PORCUPINE MARINE NATURAL HISTORY SOCIETY

NEWSLETTER

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25th anniversary

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Porcupine Marine Natural History Society

Newsletter

No. 10 April 2002

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Porcupine MNHS welcomes new members- scientists, students, divers, naturalists and lay people. We are an informal society interested in marine natural history and recording particularly in the North Atlantic and 'Porcupine Bight'. Members receive 3 newsletters a year which include proceedings from scientific meetings.

Individual £10 Student £5

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CONTENTS

EDITORIAL

The observant amongst you will notice that this issue of our Newsletter has a different cover to normal! This continues the celebration of Porcupine's 25th anniversary, begun at our AGM and annual meeting in Edinburgh over 14th-16th March 2002. The meeting was a great success both in social and scientific terms and our sincere thanks must go to Susan Chambers who organised the meeting and the National Museums of Scotland who hosted it. If any of you are in any doubt about just how much work is involved in organising such an event, try it yourselves! 78 names appear in the delegates list and the majority of those did actually attend. This may be a Porcupine record. Eight of the papers presented are written up in this issue either in full manuscript (6) or as abstracts (2). Further papers will follow in the November issue.

The conference dinner followed the first day's proceedings and was held at the Edinburgh zoo, courtesy of the Edinburgh Royal Zoological Society – very appropriate for Porcupines?! It was a strange experience wandering through the zoo at night with no-one except the animals and fellow Porcupines for company. The excellent meal and bar were much appreciated.

The Saturday morning saw an intrepid band meeting at 8.30 am at Dunbar to investigate the rocky shore there. The weather was kind and the tide sufficiently low to allow several hours of ferreting around and recording. A full report and lists of species recorded will hopefully be published in the next newsletter and interesting finds added to the Recording Scheme records.

Reproduced below is an address kindly sent by David Heppell, our first Honorary Treasurer, currently living in Canada.

Address to PORCUPINE on the occasion of its 25th Anniversary.

David Heppell

As one of the Founding Fathers of PORCUPINE, and its first Hon. Treasurer, I very much regret I cannot be with you all today to share in the celebration of PORCUPINE's 25th Anniversary. As many of you know I was taken seriously ill last August and for a while was not expected to live. However, I did survive and am very grateful for all the prayers and e-mails and cards expressing your good wishes for my recovery. I am writing this from my wheelchair in the hospital in Vancouver where I am learning to walk again.

This is meant to be merely a congratulatory address, and not a history of the Society, although I hope someone else will write up a summary of PORCUPINE's first 25 years before they fade from our collective memory. Back in 1977 I was involved in discussions about launching a new marine biological Society which would have its emphasis on the fauna and flora of the North Atlantic and Mediterranean (my own area of interest) and marine recording in particular (the main interest of our Founding Mother, Shelagh Smith). I was keen to honour the memory of John Gwyn Jeffreys, author of "British Conchology" and participant in the exploratory dredging cruises of *HMS "Lightning"* and *HMS "Porcupine*" in 1868-1870. The success of these cruises led to the subsequent circumglobal expedition of *HMS "Challenger"*. Rather than call the Society the Jeffreys Society, which would have placed too much emphasis on malacology (as Jeffreys was one of the great British conchologists), we decided on PORCUPINE, after the ship and, in the early years, always spelled all in capitals to distinguish it from the lower case mammal. For the same reason it was not called

"The Porcupine Society" as we wanted to encourage the inevitable question "What is PORCUPINE?" and thereby possibly gain a new recruit.

From the beginning the Society held both field meetings and indoor meetings, combined wherever possible. As so many meetings of interest to marine biologists were always held in London, we wanted to meet on the fringes. Early meetings were held in Orkney, South Shields, Guernsey, Portaferry, Cardiff, Menai, Plymouth, Millport and the Isle of Man, with themes ranging from marine parasites to meiofauna. Although many members were malacologists we soon had members interested in algae, sponges, polychaetes, crustaceans, pycnogonids and fish. The benefit of the field meetings was that we all learned from each other, sharing our knowledge and experience of collecting techniques and methods of identification. No longer need one write "*Lithothamnion* sp.' or "Chiton sp." into the records!

The Newsletter was a great success from the beginning, produced then from Gestaetner wax stencils, under the editorship of Fred Woodward. Later Frank Evans introduced the delightful little cartoons of marine Porcupines. We even had a Porcupine mascot at one time - where is it now? We decided our Society did not need a President - no figurehead, only working Officers. Shelagh Smith was our first Hon. Secretary and Dave McKay the Records Convener - the idea being to provide a vehicle for recording those groups for which there was no other Recording Scheme in operation. This was one of the early ideas that did not take off, but I think in all other ways the Society has held true to its original aims and ambitions.

I wish the Society continuing good fortune, and trust that the present day Porcupines will carry on the social as well as the academic traditions of PORCUPINE for the next 25 years and beyond.

IMPORTANT NOTICE!
Our Honorary Treasurer, Jon Moore and his wife Ginny have produced a potential new Porcupine member – a little girl called Kate. Congratulations to them both!

SUBSCRIPTION REMINDER

Could all members please note that annual subscritions are now (over)due for 2002 - £10 for full members, £5 for students. If you are unsure if you have paid (many of you pay by bankers order) please e-mail Jon Moore on jon@ticara.co.uk

COPY DEADLINES
Extended to **July 1st** for the next issue and **October 1st** for the November issue

www.pmnhs.org.uk

Summary of Minutes of the Council Meeting held on March 14th 2002 at the National Museums of Scotland, Edinburgh.

Present: Julia Nunn, Frank Evans, Ivor Rees, Shelagh Smith, Roger Bamber, Susan Chambers, Annette Little, Frances Dipper, Judy Foster-Smith, Jon Moore, Anne Bunker.
Appologies: Bridget Betts

1. The Edinburgh Conference was reported to be running smoothly. Council members were pleased with the turnout, the venue and the organisation of the Conference. Council expressed its thanks to Susan Chambers. A problem had occurred with some speakers expressing surprise at being asked to pay the conference registration fee. It was decided that in future, invited speakers should not be asked to pay a registration fee, but would be asked if the organisation they work for (in the case of speakers who are not self employed) would like to contribute to PORCUPINE by donating the fee.
Action: Susan Chambers to write to speakers and refund registration fees for this conference.

It was suggested that PORCUPINE could seek sponsorship in future if it looked as if the conference budget would not stretch to this.
Action: To be discussed at the autumn council meeting.

2. Council members.
Nigel Grist – dropped from Council.
Peter Tinsley – to continue as a Council member.
Bridget Betts – resigned.
Ivor Rees – would like to resign when a suitable replacement has been found.
There are currently 2 vacancies. Council decided to ask Peter Barfield and Paul Brazier if they would like to become Council members.

3. All Council members need to read the constitution.
Action: FD to e-mail constitution to all Council members and publish it in the next newsletter.

4. The accounts for the year ended 31st December 2001 were presented by the Hon Treasurer, Jon Moore.

5. A report on membership was given by Jon Moore. He reported that membership was stable, with 17 new members this year.
Action: Membership drive to be discussed at the autumn Council meeting.

6. A report on the PORCUPINE Newsletter was given by the Hon editor, Frances Dipper. She requested copy for the next issue and ideas for topics. She also suggested a special cover for the 25th anniversary edition. It was decided to try the idea of a different habitat theme for each edition (related to the Habitat Action Plans?) and to have a silver cover for the anniversary edition (No. 10 April 2002). All Council members agreed that the book reviews were a good idea and should be continued, with the addition of a list of newly published books.
Action: FD to approach publisher concerning silver cover.

7. Jon Moore reported that some records had been received for the Recording Scheme.
Action: JM to compile list of members e-mail addresses.

8. Anne Bunker reported on the web site and asked for a policy on use by non-members. It was decided that non-members wanting to put information requests on the web site should be encouraged to join but that one request was acceptable for non members.
Action: AB to encourage non-members making requests to join PORCUPINE.

9. Frank Evans reported that progress on the poster was ongoing.

10. It was decided that the 2002 field meeting would be in N. Wales with the details to be confirmed.

11. The venue and organiser(s) for the 2003 conference.
Action: Jon Moore to approach Andy Mackie at the National Museum of Wales.

12. The History of PORCUPINE is ongoing. All information should be passed to Shelagh Smith.

MINUTES OF THE 25TH ANNUAL GENERAL MEETING OF PORCUPINE MARINE NATURAL HISTORY SOCIETY

Held at the National Museums of Scotland, Edinburgh on Thursday 14th March 2002 (in the same room as the inaugural meeting of 1977).

Chairman: Julia Nunn

1. Apologies for absence

There were no apologies for absence.

2. Minutes of last AGM

These had been published in the March 2001 issue of Porcupine Newsletter and were accepted.

3. Matters arising from the minutes of the last AGM

There were no matters arising from the minutes.

4. Officers' reports.

Hon. Treasurer, Jon Moore

The unaudited Treasurer's report was presented to the meeting (*Editor's note: the audited accounts are included in this issue of Porcupine Newsletter*). The Society's funds were in a satisfactory condition. The Treasurer would like to find a repository giving a better return for the Society's deposit but this would inevitably make difficulties for those members paying their subscriptions by standing order. Over the year the cost of the production of the newsletter has benefited from the use of a cheaper but equally good printer. The meeting at Brampton, Huntingdon showed a welcome profit. Society membership stood at 194 of whom 164 were ordinary members. This year we have enrolled 17 new members, a welcome increase.

The report was accepted following proposal by Roger Bamber, seconded by Ralph Robson.

Hon. Editor, Frances Dipper

There have been three issues of Porcupine Newsletter this year. However, only about half of those who gave papers at the Huntingdon meeting have submitted reports for publication. Within the newsletter the sections headed Porcupine Pieces and Porcupine Problems have become well established. Porcupine Pieces carries articles and reports submitted by members while Porcupine Problems deals with information requests and replies. The latter ran to between two and four items per issue this year. The success of this section was illustrated by the topic of mantis shrimps, which contributors kept going for three issues of the newsletter. Reports from Plymouth and the Isle of Purbeck field meetings are still pending.

The report was accepted following proposal by Annette Little, seconded by Anne Bunker.

Chairman, Julia Nunn.

There have been two Council meetings, at Carlisle in November and in Edinburgh during the current annual meeting. Grateful thanks were offered to Mike Bailey and Frances Dipper for their work in organising the annual meeting in March 2001 at the Environment Agency in Huntingdon, and Annette Little and Anne Bunker were thanked for their labours with registration. The Chairman further thanked Susan Chambers and her team for their very successful organisation of the current meeting.

The report was accepted following proposal by Frank Evans, seconded by Judy Foster-Smith.

5. Website (www.pmnhs.org.uk).
Anne Bunker reported that the website now lists details of the meetings of the Society. A table of contents of the current Porcupine Newsletter appears, together with a print-out of "Porcupine Pieces" from its pages. Our standard recording form is reproduced, details of how to become a Society member are shown and there is a "Features" item, changed from time to time. Input from Porcupine members to this last was requested by the webmaster.

6. Poster.
Frank Evans reported that the delays in producing an advertising poster have now been overcome and the work, newly undertaken by Joshua Arnott of Whitley Bay, is advancing well.

7. Field meetings.
The Chairman expressed the thanks of the Society to the organisers of the Dorset field meeting. It is proposed that the next field meeting will be at a location in Anglesey in September 2002.

8. Election of Officers and Council members.
No proposal was made to elect a secretary. The Chairman stated that if desired all the other Officers were willing to continue in post, while Bridget Betts and Nigel Grist did not wish to stand for re-election to Council. Peter Barfield was proposed for Council membership by Susan Chambers, seconded by Annette Little and Paul Brazier was proposed for Council membership by Ivor Rees, seconded by Christine Howson. There being no other nominations the chairman proposed that Officers and Council members be elected en bloc and this was agreed with no objections.

