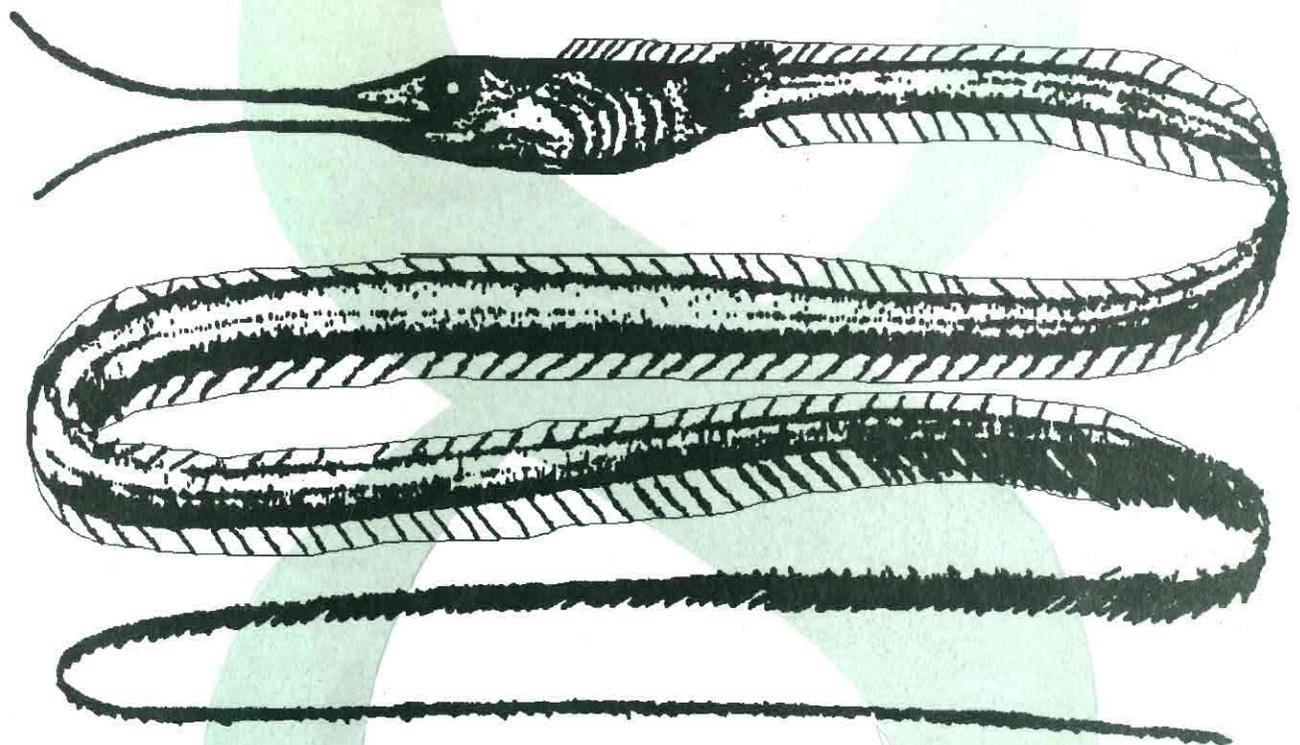




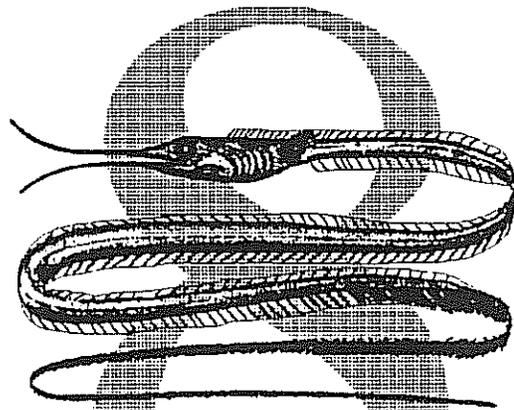
Aruba Kisan



EIGHTH DEEP SEA

BIOLOGY SYMPOSIUM

Monterey, California 1997



EIGHTH DEEP SEA

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Symposium Hosts:

Monterey Bay Aquarium Research Institute (MBARI)
Monterey Bay Aquarium

Symposium Organizing Committee

Jim Barry, Bruce Robison, Kurt Buck, (MBARI)
Randy Kochevar, Ginger Hopkins, Chris Harrold (MBA)

Symposium Office

Mailing Office:
8th Deep-Sea Biology Symposium
Monterey Bay Aquarium Research Institute
PO Box 628
Moss Landing, CA 95039-0628 U.S.A.

Email, Phone, Fax Contacts:

Annette Gough (goan@mbari.org: 408-775-1701)

Kelly Burgess (kellyb@mbari.org : 408-775-1803)

FAX: 408-775-1620

World Wide Web Site: <http://www.mbari.org>

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

Start	End	Min.	Location	Presenting Author	Title of Presentation
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SUNDAY, 21-September

15:00	18:00	180	MBA : Hovden Way		Registration
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MONDAY, 22-September

7:30	17:30	600	MBA : Hovden Way		Registration
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Session I Studies of Specialized Habitats (Vents, Seeps, Whale-falls)

