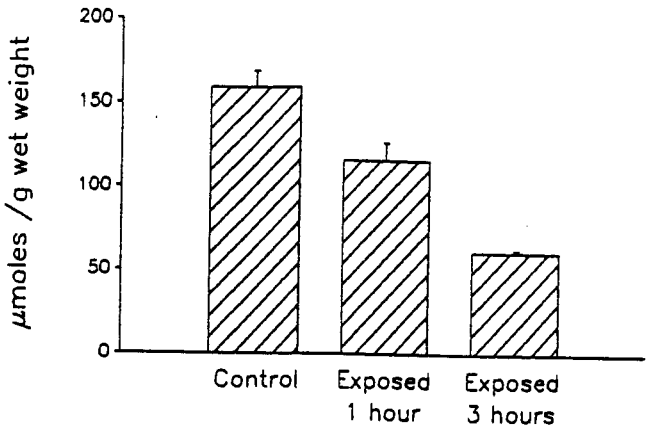


FIGURE 4. Tissue glycogen contents of O. edulis acclimated to a simulated tidal immersion/exposure cycle for 12 months. Exposure times indicate period of air exposure per cycle (N= 18 at each point, error bars are SD).

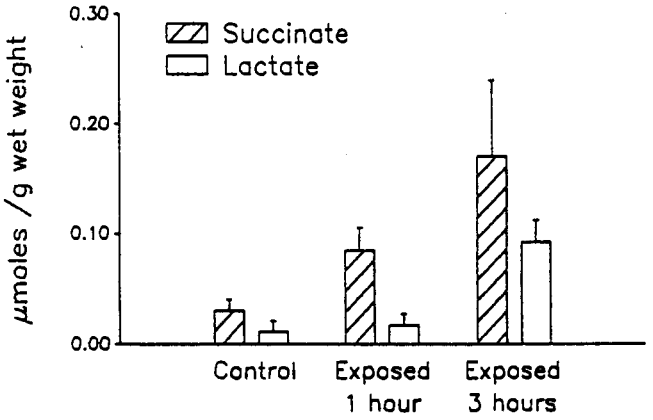


FIGURE 5. Tissue succinate and lactate contents of O. edulis, details as in Figure 4.

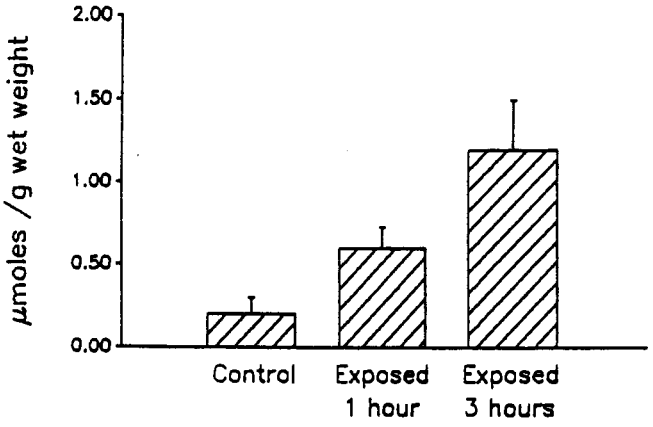


FIGURE 6. Tissue arginine phosphate contents of O. edulis, details as in Figure 4.

of *O. edulis* since these are likely to be the main defence mechanism against pathogens such as *Bonamia*. One novel index monitors haemocyte "health" by the relatively simple procedure of measuring the ratio of haemolymph concentrations of potassium to sodium ions ($[K^+]/[Na^+]$, see Figure 1C). This ratio is an indicator of the haemocytes ability to accumulate potassium ions by active transport: the larger the ratio the greater the internal metabolic activity of the haemocytes. This may be related to their ability to destroy potential pathogens. The recent studies by Fisher & Chintala (1988) and Cheng (1988) have also shown stress-related effects on the functioning of oyster haemocytes and apparent immunosuppression when challenged with pathogens. It would seem that the results obtained from the $[K^+]/[Na^+]$ measurements are explicable in terms of key enzyme theory: the activities of ionophoretic enzymes in the haemocytes respond in a similar manner to those associated with the metabolic pathways mentioned above.

To conclude, the use of stress indexation methods in the study of *O. edulis* has defined and quantified the stress-inducing conditions suggested by the anecdotal evidence. From this point it is possible to make a detailed study of stress effects on the immune system of this species, to determine its disease susceptibility within a rigorously defined framework of variables. In a wider context, stress indexation methods have a number of applications to fisheries biology by providing indices of disease susceptibility that can be used to quantify racial or specific differences in immunity or growth. They can be used to quantify the effects of commercial practices such as relaying and depuration. The deployment of a range of indices can give an overall biological index of "water quality" which would be of value in determining stocking densities and the viability of new stock or species.

Acknowledgements

This work was funded by the Ministry of Agriculture, Fisheries and Food and the Southern Sea Fisheries District Committee.

References

Atkinson D.E, 1958, The energy share of the adenylate pool as a regulatory parameter, Interaction with feedback modifiers, Biochemistry, 7; 4030-4034.

Bayne B.L, 1976, Aspects of physiological condition in *Mytilus edulis* (L.) with special reference to the effects of oxygen tension and salinity, Proc, 9th Europ, mar, biol, Symp., pp 213-238.

Bayne B.L., Brown D.A., Burns K., Dixon D.R., Ivanovici A., Livingstone D.R., Lowe D.M., Moore M.N., Stebbing A.R.D, & Widdows J, 1985, The Effects of Stress and Pollution on Marine Animals, Praeger, New York; 384pp.

Brett J.R, 1958, Implications and assessments of environmental stress, *In*; The Investigation of Fish Power Problems; H.R, MacMillan Lectures in Fisheries, British Columbia Press, Vancouver; pp.69-83.

Cheng T.C, 1988, The effects of *in vivo* exposure of *Crassostrea virginica* to heavy metals on haemocyte viability and activity of lysozymal enzymes, Proc, PAMAQ III, Gloucester Point, Va., USA, 2-6 October 1988.

Fisher W.S, & Chintala M.M, 1988, Summer stress on defense-related hemocyte activities of oysters *Crassostrea virginica*, Proc, PAMAQ III, Gloucester Point, Va., USA, 2-6 October 1988.

Gabbott P.A, 1975, Storage cycles in marine bivalve molluscs; a hypothesis concerning the relationship between glycogen metabolism and gametogenesis, Proc, 9th Europ, mar, biol, Symp., pp 191-211.

Hammen C.S, 1969, Metabolism of the oyster, *Crassostrea virginica*, Am, Zool., 9; 309-318.

Ivanovici A, & Wiebe W.J, 1981, Towards a working definition of 'stress'; a review and critique, *In*; Barrett G.W, & R, Rosenberg (Ed's);Stress Effects on Natural Ecosystems; Wiley-Interscience, New York; pp 13-27.

Smyth J.D, 1976, Introduction to Animal Parasitology, 2nd Edition, Hodder and Stoughton, London; 466pp.

Warren G.E, & Davis G.E, 1967, Laboratory studies on the feeding, bioenergetics and growth of fish, *In*; Gerking S.D, (Ed.); The Biological Basis of Freshwater Fish Production, Blackwell Scientific Publications, Oxford; pp.175-214.

Winberg G.C, 1960, Rate of metabolism and food requirements of fishes, Fish, Res, Bd, Can,Transl, Ser, 194; pp 1-253.