<u>Officers for the next year:</u>
Hon. Chairman, **Julia Nunn**
Hon. Treasurer, and Hon. Records Convenor **Jon Moore**
Hon. Editor, **Frances Dipper**

<u>Council members for the next year:</u>
Mike Bailey, Roger Bamber, Anne Bunker, Peter Barfield, Paul Brazier, Susan Chambers, Frank Evans, Judy Foster-Smith, Annette Little, Ian Killeen, Ivor Rees, Shelagh Smith, Peter Tinsley

9. Other business
There being no other business the Chairman declared the meeting closed.

PORCUPINE

RECEIPTS AND PAYMENTS ACCOUNT

for the year ended 31 December 2001 (unaudited)

Year to 31.12.00 £	Year to 31.12.00 £			Year to 31.12.01 £	Year to 31.12.01 £
		RECEIPTS			
223		Subscriptions-	1997 - 1999	10	
1572			2000	15	
40			2001	1376	
20			2002	5	
	1855				1406
	76	Bank Interest (net of tax)			69
	10	Sale of PN Back Number			14
	1941	Total Receipts			1489
		PAYMENTS			
1965		Newsletter-	Printing	476	
438			Postage	321	
2403		Total Newsletter Costs		797	
5		Bank charges		0	
357		Membership leaflets - printing		0	
94		Recording Scheme cards - printing		0	
183		Council meeting expenses (travel/catering)		163	
0		Repayment of overpaid subscriptions		24	
	3042				984
	(1101)	**SURPLUS (DEFICIT) BEFORE MEETINGS**			505
	361	**MEETINGS –** Plymouth (2000)			
	(99)	**MEETINGS –** Huntingdon (2001)			278
	(839)	**SURPLUS (DEFICIT) FOR THE YEAR**			783
	4208	**BALANCE BROUGHT FORWARD**			3369
		BALANCE CARRIED FORWARD			
1503			Current Account	747	
1866			Deposit Account	3404	
	3369				**4151**

Jon Moore, Hon Treasurer
10th March 2002

MEETINGS, MEETINGS, MEETINGS, MEETINGS, MEETINGS

PORCUPINE MEETINGS

PORCUPINE FIELD MEETING 2002

September 2002 in Anglesey. Details will be e-mailed/sent to all Porcupine members when available.

THOUGHTS

If anyone would like to volunteer to organise either the annual scientific meeting or a field meeting for future years, please contact Julia Nunn.

Similarly if you have ideas about where you would like such meetings held and their content, again please contact Julia or any council member.

OTHER MEETINGS

22nd May 2002. Making Waves: Tackling Litter in the Aquatic Environment - National Aquatic Litter Group NALG London, Keynote speaker Michael Meacher For programme go to www.coastms.co.uk

13-15th June 2002. Info'Coast 2. 2nd European Symposium on Knowledge and Information for the Coastal Zone. Noordwijkerhout, The Netherlands. (postponed from October 2001). linda@iprolink.ch +44 223 667050.

19-20th June 2002. Coastal Futures Scotland 2002 Edinburgh. Coastal Management for Sustainability. Full programme details on www.coastms.co.uk

25th June 2002. Adapting to Climate Change: Overcoming the barriers to change. CoastNET, London : Progamme details on www.coastms.co.uk

8-12th July 2002. Estuarine and Lagoon Fish and Fisheries. Fisheries Society of British Isles Annual International Symposium. University of Hull. www.hull.ac.uk/iecs

ECSA Seaweed Workshop. Either March/April or late summer 2002. Contact Martin Wilkinson: 0131 451 3468, m.wilkinson@hw.ac.uk

REVIEWS

Extraordinary Fish
By Frances Dipper
(BBC Worldwide Ltd. 2001)

Review by Judy Foster-Smith

This glossy little paperback is part of a series produced as a follow up to ‘The Blue Planet’ programmes which, I’m sure, need no introduction for ‘Porcupines’. The book is a credit to the BBC. It is a delightful synthesis of the lives of some of the weirdest animals in our waters, aimed at the informed public.

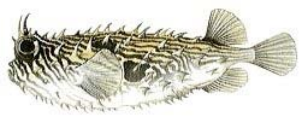
From the bioluminescent powers of the deep-sea angler fish to the wildly abstract markings of the Picasso triggerfish, and from the ugly, warty frogfish, which doesn’t swim at all, to the graceful Sargassum flying fish which not only swims, but also takes to the sky when pursued by predators, the book is full of fascinating facts.

I felt it a treat to read, like a day out, being taken on a whistle-stop tour of the amazing array of loony-looking fish and the bizarre ways in which they are adapted to survive and feed in extreme conditions. Then on to a show of sounds and light and body language – the art of fish communication, and, finally, to a display of the most elaborate means of underwater procreation. It makes you realise how vital diversity is and just how much we should value it.

The author (our editor, no less!) should be congratulated on the way she has skilfully presented such a huge amount of information in such a small book. She has brought together anecdotal observations and sound scientific insight and distilled them in a clear and yet tantalising way, carefully explaining the more complex issues. She has chosen excellent examples to illustrate her points and, as a true conservationist, has taken the opportunity to touch on the continuing need for the stewardship of our marine and freshwater systems.

My only real (but very minor) criticism is the unfortunate over-use of different font types and sizes. I have yet to work out why some bits of the text have been singled out for special font treatment when their relevance appears much the same as the rest. All they do is interrupt the reader’s flow.

However, the book is colourfully illustrated with lots of exotic photographs and will certainly appeal to anyone interested in wildlife, the sea, and …. extreme survival. At £7.99 it’s a gem. Order one now at www.amazon.com!



PORCUPINE PIECES

First British Record of a European barracuda *Sphyraena sphyraena*

Douglas Herdson
National Marine Aquarium, Plymouth

On the 25th November 2001 the crew of *F.V. Regina Maris*, skipper David Kessel, was fishing for hake with a monofilament set net when they netted a barracuda. They were fishing 8.5 miles south east of the Lizard, Cornwall. The fish was sent to Newlyn Fish Market where it was bought for £16 by John Strike of the Quayside Fish Centre in Porthleven, Cornwall.

The fish is 106 cm (total length) and 4.2 kg (gutted, so probably an ungutted weight of over 4.5 kg), and is the first record of a barracuda in British waters.

The fish was examined by Dr Paul Gainey and photos were sent to me and Alwynne Wheeler (formerly of the Natural History Museum) and we have all agreed on the identity of the fish.

Of the three species found in the North East Atlantic and Mediterranean only *Sphyraena sphyraena* extends north to the Atlantic coast of the Iberian Peninsula and southern Bay of Biscay, also neither of the other species exceeds 65 cm TL. The western Atlantic *Sphyraena barracuda* would be an outside possibility, but this fish lacks the pale tips to the lobes of the tail and the black blotches on the belly and lower flanks which are diagnostic of *S. barracuda*.

This specimen appears to be a European Barracuda *Sphyraena sphyraena* on the basis of the size, elongated body shape, fully-scaled pre-operculum, dark elongated head (like a rocket's nose cone with the upper jaw fitting neatly into a protruding lower one) and approximately twenty dark vertical half bars along its body.

The European Barracuda *Sphyraena sphyraena*, is called a Great Barracuda in a number of books, but this name should kept for the Caribbean/West Atlantic *Sphyraena barracuda.* The European Barracuda can grow to 160 cm and 38 kg. (The record for *Sphyraena barracuda* is 200cm and 50 kg.)

The fish was on display in ice at the Quayside Fish Centre in Porthleven, and is now frozen until Mr Strike decides whether to have it stuffed or sent up to the Natural History Museum in London.

A single unusual fish like this is not a sign of global warming, but it may fit into a pattern when correlated with numbers of fish records as we are starting to do at the National Marine Aquarium.

Photo by Phil Monckton

A D'Arsy Thompson transformation of crotchets to uncini and its implications for the phylogeny of polychaetes

Peter Gibson

ICAPB, University of Edinburgh, West Mains Road, Edinburgh, UK

D'Arsy Thompson in his classic book *On growth and form** showed how to transform the fish *Diadon* to the sunfish *Orthagoriscus*. The method points to, amongst other things, the importance of allometric growth (relative changes in proportions of structures) in evolution. In biological terms, transformations become irrelevant once a group of organisms or structures are known to be related to one another - this is the essence of evolutionary homology. For example, it is easy to see how four classes of echinoderms evolved from a crinoid ancestor without knowing what the selection pressures were. The systematics of the polychaetes is a far greater problem; there are large number of families and no easy way of connecting their phylogenies as has been achieved with vertebrates. Dales in his book *Annelids* (Hutchinson University Library, 1962) used the feeding structures to help show relationships between polychaete groups (Fig. 9, p. 75). Fauchald and Jumars looked at feeding guilds in detail but did not discuss phylogeny (*Oceanography and Marine Biology Annual Review*, 1978).

When considering methods for characterising chaetae (Gibson, Robson & Armitage, *Newsletter of the Porcupine Marine Natural History Society* No. 2, 1999) I felt there might be some relatively simple mathematical definition for some chaetae and that transformations could also be used to convert complex images to simpler ones as well as saying something about phylogeny. For example, an ellipse may be described by πr^2 if one knows what transformation (mapping function) is needed. In the present study a diagram of a crotchet from the spionid, *Aonides paucibranchiata*, (used in the previous study) was drawn freehand on a grid of squares. It was then replotted on a grid of straight lines which were cut by curves - the distances between these were progressively doubled (see figure). The crotchet was, as a result, transformed into an uncinus. More convincing transformations might be achieved using other dimensions for the second grid. Here, I am simply attempting to illustrate the principle. Allometric growth would achieve the same result. Indeed, the shape of chaetae probably depends upon varying growth rates for linked macromolecules within the structures.

Families with crotchets or uncini live in, or on, a variety of substrata (see table) and their chaetae appear to show appropriate structural adaptations. Crotchets are probably adapted for digging burrows: they have a long shaft for leverage, a subterminal projection which may act as a pick and frequently a crest of teeth probably for gripping the sides of the tube. The crotchets of species living in soft substrata are frequently hooded and these hoods probably act as scoops. The uncini, in contrast, are short and always bear numerous teeth; each has an asymmetrically placed basal ligament and muscle to pull the chaeta into the body to release it from gripping the sides of the tube; they act as ratchets.

The transformations described suggest that species with crotchets gave rise to species with uncini. The crotchets are likely to have been derived from simple spines (acicular chaetae) which are frequently seen within crotchet bearing species. An argument for the reverse direction is difficult to make when one considers other structures and in particular those used in feeding (see Dales). The transformation may have a similar application to other types of chaetae.

I wish to thank Dr. Cosens for checking the manuscript for shaky English and silly mistakes.

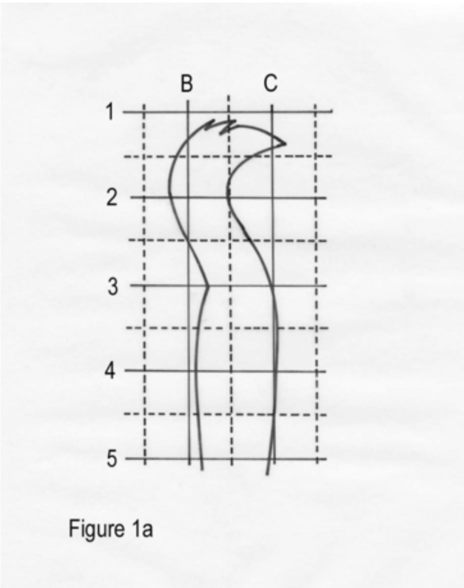
*A simple account is given by Peter and Jean Medawar in *Aristotle to Zoos* (Oxford University Press, 1985) under *Form and mathematics* (p. 102) and *Transformations* (p. 264).

Table. A selection of sedentary polychaete families bearing crotchets or uncini and the relationship between chaetae to the habitat (Fauvel's polychaete keys and Fauchald & Jumars).