7:30	8:30	60	MBA : Hovden Way		Coffee
8:30	8:50	20	Auditorium	Barry, James	Opening Remarks
8:50	9:10	20	Auditorium	MacDonald, Ian R.	Large-area imaging of hydrocarbon seep habitats
9:10	9:30	20	Auditorium	Carney, Robert S.	Explaining Edge-to-Center, bed-to-bed, and site-to-site monotony of non-chemosynthetic seep associates at five upper slope hydrocarbon seeps in the Gulf of Mexico
9:30	9:50	20	Auditorium	Linke, Peter	Manifestations of fluid flow and biogeochemical turnover at cold seeps of the Aleutian subduction zone.
9:50	10:10	20	Auditorium	Barry / Robison	Live Link Demonstration from MBA to Pt. Lobos / Ventana in Monterey Bay
10:10	10:40	30	Outer Bay Balcony		Break
10:40	11:00	20	Auditorium	Barry, James	Contrasting life styles of two closely-related vesicomid clams from cold seeps in Monterey Bay
11:00	11:20	20	Auditorium	Torres, Marta E.	Can clam shells reveal the nature and history of fluid discharge at a vent site?
11:20	11:40	20	Auditorium	Fujiwara, Yoshihiro	In situ spawning of a deep-sea vesicomid clam by increasing the water temperature
11:40	12:00	20	Auditorium	Smith, Craig Randall	Whale-Fall Communities on the Northeast Pacific Slope: Succession and Food-Web Structure
12:00	13:30	90			Lunch
13:30	13:50	20	Auditorium	Baco, Amy	Phylogenetic Relationships of Whale-Fall Vesicomid Clams Based on Mitochondrial COI Sequences
13:50	14:10	20	Auditorium	Fujikura, Katsunori	Community ecological characteristics of the seep community at the Off Hatsushima Site, Sagami Bay, Japan
14:10	14:30	20	Auditorium	Galkin, S.V.	Bottom fauna in the area of Paramushir gas-hydrate seepage (Sea of Okhotsk)
14:30	14:50	20	Auditorium	Hashimoto, Jun	Locomotory activity patterns in deep-sea crabs (Custacea, Decapod, Bythograeidae) collected from hydrothermal vent sites in the western pacific
14:50	15:10	20	Auditorium	Beck, Lothar A.	Symbiosis with Sulfur and Methane-oxidizing bacteria in hot-vent Molluscs - New Findings
15:10	15:40	30	Outer Bay Balcony		Break

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MacDonald, Ian R.

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MacDonald

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

Start	End	Min.	Location	Presenting Author	Title of Presentation
15:40	16:00	20	Auditorium	Copley, J.T.P.	Game togenic ecology of hydrothermal vent polychaetes from High Rise vent field, Juan de Fuca Ridge
16:00	16:20	20	Auditorium	Vereshchaka, Alexander	Life cycles and reproduction of the deep-sea shrimps inhabiting hot vents: facts and hypotheses
16:20	16:40	20	Auditorium	Goffredi, Shana K.	Sulfide acquisition by the vent worm <i>Riftia pachyptila</i> appears to be via uptake of HS ⁻ , rather than H ₂ S
16:40	17:00	20	Auditorium	Shillito, Bruce	Rate and process of deep-sea vestimentiferan tube growth
17:00	17:20	20	Auditorium	Trask, Jennifer	Site-Specific and Ontogenetic Variations in Mussel Carbon and Nitrogen Stable Isotope Compositions at Lucky Strike
17:20	17:40	20	Auditorium	Voight, Janet R.	Assessing the endemicity of vent predators and resultant Implications for the evolution of hydro thermal vent fauna
17:40	18:00	20			
18:00	21:00	180	Blue Fin Cafe and Billiards		Social Mixer, Blue Fin Cafe and Billiards (near MBA)

TUESDAY 23-September

Session II Pattern and Function of Deep-Sea Populations and Communities

7:30	8:30	60	MBA : Hovden Way		Coffee
8:30	8:50	20	Auditorium	Young, Craig	Potential for deep-sea invasion through isothermal water columns I. The Mediterranean
8:50	9:10	20	Auditorium	Tyler, Paul	Potential for deep-sea invasion through isothermal water columns II. The north Atlantic
9:10	9:30	20	Auditorium	Gage, John D.	Ecology and demographic characteristics of a dense brittlestar population on the Scottish continental slope
9:30	9:50	20	Tide Pool Viewing Area		8th Deep-Sea Biology Symposium Group Photograph
9:50	10:20	30	Outer Bay Balcony		Break
10:20	10:40	20	Auditorium	Escobar, Elva G.	Biomass patterns of deep-sea benthos in the Gulf of Mexico
10:40	11:00	20	Auditorium	Soltwedel, Thomas	Activity & biomass of the small benthic biota under permanent ice-coverage in the central Arctic Ocean
11:00	11:20	20	Auditorium	Nybakken, James	Distribution density and relative abundance of benthic invertebrates megafauna from three sites at the base of the continental slope off central California as determined by camera sled and beam trawl

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

Start	End	Min.	Location	Presenting Author	Title of Presentation
11:20	11:40	20	Auditorium	Stevens, Bradley G.	Through a Porthole Darkly: Observations of Behavior Changes Associated with Aggregative Mating of Tanner Crab, <i>Chionoecetes bairdi</i> : 5 year retrospective
11:40	12:00	20	Auditorium	✓ Miller, Robert J.	Food selection by deep-sea megafaunal surface deposit feeders as indicated by ²³⁴ Th, chlorophyll, and amino acid measurements
12:00	13:30	90			Lunch
13:30	13:50	20	Auditorium	✓ Sumida, Paulo Y.G.	Seasonal dispersal and allopatric settlement and growth of the bathyal brittle star <i>Ophiocten gracilis</i>
13:50	14:10	20	Auditorium	✓ Andrews, Allen	Radiometric age determination of the Pacific grenadier (<i>Coryphaenoides acrolepis</i>), a rapidly developing fishery in Monterey Bay
14:10	14:30	20	Auditorium	✓ Koslow, Tony	The fauna of mid-slope seamounts off southern Tasmania: impacts of deepwater trawling & its conservation
14:30	14:50	20	Auditorium	✓ Moore, Jon A.	The challenges of deep-sea fisheries
14:50	15:10	30	Outer Bay Balcony		Break