Crotchets	
Family	Substratum/tube
Cirratulids*	Soft, hard/variable
Spionids	Soft, hard/variable
Capitellids	Soft/variable
Arenicolids	Soft/temporary
Maldanids	Soft/mucus

Uncini	
Family	Substratum/tube
Ampharetids	Soft/mucus
Terebellids	Soft/mucus
Pectinarids	Soft/sand
Sabellids**	Soft/sand
Serpulids	Surface of/limy
Chaetopterids	Soft/horny
Sabellariids	Surface/sand

Plus spines * & crotchets**



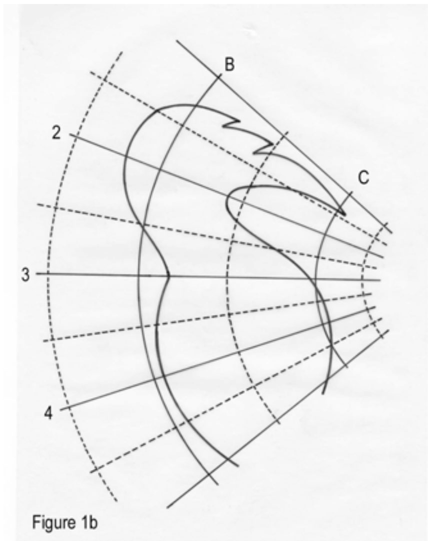


Figure 1. D'Arsy Thompson transformation of a crotchet to an uncinus, a) freehand drawing of the crotchet of *Aonides paucibranchiata* plotted on a grid of squares and b) the result of replotting the crotchet on a grid with equally spaced radiating straight lines, and curved lines where the distance between them is progressively doubled.

PORCUPINE 2002. CHANGES IN MARINE BIOLOGY OVER THE LAST 25 YEARS

Papers from the PMNHS meeting held at the National Museums of Scotland, Edinburgh from 14th-16th March 2001

The Chinese mitten crab, *Eriocheir sinensis*: the introduction of an alien species

Roni S. Robbins and Paul F. Clark

The Natural History Museum, Cromwell Road, London SW7 5BD, England

Synopsis

Eriocheir sinensis, the Chinese mitten crab, is a native of China and the western coastal regions of Korea. It predominantly lives in freshwater but migrates seawards in order to reproduce. In 1912 this alien crab was first recorded from Europe. A specimen was captured from the River Aller, a tributary of the Weser, Germany and the species was probably introduced into this river via the discharge of ballast water from a commercial vessel. This invasive crab has now spread throughout north-east Europe with a reported distribution from Finland to Portugal including England. Its recent appearance and subsequent establishment in San Francisco Bay, USA, is also thought to be from the discharge of ballast water.

In the UK, the mitten crab has been reported from the Humber, Medway, Tyne and Thames catchments. The establishment of this species within these river systems has potential environmental implications nationally. The risk of further invasions along the eastern counties may be considered low but is probably dependent on the level of shipping traffic and coastal dispersal of larvae from estuaries where the mitten crab is abundant.

Introduction

The Chinese mitten crab, *Eriocheir sinensis* H. Milne Edwards, 1854, is a native of east Asia, with a distribution from Fukien Province, China, *ca*. 26ºN, to the western areas of the Korean Peninsula *ca*. 40ºN. The life history of the Chinese mitten crab is atypical for crabs, spending most of its life in fresh water, but returning to the sea to reproduce. Males and females migrate downstream during late summer and attain sexual maturity in estuaries. It is during these mass migrations that the crabs are most visible. After mating the females are thought to continue seaward into deeper water to overwinter before returning to brackish water in the spring to hatch their eggs (Panning, 1939). Larval development probably occurs in the lower estuary, with juvenile crabs gradually migrating upstream into fresh water to complete the life cycle. These upstream migratory movements can be substantial with juvenile mitten crabs migrating up to ~ 1500 km in their native habitat whilst growing to adult size.

Additional aspects of the mitten crab life history of interest include its burrowing behaviour, which has the potential to accelerate riverbank erosion. Furthermore the Chinese mitten crab is regarded as a delicacy in the Far East especially while sexually mature. However, *E. sinensis* is the second intermediate host of the oriental lung fluke, *Paragonimus westermanii* (Kerbert, 1878): if the crab is eaten raw or is poorly cooked, the parasite can infect humans, causing the disease paragonimiasis.

Since 1912, mitten crabs have become widely dispersed from their native Asian habitat by being inadvertently transported to Europe and recently into North America, via the ballast water of ships. These invasions of *E. sinensis* have the potential to cause a number of environmental problems.

European distribution

The first record of *Eriocheir sinensis* in Europe was in 1912 when a single male was captured from the River Aller, a tributary of the Weser, Germany (Panning, 1939). Its present estimated distribution ranges from Finland (Haahtela, 1963) in the north, through Sweden, Russia, Poland, Denmark, Germany, the Czech Republic, the Netherlands, Belgium and England to France. The southernmost Atlantic coast record is in the Golfe de Gascogne, France (Vigneux *et al*., 1993), but the crab has extended its range via the Garonne canal system to Sigean, Languedoc-Roussillon, a Mediterranean district of southern France (Petit, 1960). Recently this crab was reported from the Tagus Estuary, Portugal (Cabral & Costa, 1999), but the extent of this invasion is to date unknown. Populations in the northern part of the Baltic and the Sigean lagoon system have not become established, whereas in Germany, the Netherlands and Belgium this non-native crab has been reported in pest proportions.

North America

The mitten crab has also been reported from North America with records from the Detroit River at Windsor Ontario and Lake Erie, Canada (Nepszy & Leach, 1973), the Mississippi Delta (Horwath, 1989) and San Francisco Bay (Cohen & Carlton, 1997), United States. However the only region where the crab appears to have established a reproducing population is San Francisco Bay. The American wildlife authorities are so concerned about the spread of this alien species and its burrowing behaviour that live mitten crab imports into California in 1987, and subsequently the whole of the United States in 1989, have been banned by legislation (see Horwath, 1989).

Distribution in England

The Chinese mitten crab was first recorded from the British Isles when a specimen was captured on the intake screens of the Lots Road Power Station, Chelsea in 1935 (Anon, 1935a,b; Harold, 1936). There were no further reports until 1949 when a second specimen was reported from Southfields Reservoir, near Castleford in Yorkshire (Cockerham, 1949) and the Humber (Clark, 1984).

There was a lack of mitten crab records from the Thames until the mid-1970s when Ingle & Andrews (1976) reported capturing this species at West Thurrock Power Station. After its establishment, the Thames mitten crab population remained at relatively low and constant numbers through the late 1970s and 1980s.

Thames update

To update distribution data in the Thames catchment, The Natural History Museum, supported by an Environment Agency grant, made an appeal to the general public for mitten crab sightings. This information was plotted onto a map of the Thames catchment area by Clark *et al.* (1998 figure 2). The Chinese mitten crab is now known from the west as far as the River Colne at Staines and is present in most of the Thames tributaries downstream of this point. In the east, the crab has been found in the rivers Cray, Darent, Quaggy, Pool and Ravensbourne. In the north-east, sightings are common in the rivers Roding and Lee. The most northerly report of *E. sinensis* is from the River Lee tributary at Enfield, some 15km upstream off the River Thames. The survey also recorded *E. sinensis* in every tributary from Chelsea upstream to Chertsey. These include the Beverley Brook and the Rivers Wandle, Brent, Duke of Northumberland, Crane, Hogsmill, Longford, Ember, Mole and Ash. The furthest upstream record at was Staines, *ca*. 65 km from Tilbury.

Environment Agency data analysed from power station collections at West Thurrock (1976–1993) and Tilbury (1993–1996) also indicated that the Thames mitten crab population is now firmly established and, since 1992, has been increasing in numbers as well as geographical range. These records show that small annual numbers of mitten crabs were collected at West Thurrock Power Station in the late 1970s and 1980s. However the mitten crab population increased in 1992 and that trend continued in 1993 until the power station closed in March. That this increase has persisted, is indicated from numbers at Tilbury, from 1993 to 1996.

Thames fallout

The reported distances that mitten crabs can migrate in China and Europe suggest that the whole of the Thames river system is accessible to invasion and dispersal via canal systems (Petit, 1960) linking catchments, is a reality. Further population expansion could eventually threaten freshwater habitats and communities including those currently occupied by the native crayfish *Austropotamobius pallipes* (Lereboullet, 1858), which is already under considerable threat from foreign crayfish introduced into British rivers.

A further concern is that *E. sinensis* is a burrower (Panning, 1939), and a mass invasion of all tributaries east of Staines could result in significant riverbank erosion. Burrowing could threaten unprotected engineering earthworks. This concern was one of the contributing factors that resulted in the banning of live mitten crab imports into the United States. Burrowing behaviour has been confirmed in the grounds of Syon Park, Middlesex.

Coarse fishing has also reportedly been affected in the Thames catchment. Anglers along the River Lee and at a private club near the River Cray record that during the migration period during late summer, crab strikes on bait virtually prevent sport fishing.

Recent UK records

Recent UK records include Kingsnorth Power Station, the Medway, 1990 (NHM reference collection); small numbers from the River Tyne, 1998 (Ken Watson, pers. comm.); a female crab from the mouth of the Teign Devon, 1999 (Martin Attrill, pers. comm.) and Dungeness, Kent, 2001(NHM reference collection).

Control of alien mitten crabs

Prevention is the best method of controlling the invasion of exotic species into new regions and this requires international co-operation. One of the main methods of transportation of species around the world is in ballast water of shipping (Carlton, 1985). Recent attempts to use Open Ocean Exchange or freshwater flushing of ship's ballast may not be appropriate methods to control bio-invasions (see Hülsmann & Galil, 2001 for discussion).

In the specific case of mitten crabs, extensive trapping at a particular point is an option. Not only is this method labour intensive, but Peters & Hoppe (1938) attempted to control mitten crab populations in Germany by a similar method during the migration season without success. There is, however, a potential for commercial exploitation because the mitten crabs are regarded as a gastronomic delicacy. Restaurants in Hong Kong and Japan charge a high price for such a meal. Mitten crabs may fetch up to £5.55 per pound in London when in season. An added attraction of exploiting the European mitten crabs population for food is that the establishment of parasitic lung disease is thought unlikely. Firstly, the populations in Europe were probably established by plankton i.e. larvae and juvenile specimens transported in ballast water. Consequently the adult population would probably be parasite free. Secondly, *Paragonimus westermanii* is specific to a primary intermediate host of aquatic snails assigned to the Thiaridae, and the climate in Northern Europe may be too cold for members of this gastropod family. However before the commercial export of mitten crab can be sanctioned, tests for parasites should be undertaken.

www.nhm.ac.uk/zoology/crab

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The Firth of Forth Spatial Study – Taxonomic problems associated with long-term monitoring

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Introduction

The Firth of Forth is a drowned river valley forming an embayment of the North Sea. Along its shores lie many industrial developments and residential areas, including Edinburgh, Scotland's capital city. Historically, its waters have received a mix of agricultural and urban run-off, treated and untreated sewage effluent, discharges from shipping and many other man-made pollutants, and, by the 1970s, had become one of the most intensively used sea-areas around Scotland.

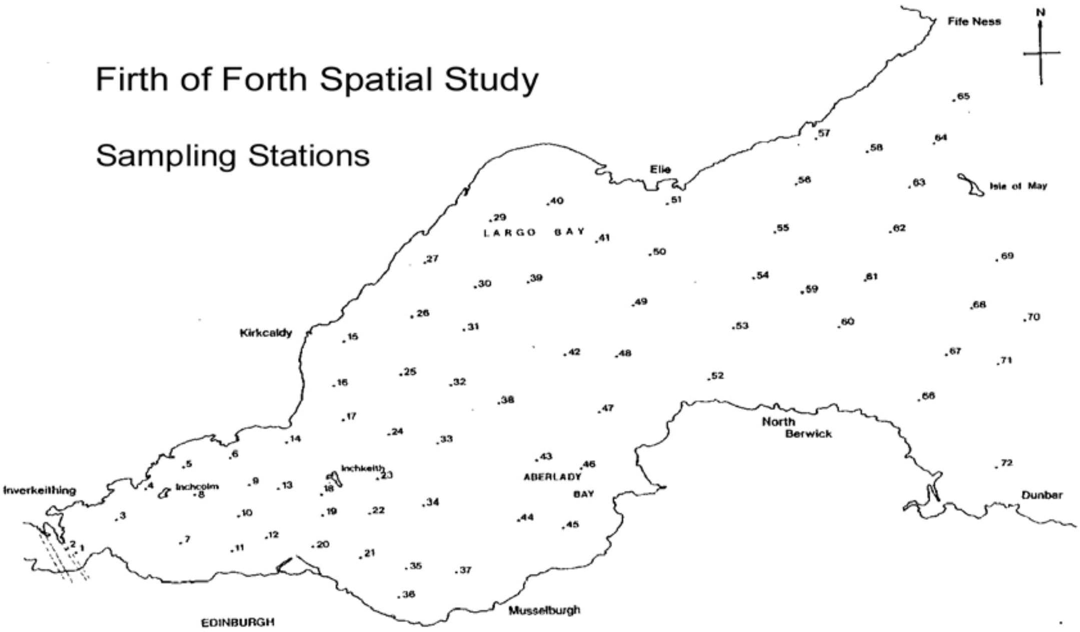
Despite much of the coastline and inter-tidal area being designated as a protected area in one way or another in order to conserve wetland habitats and the internationally significant numbers of bird life that they support, the sub tidal benthos and sediments of the estuary had not been systematically studied until then.

The Firth of Forth Benthic Faunal Survey

The first Firth of Forth Benthic Faunal Survey was carried out in 1976 - 1977 by Heriot-Watt University, in collaboration with the then Forth River Purification Board, and funded by the Manpower Services Commission. 73 sample stations were chosen, covering the Firth from the Forth Bridges to the Isle of May, two van Veen Grab samples were taken at each station and the benthic infauna identified and enumerated. The findings, together with results of a similar survey of the upper Forth Estuary, were published by Elliot and Kingston (1987).

The Forth Spatial Study

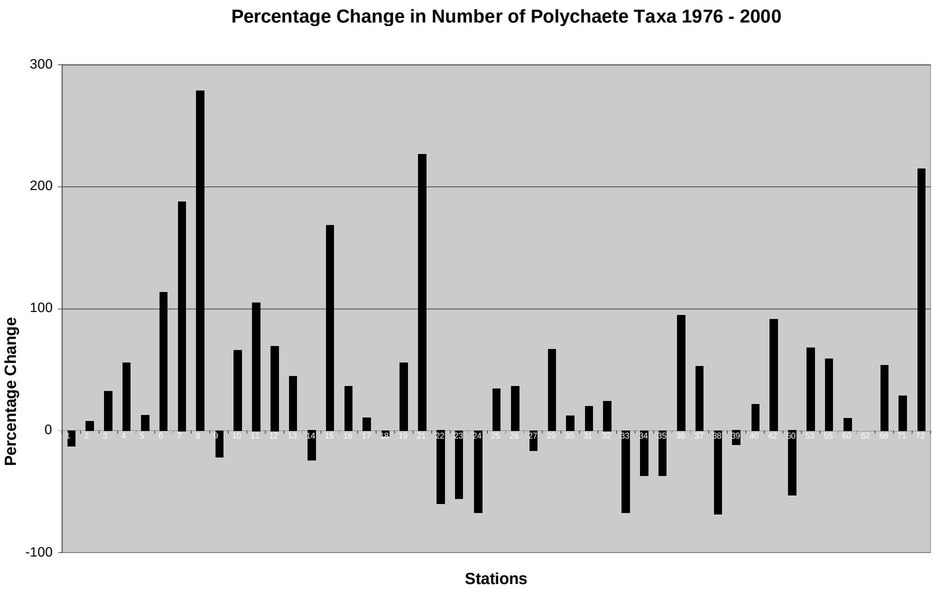
Much has changed since that first survey was carried out in 1976. A suite of legislation has been introduced to improve and protect the marine environment preceding the recent implementation of the Urban Wastewater Treatment Directive and driving investment in increased sewage treatment. The result is a significant improvement in water quality. It was decided to investigate the effects of these improvements on



the benthic environment and their animal communities by conducting a repeat survey, the Forth Spatial Study, in 2000, almost 25 years after the original, using the same sampling stations and strategy as before to allow direct comparisons to be made. The present study is a collaborative venture between SEPA, Scottish Natural Heritage, Heriot-Watt University and the National Museums of Scotland, being funded by them as well as by East of Scotland Water and Shell U.K.

Polychaete faunal trends 1976-2000

So what changes have occurred in the polychaete fauna of the Firth of Forth over these 25 years? The workup of the samples is still ongoing, we only have polychaete data from 48 of the 71 stations sampled so far, but when this was tabulated alongside the full 1976 dataset, difficulties were encountered arising from considerable differences in nomenclature and taxonomic resolution Firstly, 30 species have simply had their name changed since 1976. Now, for the sake of consistency, we can use the Species Directory, (Howson & Picton 1997), to standardise nomenclature, but then there was no recognised standard and the key texts, Fauvel's *Faune de France* 1923 and 1927, Hartmann – Schröder's *Borstenwurmer*, 1971 and Day's *Polychaeta of Southern Africa*, didn't always agree. However, assuming these species were correctly identified in both surveys this was not a problem – new names could simply be substituted for old.



However, there was also a considerable change in the number of taxa recorded overall, in the numbers of taxa found at many stations, and of their identities. Ignoring indeterminate and juvenile categories, there seemed to be an increase in the total number of taxa found from 135 to 161, (~20%), however only half of those found in 2000 were also recorded in 1976. The number of taxa found at the majority of stations had also risen.

The greatest increases were seen in the inner Firth, while the decreases seem to be mainly located in an area to the east of the island of Inchkeith. As yet we have not found any obvious explanation for this, but these results have yet to be correlated with those from the other component parts of the study. As for the stations showing substantial increases in numbers of taxa, where have all these extra species come from? Has there been a dramatic improvement in the diversity of the fauna or have some or even all of these perceived changes arisen from advances in our taxonomic knowledge and in the literature now available, enabling us to distinguish between more species? A few groups of

Polychaeta are selected as examples to illustrate this effect.

Aphroditoidea

The only taxa recorded in both years were relatively large, robust and distinctive - *Aphrodita aculeata*, *Gattyana cirrosa* and *Lepidonotus squamatus*. *Gattyana amondseni* was recorded in 1976, since cited in the literature, however in retrospect this may well have been either G. *cirrosa* as variation in this species has been noted (Tebble & Chambers 1982), or perhaps *Harmothoe antilopes* – these species are similar to the untrained eye. Two specimens of H. *antilopes* were recorded in 2000, although not at same station as G. *amondseni* in 1976. Unfortunately, the faunal material from 1976 was burned in ash-free dry weigh biomass determinations, only a few specimens remaining from outlying reference stations. One important lesson learned from that survey therefore, was the importance of keeping properly collated reference collections! In 1976, species of *Harmothoe* recorded were *extenuata, imbricata* and *lunulata*, while species recorded in 2000 were *impar, pagenstecheri, andreapolis, marphysae, arenicolae* (also including *lunulata*?) and *antilopes.* This observed change is probably due to much improved descriptions, keys, including Tebble and Chambers (1982) and Chambers and Muir (1997), in the Linnean Society Synopsis series, and their illustrations - some of Fauvel's were quite fanciful. The perception of what constituted key anatomical features differed between Fauvel and Hartmann-Schröder, as did their synonymies. There is still much work to be done on this group, especially in re-evaluating older collections. Also, there is the question of observer experience, as, when one first starts out looking at these animals they can all look remarkably similar, only years spent looking at thousands of specimens and keeping reference material guaranteeing a degree of consistency in their identification.

Pholoidae

Everything was identified as *Pholoe minuta* in 1976 – at least the '*minuta*' in Fauvel and Hartman-Schröder were both the same, however neither are the true '*minuta*' as described by Fabricius in 1780. Now we have a lot more species in the literature to chose from, with even more confusion between the different texts.

Pholoe **'*inornata*'** - as '*minuta*' (Howson & Picton, 1997), in Chambers 1985, and Chambers & Muir 1997, but as '*baltica*' in Petersen 1998
Pholoe ***'inornata'*** - Petersen 1998, similar to but distinct from '*synopthalmica*'
Pholoe ***'baltica'*** -
Pholoe ***'tuberculata'*** - Southern 1914, may be valid species (A.S.Y.Mackie), similar to '*baltica*'
Pholoe' ***synophthalmica'*** - similar to but distinct from '*inornata'* (Petersen, 1998), valid species (Howson & Picton, 1997), Chambers 1985, and Chambers & Muir 1997
Pholoe ***'assimilis'*** - Petersen 1998
Pholoe ***pallida*** - The only distinctive, eyeless species, agreed on by Chambers 1985, Petersen 1998, and Chambers & Muir 1997and also Christie 1982 as cf. *Anoculata*

Three species of *Pholoe* were recorded in the Forth this time – *P. pallida*, P. *'inornata'* and P. *'synopthalmica'*, the only species included in the new Linnean Society Guide (Chambers & Muir 1997). However, as there is at least one other distinct species occurring in the central North Sea which keys out to Petersen's '*assimilis*', this group still needs some clarification. It is certain, however, that all *Pholoe* species occurring in the Forth would have been lumped together as '*minuta*' in 1976.

Nephtyidae
While *Nephtys caeca, N. hombergii, N. incisa,* and *N. longosetosa* were recorded in both years, *N. hystricis* was recorded only in 1976, and *N. kersivalensis* and *N. assimilis* only in 2000. From this it appears that 2 new species were found in 2000 and one was lost. However, from several papers published by Rainer, (1984, 1989, 1990, 1991) we know that historically the descriptions of *N. hystricis* and *N. incisa* have been confused, and that *N. kersivalensis* and *N. assimilis* have been re-described and elevated to full species status from being varieties of *N. hombergii*. Again some material from 1976 fortunately survived, was re-examined and could be reassigned. As expected, *N. hystricis* was re-identified as *N. incisa*, *N. incisa* proved to be small specimens of *N. kersivalensis* and, although no *N. hombergii* were re-examined, they probably included some *N. assimilis*. So although a change in the fauna appears to have taken place since 1976, this is in fact not the case, the taxonomy has simply moved on.

Magelonidae
Fauvel included only 2 species, *M. papillicornis* now synonymised with '*mirabilis*' and having distinctive inflated ends to some setae on the 9th segment, and *M. rosea,* described as similar to *papillicornis* but with no mention of any pigmentation. Hartman-Schröder included 3 species, *M. alleni* – a large species with a broad pigmented band, *M. papillicornis (mirabilis*) and *M. minuta* – a small slender species with 1 tooth over the main fang of its abdominal hooks. In 1976, three taxa were recorded, *Magelona alleni*, with the broad pigmented band*, Magelona rosea*, and *Magelona* sp. These last two were both common, but as they weren't recorded at the same stations they should maybe both be lumped under *Magelona* spp.

In Hayward & Ryland 1990 it states that "probably only one species (of *Magelona*) occurs in northern European waters." The new Species Directory (Howson & Picton 1987) names 5 species – M. *alleni* (*including M. rosea*), M. *filiformis, M. minuta, M. mirabilis* and M. *wilsoni*, and Fiege, Licher & Mackie (2000) later distinguished a sixth, M. *johnstoni*, previously included in M. *mirabilis*. In 2000, *Magelona alleni, filiformis, minuta, and johnstoni*, were all found, raising the number of species from 2 or 3 to 4, purely owing to increased taxonomic resolution.