Session III Sensory Systems of Deep-Sea Fauna

10:20	10:40	20	OVCR	Widder, Edith	Signal economics of coelenterate bioluminescence displays
10:40	11:00	20	OVCR	Herring, Peter J.	Flashing anglerfish; an unexpected signalling system
11:00	11:20	20	OVCR	Douglas, Ron	Long-Wave Sensitivity in Stomiid Fish with Far Red Bioluminescence
11:20	11:40	20	OVCR	Partridge, Julian C.	The spectral sensitivities of deep-sea fish visual systems
11:40	12:00	20	OVCR	Wagner, Hans-Joachim	Development of multibank rod retinae in deep-sea fishes
12:00	13:30	90			Lunch
13:30	13:50	20	OVCR	Frohlich, Eleonore	Quantitative analysis of rhodopsin densities in rod outer segments of deep-sea fish retinae: an electron microscopic immuno-gold study
13:50	14:10	20	OVCR	Collin, Shaun P.	Topographic mismatching of the displaced amacrine and ganglion cell populations in the retinae of deep-sea lanternfish
14:10	14:30	20	OVCR	Frank, Tamara	Electrophysiologically Determined Spectral Sensitivities of Deep-sea Crustaceans
14:30	14:50	20	OVCR	Tamburri, Mario	The Chemical Ecology of Deep-Sea Scavengers
14:50	15:10	30	Outer Bay Balcony		Break
15:10	15:40	20	OVCR	Leys, Sally P.	Excitability and electrical signalling in hexactinellid sponges
15:40	16:00	20	Auditorium	Montgomery, J. C.	The Mechanosensory Lateral Line in Deep-sea Fishes: Functional Considerations

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

Start	End	Min.	Location	Presenting Author	Title of Presentation
16:00 <i>16:20</i>	16:20 <i>16:40</i>	20	Auditorium <i>OVCR</i>	Marshall, Justin	The lateral line and other sensory systems of deep-sea fish
Session IV Poster Session on Various Topics in Deep-Sea Biology					
17:30	20:30	180	Lower Outer Bay		Poster Session w/ Soft Drinks, no-host bar

WEDNESDAY, 24-September

Session V Source and Utilization of Carbon Inputs in Deep-Sea Systems

7:30	8:30	60	MBA : Hovden Way		Coffee
8:30	8:50	20	Auditorium	Lauerman, Lynn M. L.	Deep-sea epibenthic echinoderms and temporally varying food supply: a time series for the abyssal North-east Pacific
8:50	9:10	20	Auditorium	Smith, Kenneth L.	Detrital aggregates on the sea floor: Chemical composition and aerobic decomposition rates at a time-series station in the abyssal NE Pacific
9:10	9:30	20	Auditorium	Levin, Lisa A.	Macrofaunal Processing and Bioturbation of Phytodetritus On the North Carolina Continental Slope: an in situ, time series approach
9:30	9:50	20	Auditorium	Pfannkuche, Olaf	Responses of Deep-Sea Benthos to Sedimentation Patterns in the North-East Atlantic
9:50	10:20	30	Outer Bay Balcony		Break
10:20	10:40	20	Auditorium	Lavaleye, M.	Relations between the distribution of benthic Fauna and Food input on the slope and in canyons of the Celtic margin
10:40	11:00	20	Auditorium	Witte, Ursula	Patterns of benthic activity and standing stock in the deep Arabian Sea: do bulk parameters tell the whole story?
11:00	11:20	20	Auditorium	Tselepidis, Anastasios	Seasonal variability in POM flux in the oligotrophic Cretan Sea (NE Mediterranean)
11:20	11:40	20	Auditorium	Thomsen, Laurenz	Spatial and temporal variability of particulate matter in the benthic boundarylayer at the North East Atlantic Continental Margin (Celtic Sea, Goban Spur)
11:40	12:00	20	Auditorium	Jones, Emma G.	Rapid dispersal of a dolphin carcass in the deep-sea

Session VI Deep-Sea Pelagic Community Studies

10:20	10:40	20	OVCR	Priede, I.G. (Monty)	Studies on Behaviour of the Abyssal Demersal Grenadier Fish, <i>Coryphaenoides (Nematonurus) armatus</i> in North Atlantic and Pacific Oceans
10:40	11:00	20	OVCR	Toda, Tatsuki	Benthopelagic zooplankton biomass in the western North Pacific
11:00	11:20	20	OVCR	Hopcroft, Russ	Assessment of Midwater Mesozooplankton by and Optical Plankton Counter Mounted on an ROV
11:20	11:40	20	OVCR	Hunt, James	Submersible Observations of the Meso-Pelagic and Benthopelagic Fauna in Japanese waters
11:40	12:00	20	OVCR	Kikuchi, Tomohiko	Faunal characteristics of deep-sea benthopelagic zooplankton in Sagami Bay and Okinawa Trough, Japan
12:00	13:30	90			Lunch

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

Start	End	Min.	Location	Presenting Author	Title of Presentation
13:30	13:50	20	Auditorium	Robison, Bruce	Advances in Midwater Biology
13:50	14:10	20	Auditorium	Riess, Wolfgang	Real in situ measurements of respiration and metabolism of the deep sea shrimp <i>Heterocarpus grimaldii</i>
14:10	14:30	20	Auditorium	Janssens, Bernadette	Living far from oxidative stress: Adaptation of Meso-and Bathypelagic Fish to reduced oxygen toxicity
14:30	14:50	20	Auditorium	Barry	Next Meeting Location
14:50	15:20	30	Outer Bay Balcony		Break
15:20	15:50	30	Auditorium	Seibel, Brad A.	Flight of the Vampire Squid: Scaling of metabolism and aquatic "flight" in <i>Vampyroteuthis infernalis</i> (Vampyromorpha: Cephalopoda)
15:50	16:10	20	Auditorium	Herring, Peter J.	The effects of the oxygen minimum on the distribution of the mesopelagic fauna in the Gulf of Oman
16:10	16:30	20	Auditorium	Wishner, Karen	Mesozooplankton Biomass in the Upper 1000 m in the Arabian Sea: Overall seasonal and geographic patterns, and relationship to oxygen gradients
16:30	16:50	20	Auditorium	Koppelman, Rolf	Deep Arabian Sea mesozooplankton distribution and its respiratory potential
16:50	17:10	20	Auditorium	Cowles, David L.	Laboratory Measurements of Metabolism and Swimming Speed during Routine Swimming and Vertical Migration in <i>Sergestes similis</i>
17:10	19:00	130			
19:00	22:00	180	MBA: Outer Bay Waters		Symposium Banquet: Strolling Dinner at MBA