Cirratulidae
While 7 taxa were recorded in 1976 - *Caulleriella caput-esocis*, *Caulleriella sp*. (assumed to be different from *C. caput-esocis*), *Chaetozone setosa*, *Cirriformia tentaculata*, *Dodecaceria concharum*, *Tharyx (now Aphelochaeta) marioni*, and *Tharyx (now Aphelochaeta) multibranchiis* there were 10 in 2000 - *Caulleriella alata, Caulleriella zetlandica, Chaetozone setosa*, *Chaetozone gibber, Cirratulus cirratus, Cirratulus caudatus, Cirriformia tentaculata, Dodecaceria sp*., *Aphelochaeta marioni*, and *Tharyx killariensis*.
Only 4 taxa were recorded in both years - *Cirriformia tentaculata*, *Aphelochaeta marioni*, (the identifications of both these species were confirmed from surviving 1976 specimens), *Chaetozone setosa*, in all it's myriad guises and *Dodecaceria sp.* and *D. concharum*, assuming they are the same animal.

Although *Caulleriella caput-esocis* was described by both Hartmann-Schröder and Fauvel, our 1976 Forth specimens were probably either *Chaetozone gibber*, which was only described in 1994 (Woodham and Chambers 1994) and/or *Caulleriella zetlandica,* another large species equally and relatively numerous and difficult to distinguish between from incomplete or damaged material. 1 specimen remaining from 1976 was re-identified as *C. ?gibber* but this was in such poor condition it was impossible to be sure. The identities of *Tharyx multibranchiis* and *Caulleriella* spp? remain uncertain.

The situation has much improved since James Blake's partial revision of *Tharyx*, *Aphelochaeta* and *Monticellina* in 1991, Unicomarine's 1996 review of the family, and Woodham and Chambers attempts to resolve some of the problems within *Chaetozone*, but much still needs to be done. This is another group where observer experience definitely contributes to the ease and certainty of correct identification. I certainly would not like to attempt to identify Cirratulidae now using the literature available in 1976.

Summary

Of course, there are many other key papers published since 1976 that contribute to the increased number of species likely to be recorded around our coasts. These include Hartmann-Schröder's revised *Annelida, Borstenwurmer* (1996), Frederik Pleijel's review of the Phyllodocidae (1989) and Torleif Holthe's *Polychaeta Terebellomorpha* (1986), as well as Brendan O'Connor's work on the Glyceriidae (1987), John Hartley's 1981 paper exploding the myth of the ubiquitous *Aricidea jeffreysii*, and others too numerous to mention here but gratefully acknowledged by anyone faced with a dish of worms to identify. And we must not forget the important part we all play ourselves by recording and sharing our observations and specimens at workshops and seminars, and in this newsletter.

So, as far as the Firth of Forth Spatial Study is concerned, until all the data is collected, species reassigned where possible, or lumped where not, it is impossible to say what proportion of the perceived change in the species composition suggested by these preliminary results might represent a real increase in the diversity of the polychaeta in the Firth of Forth, and what may be more a reflection of an increase in our knowledge and experience of these fascinating animals over the last 25 years.

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Meiofauna in marine pollution studies and environmental assessments

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Introduction

This paper is not intended as an exhaustive review of pollution effects on meiofauna. More comprehensive treatments can be found in Coull & Chandler (1992) and Giere (1993) and these works should be consulted for further reading. The purpose of this short contribution is to provide a brief summary of the reasons for and against their use and to point out that there are circumstances, more frequent than often thought, where high quality samples can be obtained relatively easily. Used in conjunction with recent identification literature, meiofauna samples can form the basis of effective and meaningful environmental assessments.

What is meiofauna?

Meiofaunal animals are those taxa that are routinely thrown away in biodiversity studies and environmental assessments. They are traditionally defined as benthic metazoans (including sometimes Foraminifera) that pass through a 0.5 mm sieve and are retained on a 63 (or 42) micron mesh. They occur in most aquatic habitats from mid-continental streams and lakes to the abyssal ocean plains, and can reach phenomenal densities, frequently more than 1 million individuals per square metre of sediment, sometimes an order of magnitude greater. Taxonomically, in marine habitats, meiofauna is almost invariably dominated by nematodes, usually followed in number by the harpacticoid copepods. However, one of the fascinations of studying meiofauna is its high diversity. Species rich assemblages of nematodes and copepods are frequently accompanied by the larval stages (termed "temporary meiofauna") of larger, more familiar marine invertebrates as well as some more obscure meiofaunal groups. These include the little–known kinorhynchs, gastrotrichs and gnathostomulids which, although widespread, are seldom encountered even by professional zoologists. Because of their unique features they are ranked as phyla in their own right, and are exclusively meiobenthic. Tardigrada and Loricifera also fall into this category. In all, twenty-two of the metazoan phyla have meiobenthic representatives.

Because these animals are so abundant and diverse they are potentially an extremely useful source of information for mankind. They are helping to shed light on aspects of evolution, speciation and biogeography but, on a more immediately practical level, they can also be used to track long- and short-term changes in the marine environment.

Why should they be used in environmental assessments?

Analysis of marine macrofauna has long been used in ecological studies and is a standard tool in environmental assessments and monitoring programmes where the potential effects of man's activities in the oceans are of concern (e.g. oil and gas development, aggregate extraction). Meiofauna is also useful in this respect and arguments for using it as an indicator of environmental change have been cogently set out elsewhere (most recently by Kennedy & Jacoby, 1999). Three pertinent attributes have been touched upon already, namely the sheer abundance, ubiquity and diversity of meiofauna. However, it has two distinct theoretical advantages over most macrobenthic taxa. The first relates to rapid generation times. Many nematodes and harpacticoids reproduce frequently and life cycles can be completed in a matter of weeks. This means that meiofauna communities react more rapidly to environmental perturbations which may then be detected in changes in community attributes such as diversity or "evenness". This responsiveness is extremely useful where early warning of environmental degradation is required in sensitive areas, and could be achieved by frequent sampling and analysis of the meiofauna. Meiofaunal sampling improves temporal resolution of survey data.

The second advantage is that the meiobenthic species complete their whole life cycle within the sediment. Marine mud and sand act as a sink for many pollutants which then become bioavailable (it is this bio-availablility rather than absolute concentration which makes the use of the biological components of the ecosystem so essential in monitoring and effects studies). With meiofauna the most sensitive life-stages, the larvae, are exposed to this hostile environment, making meiofauna communities potentially more responsive to pollution events. Most macrofaunal larvae develop in the plankton and are thus not so exposed. The sedentary habit of meiofauna also means that effects are localised. In contrast, changes in macrofauna communities may be due to "supply-side" events, removed from and unrelated to the area under consideration. Thus meiofauna show high spatial resolution.

There are other practical advantages. Small size means that smaller samples are required with obvious implications in the field and for sample storage. This can allow a greater degree of replication and statistical robustness. Harpacticoids and nematodes are often relatively straightforward to culture and so can be used in toxicity or "effects" testing. *In vitro* studies on harpacticoids have shown that they are often more sensitive than nematodes. Easily measurable sub-lethal responses such as clutch size or development time can be highly informative. These tests may then be conducted with species from the local environment and so provide some predictive modelling capability relevant to the study area.

What are the disadvantages?

There are, of course, disadvantages in using meiofauna in pollution studies. It is certainly true, for instance, that much more is known about the autecology of macrofaunal species. This makes it possible to make use of gross changes in feeding mode of certain groups (e.g. polychaetes) by computing trophic indices. However, many assumptions are made in constructing these indices and multiple feeding behaviour is often not taken into account. A certain degree of trophic information can be gained from meiofauna by using the classification of nematode feeding types based on buccal armature (see Giere, 1993 and references therein). Otherwise, if individuals are regarded simply as "bits" of information for use in statistical analyses (i.e. their ecosystem function is disregarded), then there is no theoretical difference between using meiofauna or macrofauna sample data, as long as samples are taken in the appropriate way.

Remote sampling for deep water meiofauna is technically difficult and expensive. High concentrations of meiofauna inhabit the flocculent layer that is nearly always dispersed by the bow wave of conventional sampling gear. No doubt this undesirable effect is not confined to meiofauna, but it is assumed that these animals are disproportionately affected. The inefficiency of macrofauna sampling and sample processing is often overlooked or misunderstood.

Meiofauna distribution is dynamic and patchy on small (cm) scales. Extra care is needed in designing the appropriate sampling strategy and setting the correct level of replication. Sampling theory still applies but the different spatial scales should be taken into account.

Identifying meiofauna to species level is still the domain of specialists. However, new identification books and practical manuals are available. The nematodes can be identified to genus using three Linnean Society Synopses (Platt & Warwick, 1983, 1988, Warwick, Platt & Somerfield, 1998) and web- and CD-based material from the Darwin Nematode Project (www.pml.ac.uk/nematode/index.html). The harpacticoids can be taken to family (and often genus) using another book in the Linnean Society series: Huys et al (1996). Practical sample processing methods may be found in Higgins & Thiel (1988), Giere (1993) and Somerfield and Warwick (1996). With these publications, a few inexpensive items of equipment and some patience it should be possible to identify the main taxa and produce reference material from a survey in any marine biology laboratory. Even if taxa cannot be named they can still be used for statistical analysis as long as identification is consistent throughout the study. Nematode and harpacticoid experts may then be approached to identify the reference specimens if necessary.

Further time-saving may be achieved by subsampling (imperative when meiofauna is abundant). Rapid and efficient extraction from the sediment can be achieved by flotation methods with centrifugation and sorting (to major taxa) is a non-specialist task. Some research has shown that analyses at genus or family level are just as sensitive as those conducted at species level. Such taxonomic “minimalism” may also be considered as a time-saving device but should be adopted with care.

When is meiofauna sampling most useful?

Ecosystems are complex and obtaining reliable information from natural populations (by sampling) is notoriously difficult. Meiofauna sampling does not provide a “magic bullet” capable of solving these problems. The weight of current and historic macro-invertebrate research ensures that the use of meiofauna will not become prevalent. Nor should this be so. Carefully planned and executed surveys using macrofaunal invertebrates are just as valid a way of detecting or tracking environmental change as similarly diligently undertaken meiofauna surveys. However, there are certain situations where high quality samples can be taken in shallow water (by diver or remote coring device) or in intertidal habitats, when the use of meiofauna should be considered.

One such situation has been alluded to already. This is the case where frequent monitoring is required to provide an early warning system, for example, around a small outfall. In some such cases the deployment of artificial substrata (pan scourers, for example) may be possible, a technique used by freshwater ecologists. This will standardize sampling units, control for differences in habitat structure and speed up the sampling process. A pilot study will be needed to determine colonization rates but meiofauna usually colonize new habitats very quickly (Atilla & Fleeger, 2000).

Large surveys with many sampling sites in areas where meiofauna is abundant (e.g. intertidal mudflats) may benefit from targeting the meiobenthos in terms of sampling logistics, transport, storage and the reduced volume of formalin required.

Finally, in two recent surveys undertaken on the south and east coast of England very few macro-invertebrates were encountered and little information was obtained from the samples. One of these sites, an area of sand swept by strong tidal currents, was teeming with interstitial nematodes and copepods. Other than those samples quickly investigated out of idle ecological curiosity, all of this "information" was carefully washed down the sink. In another study beach samples processed for macrofauna produced a few nereid polychaetes. In this case, however, contingency was built into the sampling plan and meiofaunal animals were extracted so that at least some information could be gleaned from the survey. In such cases, when it is suspected that macro-invertebrate populations are impoverished, it is always advisable to take meiofauna samples as a potential insurance strategy.

The few examples here have highlighted the fact that meiofauna can be of great practical value in environmental monitoring and assessment. This has been demonstrated many times in academic studies. Now that practical methodologies and identification keys are readily available, the meiofauna should no longer be regarded in the environmental industry as a collection of esoteric animals of interest only to the specialist zoologist. These diverse and abundant assemblages can be used with good effect as an important means of studying and monitoring environmental change.