THURSDAY, 25-September

Session VII Evolution and Diversity of Deep-Sea Fauna

7:30	8:30	60	MBA : Hovden Way		Coffee
8:30	8:50	20	Auditorium	Etter, Ron J.	Evolution in the deep sea: A molecular genetic approach
8:50	9:10	20	Auditorium	George, Robert Y.	Origin and Evolution of the Asellote Isopod Crustacea in the Atlantic Deep-Ocean Environment with Emphasis on the Eurycopid genus <i>Storhyngura</i>
9:10	9:30	20	Auditorium	Wilson, George D.F.	Historical Influences on deep-sea isopod diversity in the Atlantic Ocean
9:30	9:50	20	Auditorium	Rees, Jean-Francois	Shifting Targets: Anti-oxidative mechanisms as an origin of bioluminescent anti-predation systems in the deep-sea
9:50	10:20	30	Outer Bay Balcony		Break
10:20	10:40	20	Auditorium	Brandt, Angelika	Biodiversity of Paracarida (Crustacea, Malacostraca) from the shelf to the deep Arctic Ocean : (New results from an expedition with RV Polarstern in autumn 1995)

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

Start	End	Min.	Location	Presenting Author	Title of Presentation
10:40	11:00	20	Auditorium	Williams, Gary C.	Diversity and Evolution of Deep-Sea Pennatulacean Octocorals
11:00	11:20	20	Auditorium	Creasey, Simon	Population Genetics and Biology in a Deep-Sea Spider Crab
11:20	11:40	20	Auditorium	Rogers, Alex	Genetic and morphometric comparison of two continental slope populations of the squat lobster <i>Munidopsis scobina</i> (Decapoda: Anomura: Galatheididae) from the North West Arabian Sea, with notes on the phylogeny of the Galatheididae
11:40	12:00	20	Auditorium	Beaulieu, Stace E.	Diversity of epizites on glass sponge "stalks": a unique investigation of a deep-sea hard substrate community"
12:00	13:30	90			Lunch
13:30	13:50	20	Auditorium	Scheitma, Amelie H.	Aplacophoran Molluscs of Seamounts
13:50	14:10	20	Auditorium	Amofsky, Pamela	A comparison of species in the new aplacophoran genus <i>Spiomenia</i> with a systematic overview of the deep-sea Family Simrothiellidae
14:10	14:30	20	Auditorium	Tsuchida, Eiji	Taxonomic descriptions of bathyal and abyssal gastropods, Solanisida, Bathybembix, and Lischkeia (Trochidae) from off the Pacific coast of Japan
14:30	14:50	20	Auditorium	Zal, Frank	Phylogenetic relationship between Annelida, Vestimentifera and Pogonophora revealed by the amino acid sequence of globin chains
14:50	15:10	20	Auditorium	Kojima, Shigeaki	Calptogena (Bivalvia) around Japan: taxonomy, distribution, and speciation process
15:10	15:40	30	Outer Bay Balcony		Break
15:40	16:10	30	Auditorium	McAleece, Nell	BioGrowth, a computer work bench for analysis of the demographic characteristics of deep-sea invertebrates from measurements of body size
16:10	16:30	20	Auditorium	Lambhead, P John D	BioDiversity Professional Ecological Analysis Package
16:30	16:50	20	Auditorium	Barry	Closing Remarks

Session VIII Microbial and Meiofaunal Processes in Deep-Sea Habitats

10:20	10:40	20	OVCR	Bernhard, Joan	Microaerophilic Meiofauna of the Santa Barbara Basin: Novel symbioses
10:40	11:00	20	OVCR	Rathburn, Anthony	The Ecology and Stable Isotopic Composition of Living (stained) Deep-Sea Benthic Foraminifera from the California Current System
11:00	11:20	20	OVCR	Gross, Onno	Migration and bioturbation of benthic deep-sea foraminifera
11:20	11:40	20	OVCR	Boetius, Antje	Extremely high microbial biomass and degradative activity in deep-sea sediments of the Arabian Sea
11:40	12:00	20			
12:00	13:30	90			Lunch

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

Start	End	Min.	Location	Presenting Author	Title of Presentation
Session IX Effects of Disturbance in Deep-Sea Habitats					
13:30	13:50	20	OVCR	Thistle, David	Harpacticoid copepod diversity at two physically reworked sites in the deep-sea
13:50	14:10	20	OVCR	Schriever, Gerd	Does an anthropogenic alteration of sediment parameters induce a shift in the deep-sea meiofaunal community?
14:10	14:30	20	OVCR	Schriever, Gerd	Environmental Risks of large-scale Deep-Sea Impacts
14:30	14:50	20	OVCR	<i>Seamount Conservation meeting</i>	
15:10	15:40	30	Outer Bay Balcony		Break
16:50	17:15	25	MBA		Break
17:15	18:00	45	MBA		Transport to MBARI from MBA
18:00	21:00	180	MBARI		Reception @ MBARI + Slide Show by Peter Parks

FRIDAY, 26-September

EXCURSION DAY

9:00	11:00	120			Western Flyer Tour / Cruises (possible)
9:00	15:00	360			Elkhorn Slough Nature Viewing Excursion
9:00	14:00	300			17 Mile Drive / Pt. Lobos Excursion
9:00	14:00	300			Wine Tasting Excursion

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

No.	First Author	Title of Presentation
Source and Utilization of Carbon Inputs in Deep-Sea Systems		
1	Duineveld, G.	Benthic-pelagic coupling on the shelf and slope of the oligotrophic Cretan Sea (E-Mediterranean)
2	Mitchell, L.	Origin and fate of organic carbon at the Hebridean shelf edge, west of Scotland
Effects of Disturbance in Deep-Sea Habitats		
4	Bluhm, Hartmut	Megabenthic Recolonization in the DISCOL Area (Abyssal Peru Basin): Results from the environmental research programs DISCOL and ECOBENT
5	Borowski, Christian	Macrofauna recolonization after physical disturbance in the Peru Basin. Results from the environmental research programs DISCOL and ECOBENT
6	Froescheis, O.	Does the Deep-sea function as the ultimate sink for Semivolatile pops?
7	Roberts, Murray	The sensitivities of the cold water coral <i>Lophelia pertusa</i> to oil, gas and fishing activities of the West o
Evolution and Diversity of Deep-Sea Fauna		
9	Creasey, Simon	Details of the morphometric comparison of two continental slope populations of the squat lobster <i>Munidopsis scobina</i> (Decapoda: Anomura: Galatheididae) from the North West Arabian Sea
10	Fisher, Erin C.	<i>Ophiura bathybia</i> : An Enigmatic Ophiuroid from the Abyssal NE Pacific
11	Fuiman, Lee A.	Shell morphology in the deep-sea protobranch bivalve <i>Ledella pustulosa</i> in the Rockall Trough, N.E. Atlantic
12	Hood, Sarah	Phylogenetics and Taxonomy of <i>Brisaster</i> , a genus of deep water schizasterid spatangoids
13	Levin, Lisa A.	Oxygen and Organic Matter Controls on Macrobenthic Diversity in the Bathyal Indian and Pacific Oceans
14	Mah, Christopher	Paedomorphosis, Range Extensions and an answer to the question: Can <i>Brisingsidans</i> Swim?
15	Mah, Christopher	Phylogeny and Taxonomic Revision of the <i>Brisingsida</i>
16	Schulze, Anja	A morphological approach to the phylogeny of <i>Vestimentifera</i>
17	Trask, Jennifer	Comparative Biodiversity: Hydrothermal Vent and Intertidal Mussel Communities
18	Zhadan, Dmitry G.	Biogeography of <i>Parapaguridae</i> in the IndoPacific
Microbial and Meiofaunal Processes in Deep-Sea Habitats		
20	Boetius, Antje	Relation between substrate supply and degradative capacities of microbial assemblages in deep-sea sediments
21	Buck, Kurt	<i>Thioploca</i> sp. From cold seep sites in Monterey Bay
22	Dawe, T.C.	Adaptation of the deep-sea multicorer for obtaining sediment samples with an ROV
23	Heineze, P.	Response of deep-sea benthic foraminifera from the Gulf of Tarent (Mediterranean Sea) to phytoplankton
24	Kurbjeweit, Frank	Population dynamics of deep-sea benthic foraminifera in the Arabian Sea (Indian Ocean)
25	McHatton, Sarah	Nitrate Respiration by Seep Populations of <i>Beggiatoa</i> from Monterey Canyon
Pattern and Function of Deep-Sea Populations and Communities		
27	Company, Joan	Effects of starvation on enzymatic activities of the deep-sea crab <i>Geryon longipes</i> (Decapoda, Geryonidae) from the western Mediterranean Sea
28	Drazen, Jeff	Seasonal variation in nutritional condition of <i>Coryphaenoides armatus</i> and <i>C. yaquinae</i> from the abyssal NE Pacific
29	Fautin, Daphne G.	Reproductive Periodicity in an Abyssal Sea Anemone
30	Gage, John D.	Megafauna distributions on the Hebridian continental slope from sea-bed photographs provide an integrated expression of hydrodynamic forcing of sediment processes
31	Knowlton, Ann L.	Reproductive Biology and Population Structure of Commensal and Free-Living Polynoid Polychaetes at the Lucky Strike Hydrothermal Vent Field
32	Lamont, Peter A	Benthic size structure and the oxygen minimum zone (OMZ) in the Arabian Sea

SCHEDULE OF EVENTS, ORAL PRESENTATIONS, LIST OF POSTER PRESENTATIONS

No.	First Author	Title of Presentation
33	Lamont, Peter A	Estimates of growth and production in a deep-sea Lumbrinereid polychaete from jaw mandible growth banding
34	Martin, Christopher	Changing Patterns of Macrobenthic Community Structure Across the Arabian Sea Oxygen Minimum Zone
26	Pfannkuche, Olaf	BIGSET: A New German Deep-Sea Programme
35	Roberts, Dai	Sediment distribution, enzyme profiles and bacterial activities in the guts of <i>Onerophanta mutabilis</i> , <i>Psychropotes longicauda</i> and <i>Pseudostichopus</i> sp. - What do they tell us about digestive strategies of abyssal holothurians?
36	Thistle, David	Evaluating impacts of predation by large motile epifauna on macrofauna and meiofauna in the deep sea: a test of cage performance
37	Thomsen, Laurenz	Aggregation Processes in the Benthic Boundary Layer at the Celtic Sea Continental Margin
38	Vopel, Kay	Does physical disturbance cause a persistent change in the structure of an abyssal meiobenthic community? Results from the environmental research programmes DISCOL and ECOBENT
39	Young, Craig	Unexpected feeding strategies of ascidians from the deep Arabian Sea

Deep-Sea Pelagic Community Studies

56	Braby, Caren	Sensory adaptations of midwater squids
41	Gowing, Marcia M.	Feeding ecology of the copepod <i>Lucicutia grandis</i> near the lower interface of the Arabian Sea oxygen minimum zone: implications of carbon flux
42	Parks, Peter	Oceanic & Midwater Plankton from Pacific & Atlantic Waters (SLIDE SHOW at MBARI RECEPTION)
43	Raskoff, Kevin A.	Feeding behaviors and verticle distribution of the medusa, <i>Solmissus</i> (Narcomedusae): In situ studies with the MBARI ROV Ventana
45	Richter, Claudio	Invertebrate predator control of zooplankton seasonal vertical migration in the Greenland basin
44	Richter, Claudio	Zooplankton community structure and seasonal vertical migration in the Greenland deep-sea
46	Scherzinger, Till	Nutritional patterns of mesopelagic copepod species in the Arctic Ocean - Indications for selective feeding
51	Schlining, Brian	Observations and analysis of midwater animal distributions using the ROV Ventana
47	Seibel, Brad A.	Post-spawning egg care in the mesopelagic squid, <i>Gonatus</i> (Teuthoidea: Cephalopoda)
48	Sherlock, R.E.	Effects of temperature on development of the siphonophore, <i>Nanomia bijuga</i>
49	Suntsov, Andrew	Distribution of larvae of mesopelagic fishes in the Western South Pacific
50	Sutton, Tracey T.	Trophic ecology of the deep-sea fish <i>Malacosteus niger</i> Ayres: planktivory by a top mesopelagic predator?