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Long-term changes in the zooplankton community of the North Sea

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Introduction

The marine ecosystem of the North Sea suffers considerable human impact from over-fishing, eutrophication and possible climate change. To assess these human-induced impacts, plankton, which are at the base of the marine food web, can be used as a biological indicator of the state of the marine ecosystem.

The most comprehensive data set on plankton in the North Sea is from the Continuous Plankton Recorder (CPR) survey. This survey has provided a measure of the state of the plankton community throughout the North Atlantic on a monthly basis for more than 50 years. The CPR is an automatic plankton sampler towed behind merchant ships at about 7 m depth. It filters plankton from the water on a constantly moving band of silk. Using this simple but highly cost-effective device, over four million nautical miles have been towed by volunteer ships, collecting nearly 200,000 plankton samples from all over the North Atlantic. Approximately 400 phyto- and zooplankton taxa are counted within each sample. Thus the CPR survey is the single largest plankton data set in the world, providing a unique indicator of oceanic- and decadal-scale trends in distribution and abundance of plankton to address global change and ecosystem health issues.

The aim of this study is to identify characteristic inter-annual time series of the North Sea zooplankton community from CPR data, and then to interpret the shapes of these characteristic time series in terms of climatic signals and particular taxonomic traits. A technique that has been applied fruitfully to extracting interpretable patterns from a variety of data types is the Self-Organising Map (SOM, Kohonen 1997). The SOM is a type of unsupervised artificial neural network adept at pattern recognition and classification. There have been over 4300 published papers based on the SOM, in a wide variety of areas including assessing beer quality, identification of breast cancer, analysing insect courtship songs, predicting bankruptcies, and in speech and fingerprint recognition (see Kaski et al. 1998). This study represents a preliminary analysis of the suitability of the SOM technique to extract interpretable patterns from plankton time series data.

Methods

Each CPR sample, equivalent to ~10 nautical miles (18.5 km) of tow and approximately 3 m^3 of water filtered, is analysed under a microscope using a standard procedure (Warner and Hays, 1994). The area of interest for this study was the central North Sea, as this was the most comprehensively sampled area during the period 1958-2000 when the taxonomic resolution of the zooplankton counting has remained unchanged. Only zooplankton taxa that were present in more than 50% of the months were included, amounting to 31 taxa.

To focus the analysis on long-term trends, the SOM analysis was performed on annual abundances. Annual means were derived by simply averaging the monthly values for each year, as there were no missing months in the data set. Prior to the SOM analysis, the time series for each taxon was standardised by subtracting its mean and dividing by its standard deviation. This allowed the shape of the time series to be compared, despite the more than three orders of magnitude difference in the annual abundances between some taxa.

The SOM was performed using the SOM_Pak software Version 3.1 (Kohonen *et al.*, 1995), which is produced by, and freely available from the Neural Network Research Centre at the Helsinki University of Technology. Input data for the SOM consisted of a matrix of 43 (years) columns by 32 (taxa) rows. A SOM with a rectangular topology was used. It was randomly initialised and a two-step training process was used. The first training captures broad-scale patterns: it had a length of 1000 iterations, a learning rate of 0.2, and a radius of 3. The second training reflects finer scale patterns: it had a training length of 10000, a learning rate of 0.1, and a radius of 0.

Results and Discussion

A 3x2 SOM of the 31 zooplankton time series, displaying the characteristic time series identified, is shown in Fig. 1. Taxa that correspond to each pattern are also included. Despite the considerable inter-annual variation in the original time series, the SOM has identified real patterns in the time series of the various taxa, as the superimposed raw data series that correspond to each pattern confirms.

Patterns are spread in a continuum across the two-dimensional space. On the left side of the SOM, patterns are generally showing an increase in abundance, on the right side the patterns are generally decreasing, and in the centre the patterns show less of a trend. Superimposed on this general pattern is a considerable amount of inter-annual variation. A common feature in the patterns in the top row of the SOM and in the bottom right corner, is a marked peak in abundance around 1989-1990. Looking at the SOM in more detail, the bottom left series shows a step function, with the period to 1981 relatively low, and the following years relatively high. The top left series also has a similar step functions, although there is a massive peak in 1990. The two middle patterns have very low abundance from 1979-1981: most other patterns also reflect this phenomenon, although to a smaller extent. The top right time series has a high abundance in the early 1960s, and then flattens out from the late 1960s. The bottom right corner has a very steep negative slope, with an increase in abundance in 1978.

To relate the characteristic time series to hydrometeorological events, we have superimposed the timing of the low salinity (cool temperature) event of 1978-1980 and the high salinity event (warm temperature) in 1988-1990 (Fig. 2). It appears that the characteristic abundance series were strongly affected by these events. It is noteworthy that the low salinity event led to a decrease in the abundance of many taxa, whereas the high salinity event led to an increase in abundance. By combining information from Figs 1 and 2, it is possible to identify particular taxa that were affected by the anomalous hydrometeorological events. Taxa that had a large decline in abundance during the cold period of low salinity inflow in 1978-1980 were *Centropages typicus*, cyphonautes larvae, harpacticoids, hyperiids, *Acartia* spp., cumaceans, *Evadne* spp., lamellibranch larvae and mysids, and to a lesser extent *Calanus helgolandicus*, *Candacia armata*, decapod larvae, echinoderm larvae and post-larvae, fish larvae and *Tomopteris*. The taxa that had a massive increase in abundance corresponding to the warm period of high salinity inflow in 1988-1990 were *Calanus helgolandicus*, *Candacia armata*, decapod larvae, echinoderm larvae and post-larvae, fish larvae and *Tomopteris*; others that were affected to a moderate extent were *Centropages typicus*, cyphonautes larvae, harpacticoids and hyperiids;

those that were affected to a smaller extent were chaetognaths, fish eggs, gamariids, *Limacina* spp., *Metridia lucens*, *Calanus finmarchicus*, *Euphausiids*, *Oithona* spp., *Para/Pseudocalanus* spp. *Pseudocalanus* spp.

To identify whether taxa that correspond to a particular pattern have common traits, we have compiled a list of some important traits of each taxon (Table 1) and superimposed these on the SOM output (Fig. 3). These traits include their permanence in the plankton (meroplanktonic or holoplanktonic), their egg-laying strategy (broadcast or egg-carrying) and whether they produce diapausal eggs. Although there is considerable mixing of different traits in the SOM groups, there are some interesting general tendencies. For instance, most taxa on the right side of the SOM are holoplanktonic (H), with a greater proportion of meroplanktonic (M) taxa on the left side. In terms of spawning behaviour, there are more broadcast spawners (B) on the left side than are on the right side. And in taxa that have diapausal eggs (T), there are none (F) on the right and many on the left side.

It is noteworthy that taxa that have some or all of the traits of being meroplanktonic, a broadcast spawner, and having diapausal eggs are generally increasing in abundance (more common on the left side of the SOM) (also see Lindley and Batten 2002). These traits correspond to an *r*-selected strategy, well adapted to a variable or stressed environment. By contrast, taxa with traits of being holoplanktonic, egg sac spawners and not having diapausal eggs have decreased in abundance (right side of SOM). These traits correspond to a more *K*-selected strategy (holoplanktonic, egg sac spawners and no diapausal eggs), more suitable for a less variable or more less-stressed environment. Has there been an increase in the variability of the environment in the North Sea, or are environmental stressors in action? More research is needed before this question can be answered.

This study presents a fruitful and new approach of using pattern recognition to identify characteristic abundance time series of the zooplankton community, then to link these to hydrometeorological events and traits of taxa. The current study shows that many taxa in the North Sea are affected by hydrometeorologic conditions, and suggests that taxa with *r*-selected traits are doing better than their *K*-selected counterparts.

Acknowledgements
CPR data used in this study are freely available to all researchers (see http://www.npm.ac.uk/sahfos/sahfos.html). The authors are grateful to all past and present members and supporters of the CPR survey, especially the shipping industry that voluntarily tows CPRs on regular routes. The CPR survey has been recently funded by a consortium comprising IOC, and agencies from Canada, The Faroes, France, Iceland, Ireland, Netherlands, Portugal, UK (DEFRA and NERC) and USA.

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Table 1. Traits and preferences for each taxon used in the analysis. These include their permanence in the plankton (holoplanktonic (H) or meroplanktonic (M)), their egg-laying strategy (broadcast (B) spawner or egg-sac spawners (E)), and whether they produces resting eggs (true (T) or false (F)).

Taxa	Permanence in Plankton	Egg Laying	Resting Eggs
Acartia spp.	H	B	T
Calanus finmarcicus	H	B	F
Calanus helgolandicus	H	B	F
Candacia armata	H	B	T
Centropages hamatus	H	B	T
Centropages typicus	H	B	T
Chaetognatha	H	B	F
Cirripede larvae	M	E	T
Cumacea	M	E	F
Cyphonautes larvae	M	E	F
Decapoda larvae	M	E	F/T
Echinoderm larvae	M	B	F
Echinoderm post-larvae	M	B	F
Euphausiacea	H	B	F
Evadne spp.	H	E	T
Fish larvae	M	B	F
Gammaridea	M	E	F
Harpacticoida	H	E	F
Hyperiidea	H	E	F
Lamellibranch larvae	M	E	F
Larvacea	H	B	F
Limacina retroversa	H	E	F
Metridia lucens	H	B	F
Mysidacea	H	E	F
Oithona spp.	H	E	F
Para-pseudocalanus spp.	H	E	F
Podon spp.	H	E	T
Polychaeta larvae	M	B	F
Pseudocalanus elongatus	H	E	F
Temora longicornis	H	B	T
Tomopteris spp.	H	B	F

Fig. 1. A 3x2 SOM of the 31 zooplankton taxa in the North Sea, showing the characteristic time series identified (dark line) and the raw data series for each taxon superimposed (dotted line). Taxa corresponding to each raw data series is also shown.

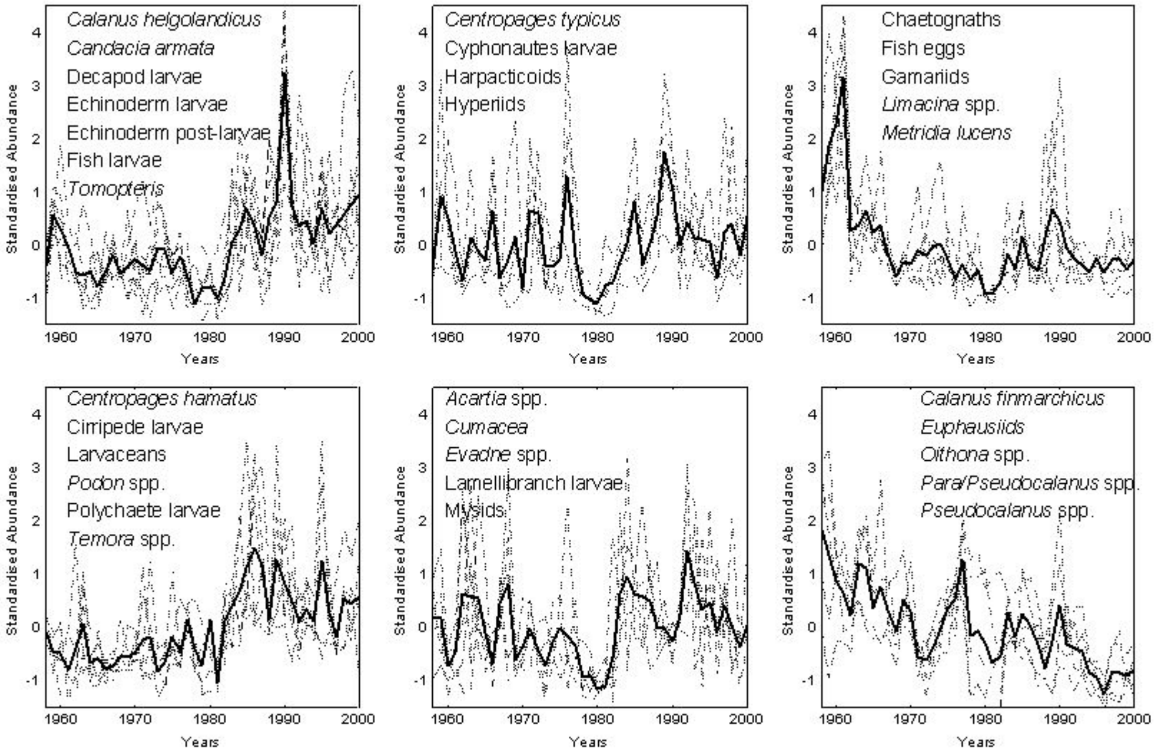


Fig. 2. The low salinity (1978-1980) and high salinity (1988-1990) events superimposed on the characteristic time series identified by the SOM.