Sensory Systems of Deep-Sea Fauna

52	Diebel, C.	Olfactory Search Tracks in an Antarctic Fish
54	Kent, Jeremy	Visual Pigments in Deep-Sea Crustaceans
55	Witte, Ursula	Scavenging communities in the deep Arabian Sea: observations by baited camera

Studies of Specialized Habitats (Vents, Seeps, Whale-falls)

57	Chevaldonne, Pierre	Temperature temporal variability within deep-sea hydrothermal-vent animal communities: a global overview
58	Eckelbarger, Kevin J.	Ultrastructure of the ovary and oogenesis in the methane-seep mollusc <i>Bathynereis naticoides</i> (Gastropoda: Neritidae) from the Louisiana slope
59	Escobar, Elva G.	Pelagic vs. vent carbon input in megafauna of the Guaymas Basin hydrothermal vents
60	Ginguis, Peter	Inorganic nitrogen assimilation and utilization by the tubeworm <i>Riftia pachyptila</i>
61	Levai, Gyongyver	Preliminary Trophic Studies of the Hydrothermal Vent-Endemic Fish <i>Thermarces cerberus</i> (Zoarcidae)
62	Pfingst, Tynan	Characteristics of Hydrothermal Vent Communities along the southern East Pacific Rise, 17°15' to 17°40' S
63	Sahling, Heiko	Faunal community structure at cold seeps of the Aleutian subduction zone

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No.	First Author	Title of Presentation
64	Schurmeier, Jennifer	An Illustrated Guide to Lucky Strike Hydrothermal Vent Fauna
65	Shank, Timothy M.	Environmental Periodicities and Faunal Colonization Associated with Nascent Low-Temperature Hydrothermal Venting; Results of Time-Lapse Videography and Multi-Probe Temperature Measurements at 9 degrees 49.8'N on the East Pacific Rise
66	Sobjinski, Kathrin	Systematics and phylogeny of the hot vent family Lepetodrilidae McLean, 1988 (Gastropoda: Lepetodrioloidea) - a cladistic analysis
67	Zal, Frank	Identification of the sulfide-binding sites on the hemoglobin from the hydrothermal vent tube worm <i>Riftia pachyptila</i>

Radiometric age determination of the Pacific grenadier (*Coryphaenoides acrolepis*), a rapidly developing fishery in Monterey Bay

ALLEN H. **ANDREWS**, GREGOR M. CAILLIET, KENNETH H. COALE

Moss Landing Marine Laboratories, PO Box 450, Moss Landing, CA 95039

Current longevity estimates for the Pacific grenadier range from 6 to 60+ years. Age estimates in this study using the quantification of growth increments in thin otolith (ear-bone) sections indicate that the Pacific grenadier is a long-lived fish that may approach 75 years. To validate this trend, age was determined using the radioactive disequilibria of ^{210}Pb and ^{226}Ra in otolith cores from adult Pacific grenadier. Radiometric ages closely agree with age estimates from the quantification of growth increments. This confirms the annual periodicity of these increments. Therefore, the longevity of the Pacific grenadier is at least 55 years, based on radiometric aging results, and greater than 70 years, based on annual growth increments. Because the Pacific grenadier is long-lived and matures late, it may be vulnerable to heavy fishing pressure. Landings of Pacific grenadier from Monterey Bay have increased from zero for 1992 to nearly 2 million pounds for 1996. Therefore, conservative measures should be taken in this rapidly developing and unregulated fishery.

A comparison of species in the new aplacophoran genus *Spiomenia* with a systematic overview of the deep-sea Family Simrothiellidae.

PAMELA L. ARNOFSKY

Woods Hole Oceanographic Institution. Woods Hole, MA 02543

Species in the genus *Spiomenia* have been identified from localities throughout the Atlantic at depths between 1600 and 4100 m. The genus is placed in the Family Simrothiellidae (Salvini-Plawen, 1978) based on radula morphology, specifically possession of distichous bars with many denticles at some point during ontogeny and paired anteroventral radular pockets. Morphology of the radulae and spicules suggests that species from the Argentine Basin and Cape Verde/Canary Basin are more closely related to each other than either is to the Northern Atlantic species. Other genera within this family include *Helicoradomenia*, a vent species, which possesses some plesiomorphic morphological characters which are useful for defining and describing the primitive type Neomeniomorpha. Further investigation of other genera in this family may demonstrate that this family is not monophyletic.

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Phylogenetic Relationships of Whale-Fall Vesicomyid Clams Based on Mitochondrial COI Sequences

AMY R. BACO¹, CRAIG R. SMITH¹, ANDREW S. PEEK², AND ROBERT C. VRIJENHOEK²

¹University of Hawaii, Department of Oceanography, 1000 Pope Road, Honolulu, Hawaii 96822, Email: abaco@iniki.soest.hawaii.edu

²Center for Theoretical and Applied Genetics, Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, New Jersey 08903-0231

Whale skeletons on the deep-sea floor may be important habitats for organisms dependent on chemoautotrophy, acting as sulfide-rich stepping stones for dispersal. Numerous adult and juvenile vesicomyid clams have been collected at two whale fall sites on the California Slope, one at 1240 m in the Santa Catalina Basin and one at 960 m near San Nicolas Island. To identify the clams, DNA from mitochondrial cytochrome c oxidase I (COI) was amplified and sequenced from muscle tissues of nine adults and one juvenile. Phylogenetic analysis reveals that the vesicomyids collected on the whale falls represent three clades (putative species) known from other reducing habitats. Seven adult whale clams fall within a *Vesicomya gigas*/*Calyptogena kilmeri* vent clade; the juvenile clam falls into the *V. gigas*/*C. kilmeri* seep clade; and another adult falls near *Calyptogena elongata*. The final adult did not associate with any clade and may represent a newly collected species. Within their clades, most whale clam individuals are within the 1-2% range observed for intraspecific mitochondrial COI variation for conspecifics from the same geographic location. All are within the observed 7-9.5% range for conspecifics from different geographic locations. These data suggest that three of the vesicomyid taxa found on whale falls are members of distinct species that have been collected previously from other deep-sea sites. With the inclusion of the three vesicomyids, a total of fourteen species found on whale falls are now known to overlap with other reducing habitats, such as vents and seeps. Based on mitochondrial COI sequence variation, vesicomyids had a last common ancestor 22-48 mya, which coincides with the appearance of large whales in the fossil record about 40 mya.

Vesicomyid clams transfer bacteria from
adult ~~to~~ to egg

Contrasting life styles of two closely-related vesicomyid clams from cold seeps in Monterey Bay

JAMES P. BARRY¹ AND RANDALL E. KOICHEVAR²

¹Monterey Bay Aquarium Research Institute, PO Box 628, Moss Landing, CA 95039-0628; 408-775-1725, Fax 408-775-1645, email: barry@mbari.org

²Monterey Bay Aquarium, 886 Cannery Row, Monterey, CA 93940; 408-644-7522, email: rkochevar@mbayaq.org

Sea floor seepage of fluids rich in sulfide and methane occur in several geologic settings in Monterey Bay and supports faunal communities based on chemosynthesis (cold seep communities). These cold seep communities are dominated by vesicomyid clams that rely nutritionally on sulfur-oxidizing endosymbiotic bacteria. Variation in the species composition among and within seep communities is linked directly to pore fluid chemistry, suggesting that geochemistry, rather than biological interactions, plays a fundamental role in structuring these communities.

Physiological adaptations mediating sulfide toxicity and production by bacterial symbionts vary considerably between the two dominant vesicomyids (*Calymene kilmeri* and *C. pacifica*), resulting in divergent 'strategies' to contend with environmental variability. *Calymene kilmeri*, which inhabits sulfide-rich seeps, has a low sulfide binding affinity and greater sulfide tolerance than *C. pacifica*. The apparent ecological trade off between these adaptations allows for limited metabolism and growth with a wide spatial distribution, or a high growth potential with a more restricted distribution. Furthermore, differences in metabolic potential likely contribute to differences in the population dynamics of each species.

Unlike entirely heterotrophic metazoans, the evolution of bivalve-bacterial symbioses appears linked to selective pressures influencing both the host and its symbionts. Because host metabolism, growth, and reproduction is coupled directly to symbiont production, diversification in this group has probably arisen in response to selection for maximal rates of symbiont productivity in a spatially heterogeneous environment.

Diversity of Epizoites on Glass Sponge "Stalks": A Unique Investigation of a Deep-Sea Hard Substrate Community

STACE E. BEAULIEU

Marine Biology Research Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0202; 619-534-4858; e-mail: stace@ucsd.edu

Hard substrate communities in the deep sea are little-studied due to the difficulties of obtaining intact samples using traditional trawling or coring methods. Stalked epibenthic organisms, in particular the hexactinellid sponges *Hyalonema* spp., offer hard substrate in otherwise soft bottom deep-sea environments. In photographic transects conducted at an abyssal station in the N.E. Pacific (Sta. M; 4100 m depth), "stalks" and their associated epizoic community appeared to provide a substantial fraction of the epibenthic faunal diversity.

Tube cores deployed by the submersible *Alvin* at Sta. M were used to obtain 37 intact stalks with undisturbed epizoites and underlying sediment. Stalk-associated specimens were sorted and identified to the lowest possible taxonomic level. The diversity of the stalk community was compared to published values for other deep-sea and shallow water communities.

In addition to the description of the community epizoic on stalks collected in tube cores ("natural" stalks), the recruitment of organisms to stalks was examined in a series of four deployments of "artificial" stalks. The artificial stalks, constructed of *Hyalonema* spicules that were collected in trawls, were deployed for ~4-month periods at Sta. M. The diversity of epizoites on artificial stalks was compared to that of the natural stalks.

Symbiosis with sulfur- and methane-oxidizing bacteria in hot-vent molluscs — new findings

LOTHAR A. BECK

Fachbereich Biologie, Der Phillips-Universität, Zoologie, D-35032 Marburg, Germany; Beck@mail.uni-marburg.de

An unusual black mesogastropod, *Ifremeria nautilei* (= *Oligaconcha tufari*) from the deep sea hydrothermal vent site Vienna Woods in the Manus Back-Arc Basin (western Pacific) contains sulfur-oxidizing and methane-oxidizing bacteria. The snails inhabit warm vent zones (up to 30 ½ C) of active black smokers and are exposed to sulfide and methane rich hydrothermal emanations (pH 3.6). Ultrastructural examination (TEM, SEM) proves the presence of numerous thread-like sulfur-oxidizing bacteria and some coccoid methane-oxidizing organisms in specialized bacteriocytes of the gill and also some putative methane-oxidizing coccoid bacteria in the interstice of gill cells. Morpho-functional evidence shows an enormous enlargement of the gill as well as the reconstruction of the pallial complex for the purpose of ciliary filter-feeding and of space for bacterial symbionts.

SEM and TEM examinations detected endosymbiotic organisms in the extremely enlarged gill of another hot-vent gastropod, *Hirtopelta* sp. n. from East Pacific Rise 21 ½ S. Bacterial symbionts were found to live in vacuoles of numerous bacteriocytes sites in the gill leaflets of this archeogastropod.

SEM examination of the hot-vent bivalve *Bathymodiolus brevior* from hydrothermal sites at Fiji Basin also revealed gill bacteriocytes which contain bacteria in their vacuoles.