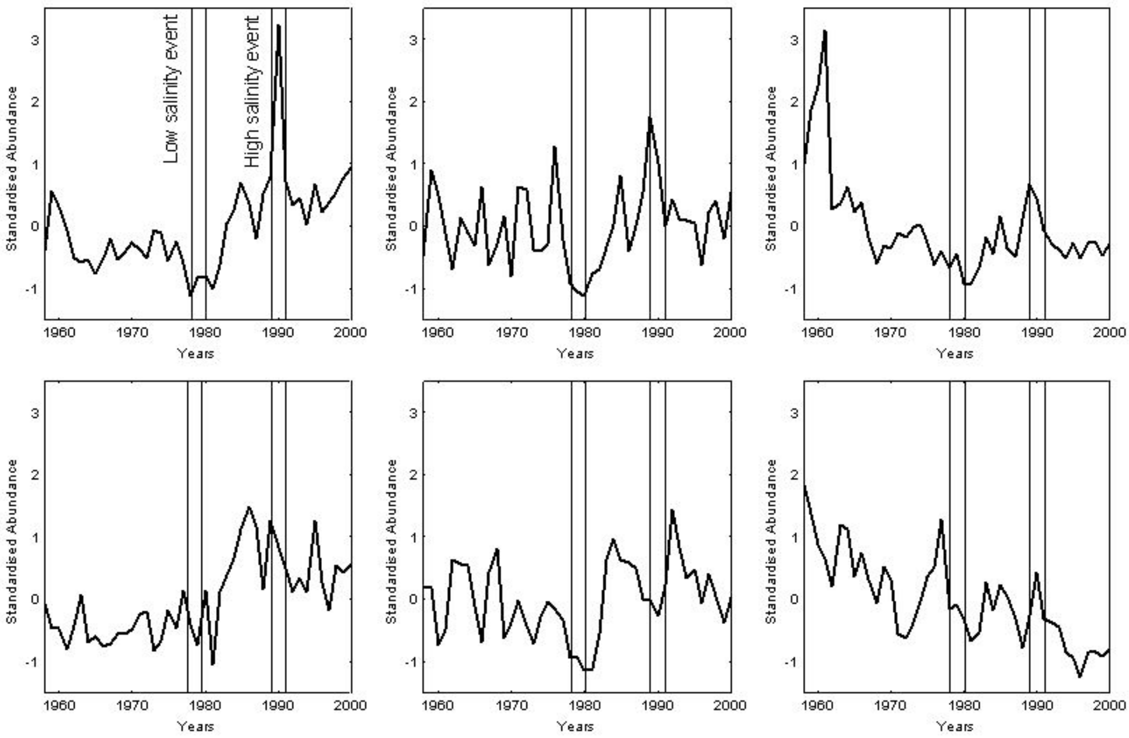
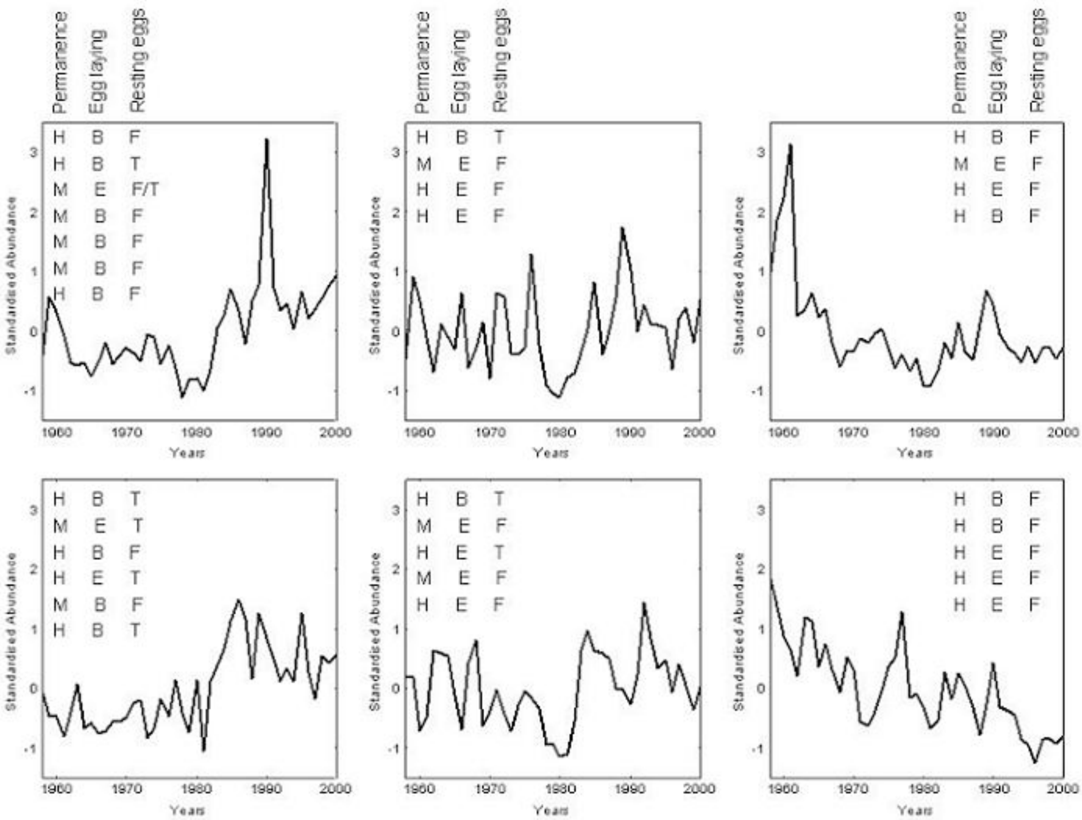


Fig. 3. Traits of taxa that mapped to each SOM pattern. Codes for variables are: These include their permanence in the plankton (holoplanktonic (H) or meroplanktonic (M)), their egg-laying strategy (broadcast (B) spawner or egg-sac spawners (E)), and whether they produces resting eggs (true (T) or false (F)). The order of the taxonomic traits for each SOM pattern is the same as that of the taxonomic names in Fig. 1.



Broad scale mapping in the Forth:The Firth of Forth Spatial Project

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Abstract only

The Firth of Forth Spatial Study (FFSS) aims to review the current status of soft sediment benthos in the Forth. This short presentation will describe the collaborative interests and roles of National Museums of Scotland, Heriot-Watt University, Scottish Natural Heritage and Scottish Environment Protection Agency in the FFSS and briefly discuss the relevance of this review to the Urban WWTD and Water Framework Directive. The presentation will include examples of broad scale mapping of sediment type and benthic habitats within the inner firth.

Challenges in Marine Biodiversity: The Global View

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Abstract only
This talk considers how the study of marine biodiversity has developed over the years, looking first at the early days when the work was not graced with a formal name. The study went through a difficult period when identifying organisms was not seen as a relevant science, but the importance of biodiversity is now globally recognised, and its study is increasingly supported. Its impact on the global scene is noted, and a relevant emerging research programme is briefly discussed.

Marine technology: challenges of the last frontier

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I grew up in cold war Scotland, where regular reports of missile and bomb tests imbued our daily lives with a distinct sense of unease. Then, in parallel to the Arms Race, came the Space Race. Kennedy's commitment to put a man on the moon within 10 years assured NASA of limitless funds for space exploration. But it was the Voyager missions, the exploration of the outer reaches of the solar system by small smart probes that really caught my imagination.

In a way, though, the explorers of space had it easy. The missile programme had solved the launcher problems, so escaping the Earth's gravity was eminently feasible, if expensive. Once in space the rest was straightforward – limitless supplies of energy from solar panels, or your personal chunk of plutonium as in the Voyager craft; no motion resistance, no corrosion, and so on. But the greatest boon of space was its transparency to the electromagnetic spectrum, allowing unfettered optical and radar imaging of planetary surfaces and, more significantly, ease of radio-communication with the spacecraft.

However, my university education in physics, coupled with several summers exploring in Greenland, led not to space science but to the Scott Polar Research Institute. There I joined a team using airborne radars to map the Antarctic continent, hidden under several kilometres of ice. Unfortunately ice is not as transparent as space: powers that could bounce signals off the moon are needed to generate detectable echoes through 5 km of polar ice. But at least radio waves do penetrate ice. And we did find the unexpected – Lake Vostok, deep in the heart of the continent, under more than 4 km of ice.

When this programme wound down I moved back to Dunstaffnage in Scotland to study a natural medium that is, for all practical purposes, totally opaque to radio waves – the sea. Because of this simple fact the bottom of the oceans is much less well mapped than, say, the far side of the moon, or the surface of Mars. Satellite-borne instruments, which have done so much to advance our knowledge of the Earth's surface and atmosphere, are powerless to see beneath the surface of the ocean. Seabed mappers have to rely on acoustic instruments to build up images of the ocean floor, and these instruments have to be within the water. Unlike space, water resists the motion of objects through it: building the oceanographic equivalent of a satellite – an autonomous underwater vehicle (AUV) – faces the immediate problem of supplying the vehicle with enough energy to navigate. And, unlike the days of Voyager, small nuclear reactors are no longer popular.

Water friction can, however, be turned to advantage: the oceans move, and it is possible to hitch a free, if largely unpredictable, ride on the back of ocean currents. At Dunstaffnage I have become closely involved in exploiting this free ride, and in recycling new technologies such as GPS for the detailed study of ocean currents. We have deployed drifting instruments in many areas, including the polar ice packs, where they have yielded new data for the climate change debate. Elsewhere, the profiling floats of the international Argo programme drift for days on deep currents, surfacing periodically to download thermal data that will help us understand the interplay between the oceanic heat reservoir and climate change.

This still leaves the ocean floor largely unmapped: speculative reconnaissance – exploration in the true sense – is largely ruled out. However, change is afoot, spurred by events such as the chance discovery of the biological communities thriving around hydrothermal vents. Plans are well advanced in many countries for the establishment of ocean observatories linked by sea-floor cables - an Internet of the deep ocean, open to primary schools as well as universities. Instrument pods, connected to the network via sea-floor junction boxes, will both deliver data and receive commands and energy. AUVs will now be able to dock routinely to report their findings and recharge their batteries. The spirit of exploration which has led to such amazing discoveries as the volcanic activity on Jupiter's moon Io, and Lake Vostok in the Antarctic, is about to be fostered once more in the oceans. And, connected to the Internet, what new wonders will our last frontier reveal – and to whom?

Practical developments in numerical analysis techniques used for marine biological surveys

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Abstract

Marine biological surveys usually generate complex datasets, representing the presence and abundance of numerous species at different sampling locations and sometimes also at different times. Various numerical methods have been developed to help summarise the data and to identify trends in spatial distribution or changes over time. The last 25 years have seen enormous developments in the availability of computers and vast increases in computational power. The talk examines how the numerical methods available for analysing survey data have changed over the this period, and how this may have influenced our working practices and our interpretation of survey data. Practical examples are drawn from experiences in our own laboratory, which was founded in 1976. In more general

terms, modern program packages have made complex multivariate techniques widely available and easy to use, but is there a downside to this? And what aspects of data analysis remain fundamentally the same despite the developments in computer technology?

Introduction

The aim of the talk is to look at how the considerable developments in computer technology over the last 25 years have affected the way we conduct numerical analysis of marine biological survey data. I thought it would be interesting to look at how these changes may have affected the way we work, for example in terms of how we collect data and how we interpret the results of surveys. Emphasis is on the practical aspects of conducting the analyses, rather than on theoretical developments. I am drawing on the experiences in our own laboratory at ERT, founded in the mid-1970s at the Institute of Offshore Engineering (IOE) at Heriot-Watt University. The talk was put together by speaking to people who analysed data there at different times in the last 25 years, and is illustrated with examples of how we actually worked and the problems tackled. I was analysing survey data myself mostly between 1990 and 1996 and saw considerable changes even over that relatively short period of time. Of course, other laboratories will have done things differently, but I think the general evolution of trends is quite typical.

What kind of data?

The kind of data I am referring to are those generated from the processing of grab or core samples taken subtidally or intertidally. The fauna in each sample is extracted, identified and counted, and sometimes weighed. This results in a large number of records of abundances of different species at different places, and sometimes also at different times.

Objectives of data analysis

A variety of numerical methods have been developed to help summarise large datasets and make them easier to interpret. These techniques help to identify trends in spatial distribution or changes in community composition over time. We have used them in particular to detect impacts from possible sources of pollution, as part of monitoring programmes. These programmes usually involve conducting baseline and post-operational surveys, with samples taken from a number of stations that may be affected and from reference stations. Numerical analysis techniques are also used in pure research aimed at describing communities and their distributions.

Types of numerical analysis

The numerical techniques used fall into three general types: univariate methods, graphical methods and multivariate methods. Univariate methods involve looking at simple community statistics such as the number of species and the number of individuals, and a variety of diversity and evenness indices which are calculated from the numbers of species and individuals and the distribution of individuals among the species. Univariate statistics are calculated for each sample or station separately, and can then be used to compare stations with each other. The various graphical methods, such as rarefaction curves, log normal distributions and ABC curves, are different ways of plotting basic univariate statistics onto graphs so that their shapes can be compared for different stations.

Multivariate methods use the whole dataset from a survey or series of surveys, and compare each sample with all the others. They take into account the identities of the species at each station, as well as their abundances. Such methods include: cluster analyses, which group stations according to their faunal similarity, represented by a dendrogram (fork diagram); gradient analyses, which detect linear gradients in the faunal data; and multidimensional scaling, which maps stations in a way that reflects their faunal similarity.

Timeline

It emerged that the changes in practices could best be presented by dividing the period since 1976 roughly into four time periods that reflect the most significant developments. The practicalities of data analysis during the different periods are outlined below. The divisions are not distinct but convenient. The changes occurred to various aspects of the process: data entry and management; data analysis; and output and presentation of results. These aspects are considered for each time period.

Approximately 1976 to 1982

At this time there were no PCs, but access could be gained to mainframe computers at the universities.

The survey data were collated by transcribing all of the species-abundance records from the individual site sheets onto large hand-written spreadsheets. Firstly, the names of all the species recorded were listed in the first column, using the contents list in Hartmann-Schröder (1971) as a guide to taxonomic order for the many polychaetes. A system of squares was used to record the abundances of each species in each sample (replicate) at each station. The numbers were checked by manually adding up columns in both directions. Sue Hamilton worked for IOE at the time and used to do this on her kitchen table.

Univariate statistics were calculated by hand. Examples used in early surveys included Margalef's diversity index (d), the Shannon-Wiener information function (H_s) and Pielou's evenness measure (J). Graphical techniques used included Preston's log normal distributions and Sander's rarefaction curves. Later on, Simpson's (D) and Brillouin's (Hb) diversity indices and Heip's evenness measure (E_h) were added, and Hurlbert's rarefaction curves replaced Sander's.

Multivariate statistical techniques were not used routinely for marine monitoring, and the reports from that time instead provide relatively detailed discussions on the distributions, abundances and biology of individual species in the community. Univariate data were calculated and compared for each phylum in addition to the whole dataset.

The reports were typed on typewriters of course, including the species lists which caused considerable problems with spelling. Mistakes had to be corrected by retyping the whole page, but each time this was done other mistakes occurred, so pages were corrected until the number of mistakes was constant.

Early computers became available in the late 1970s, and IOE used BBCs and a 'Pet'. These had 16 or 32 Kbytes RAM and a clock speed of 4 Khz, and there was no hard disk. This leads into the next period.

A BBC computer

Photograph: Philippa Kingston

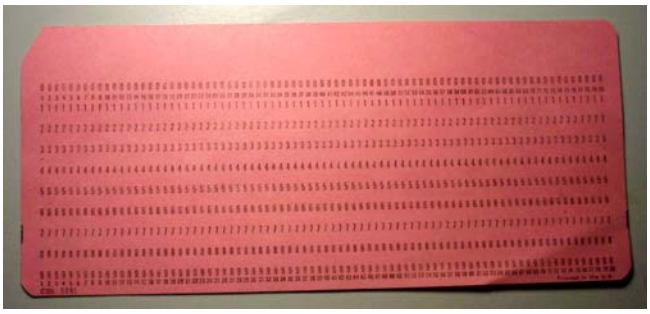
Approximately 1983 to 1987

IBM PCs came in and started to be used for some univariate analyses, but multivariate analysis was carried out on a mainframe computer.

The data were typed directly into the PCs as data files in specified formats. We used the program 'Stirling 3' and later versions (Moore, 1983), which provided a list of the ten most abundant species at each station, together with a range of diversity indices (H_s, D and H_b) and evenness measures (E_h and J), and the co-ordinates for calculating Hurlbert's rarefaction curves. The results were presented only as a hard copy via the printer onto computer paper in a continuous roll. The process was very slow - we would wait with anticipation for the next co-ordinate for a Hurlbert's curve to be generated. Consequently the program was often left to print overnight, and then by the morning the paper would have jammed.

We started to use multivariate analyses routinely during this period, and these were carried out using a mainframe computer, initially at Aberdeen University and later at Heriot-Watt. The first program used was 'clustan l. c.' (Wishart, 1978), for cluster analysis, and was frequently carried out on binary data (species presence and absence). Later, the FORTRAN IV versions of the Cornell Ecology Program series were used, particularly a type of gradient analysis called detrended correspondence analysis or Decorana (Hill, 1973). The data had to be input in FORTRAN format, which was achieved by laboriously writing out coding cards. Accurate placement of all of the species abundance data (and zeros) in the grid boxes was essential to the successful running of the programs. The coding cards were in turn used to make up punch cards; one punch card for each species, ie each column of data. Initially we supplied data on coding cards, but later had access to a punch card machine ourselves. This was the size of a desk and resulted in a box of punch cards maybe 60-90 cm long for a single survey.

A punch card used for data input to mainframe computer



Photograph: Paul Kingston

The results from the analyses had to be plotted by hand, and figures for reports were drawn on tracing paper using Rotring pens and Letrasett.

Approximately 1988 to 1993

Faster PCs became available over this period, so that we could now carry out all analyses in-house. All of our software was DOS-based, and there was much less standardisation of general software, such as spreadsheets and word processors, than there is today.

A key development in the laboratory was the creation of a system for entering data easily and accurately. IOE commissioned Dr Colin Moore of Heriot-Watt University to write a program for data entry. This resulted in WORMS, a data entry and management program (Moore, 1989, unpublished). Based on the database DB3+, WORMS sorts entries into taxonomic order and provides output files for numerical analysis. Use of WORMS involved developing a species coding system as part of our in-house species directory. Each species was allocated an 8-character alphanumeric code and a brief code consisting of a 3X3 couplet. The nomenclature and taxonomic order were based on the Directory of British Marine Fauna and Flora (Howson, 1987). A rather dog-eared photocopy of this had all of our species code numbers written in it, so that we would know how to code any additional species we found.

Later versions of STIRLING (why did we start using upper case for programs?) were used for univariate analyses, while the program package PATN (Belbin, 1988) was used for multivariate analyses. The latter were dominated by cluster analysis and DECORANA. Multidimensional scaling became feasible as PCs became more powerful, and later on in this period we started using the program MDS, amongst others, in an early version of the PRIMER package developed at the Plymouth Marine Laboratory.

The main impression I have from this time is that no software was compatible with anything else. Each program required data to be input in its own particular format. We had programs specially written to convert data into different forms for different packages. The conversion of the data for all the different programs, and for the tables we needed for our reports, was quite complicated, and one of my jobs was to write the laboratory computer manual to remind us all what to do. There were also limitations on the amount of data that could be analysed at once; one ten-year dataset had to be split in half for some of the techniques we wanted to use.

The quality of the output from PATN was not suitable for reports, and the co-ordinates from DECORANA and cluster analysis were plotted afterwards from the results files generated. By this time we had invested in Apple Macs for our desk-top publishing, which only added to our incompatibility problems.

Approximately 1994 to present

PCs have become increasingly powerful, with 386s, 486s and then Pentium processors. We eventually started using Microsoft Windows in the laboratory, with some resistance.

Around 1996, we started using Microsoft Excel spreadsheets to enter data. WORMS had served us very well, but Excel was easy to use with the new software packages. However, we still use our species directory database, with its 8-character coding system and 'brief' codes, to sort species into taxonomic order, provide correct spelling and authorities, and help us manage our species reference collection.

For univariate analyses, a program DIVCALC was written for us by Rob Rolph, to provide output exactly as we wanted it. Some projects, such as surveys around fish farm cages and sewage outfalls, required use of the Infaunal Trophic Index, which is calculated for each station based on the feeding types of the animals there, so Rob also wrote ITICALC.

More powerful computers mean that multivariate analyses can now be carried out much faster than before. This is especially noticeable with MDS, in which the whole computation is repeated several times in order to achieve the plot that best represents the data. When I first started using PRIMER I chose 5-10 repeats because this could be completed within an hour or less. Now we routinely do 40 and it takes seconds. The packages we use most commonly now are PRIMER for Windows; MVSP (Multivariate Statistical Package) as a more modern package for DECORANA and other programs; and PC-Ord.

Software generally has become more compatible in recent years. PRIMER output was always neat but we used to redraw figures on the Macs. Now, graphics output is easily incorporated into reports and we have much more flexibility in presentation. Also we now use PCs for report production.

Discussion

The developments in computer technology over the last 25 years that have affected the way we analyse and present marine biological survey data include both hardware developments (the availability of PCs and then vast increases in computer power) and software developments (both general and specialist software).

These have made numerical analyses easier to carry out and more widely used. Complex multivariate techniques have become much more user-friendly and a wide range of techniques is now readily accessible. Analysis is fast, allowing us to carry out a number of different tests to 'explore' a dataset. We can handle bigger data sets, combining data collected over long-term studies and analysing them together. We also have tremendous flexibility in the way we present survey findings. These are all positive aspects, but are there any downsides to all this progress?

Can it be too easy? I have heard examples of students using multivariate software packages without really understanding what they are doing with their data, and misinterpreting the output. This may always have been the case, but the earlier packages demanded a lot more study before you could operate them, and you were more in touch with what was happening to the data. There may also be an impression now that the techniques can do more than they can, ie that they can provide all the answers, rather than just being tools.

Also, I wonder if there is a tendency to adopt methods that are readily available, at the expense of other methods. A certain amount of conformity is necessary in terms of environmental regulation, but we must avoid over-standardization and think before we press the default button. Another consideration is whether we are putting too much emphasis on multivariate routines generally, at the expense of looking at the species list. Early survey reports focused more on individual species and their distributions, and a wider range of univariate statistics were used.

What hasn't changed in the last 25 years? Despite all the benefits of technological advances mentioned above, many aspects of data analysis remain fundamentally the same. The same univariate statistics tend to be used, for example, and cluster analysis and DECORANA have stood the test of time.

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