*Symbiosis w/ Two Types of bacteria, sulfur oxidizing
of methane oxidizing, leads to greater growth
rate and high abundance*

Microaerophilic Meiofauna of the Santa Barbara Basin: Novel symbioses

JOAN M. BERNHARD AND SAMUEL S. BOWSER

Wadsworth Center, New York, State Department of Health, P.O. Box 509, Albany, NY 12201-0509 and Department of Biomedical Sciences, The University at Albany, State University of New York; bernhard@wadsworth.org

Sediments of the Santa Barbara Basin (SBB; 34°15'N, 120°02'W) are bathed in severely dysoxic to anoxic water (i.e., typically <5 μ M or 0.1 mL/L) containing considerable sulfide concentrations (e.g., >0.1 μ M). Previous studies of these sediments concluded that few taxa other than the filamentous sulfide-oxidizing bacterium *Beggiatoa* inhabited these hostile conditions. Using a novel life-position method, we have found that a eukaryotic meiofaunal community thrives in the *Beggiatoa*-laden SBB sediments. Members of the benthos include numerous species of protists (mostly foraminifera and ciliates), nematodes, a polychaete, and an epifaunal gastropod. Our ultrastructural studies show the majority of the SBB eukaryotic community harbors bacterial ecto- or endobionts, most of which have not been previously reported. Putative endosymbionts were observed in the foraminifer *Buliminella tenuata* and chloroplasts are sequestered by the foraminifer *Nonionella stella*. A previously undescribed flagellate, which is structurally most similar to those inhabiting insect guts, has hexagonally-packed bacteria forming transverse bands on its surface. A Desmodorid nematode has bacteria harbored under the fold of its annulate epidermis. An undescribed polychaete has a dense layer of bacteria vesting its cuticle. To our knowledge, the only previously reported incidences of polychaete-bacterial symbioses are of species from hydrothermal vents. All three of these cases involving ectobionts have hosts with integument modifications to enhance contact with the prokaryotes, providing strong structural evidence for symbiosis. Considering the lateral extent of *Beggiatoa* mats (e.g., hydrothermal vents, hydrocarbon cold seeps, silled basins, whale carcasses, sewage outfalls, eutrofied coastal areas), it is likely that the meiofauna inhabiting them play a more significant role in a variety of processes such as nutrient cycling than previously thought. While little is known about hydrothermal vent and seep protists, it is possible that environments like the SBB provide refuge and dispersal of protistan communities to such environments, as suggested by C. Smith and co-workers for areas impacted by whale carcasses. The Santa Barbara Basin provides a readily accessible model for studying bathyal meiofaunal communities associated with *Beggiatoa*.

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Extremely high microbial biomass and degradative activity in deep-sea sediments of the Arabian Sea

ANTJE BOETIUS¹, PETRA SCHÄFER², SIBYLLE GRANDEL³, KLAUS WALLMANN³ AND KARIN LOCHTE³

¹*Baltic Sea Research Institute, 18119 Warnemünde, Germany)*

²*Institute of Biogeochemistry and Marine Chemistry, 20146 Hamburg, Germany*

³*GEOMAR, 24148 Kiel, Germany*

As part of the interdisciplinary research programme 'Biogeochemical Transport of Matter and Energy in the Deep-Sea (BIGSET)', microbial biomass, production, enzyme activity and remineralization rates were measured at five different stations in the Arabian Sea. In its western and northern regions, the Arabian Sea is strongly influenced by monsoonal winds which cause enhanced primary production and high episodic sedimentation of particulate organic matter (POM) to the deep sea. While POM flux and composition were studied in detail during several years of sediment trap deployments, we collected the first data on benthic microbial biomass and degradative activities during three expeditions from 1995-1997. A strong gradient in microbial biomass was found from the northern to the southern stations, related to the differences in the annual POM input. The extremely high microbial biomass and enhanced extracellular enzyme activities at the western station (WAST) indicate the presence of a very active microbial community. This was reflected in the high rates of carbon remineralization at WAST, largely exceeding values measured in sediments of other open-ocean regions.

Relation between substrate supply and degradative capacities of microbial assemblages in deep-sea Sediments

ANTJE BOETIUS AND KARIN LOCHTE

Baltic Sea Research Institute, 18119 Warnemunde, Germany

In deep sea sediments, the processes of organic matter (OM) degradation are dominated by bacteria. The first step in the utilization of any polymeric compounds is their digestion by extracellular enzymes, since only small molecules can pass the cell membranes. However, little is known on the regulation of the degradative capacities of natural microbial assemblages, since the measurement of hydrolytic enzyme activities by means of fluorogenic substrates was introduced to studies of microbial processes in deep-sea sediments only five years ago. Based on the results of several field investigations as well as enrichment experiments, this method is since used to detect variations in the degradative capacities of natural microbial assemblages and their relation to different levels of organic matter (OM) supply. Here we present new results from experimental studies which were carried out to test a) if the relationship between OM supply and enzyme activities is substrate specific, b) if there is a quantitative relation between substrate input and the production of specific enzymes by natural microbial assemblages and c) if new production of specific enzymes above the background level is a prerequisite for the utilization of the supplied OM.

Poster

Macrofauna recolonization after physical disturbance in the Peru Basin. Results from the environmental research programs MSCOL and ECOBENT.

CHRISTIAN BOROWSKI AND HALMAR THIEL

Alfred-Wegener-Institut für Polar- und Meeresforschung, Tiefseeforschung, Columbusstr., D-27568 Bremerhaven, Germany.

Macrofauna recolonization of experimentally disturbed sediments in the DISCOL area (ref. Poster Thiel et. al) was monitored over seven years. This presentation compares faunal abundances (animal size class >0.5 mm, obtained from 0.25 -m² box-core samples) in impacted sediments (plow tracks) to those in undisturbed areas at the experimental site and at unfenced reference sites. As analyses of the latest post impact samples presently are in progress, results of the "seven years after" situation are still of preliminary nature.

The experimental impact in early 1989 resulted in reductions of macrofauna densities to 38.6% of those in undisturbed sediments, and some major taxa were nearly eliminated (e.g. Bivalvia 9.2%). Recovery started rapidly: Only half a year after impact, macrofauna densities in disturbed samples rose to 81.8% of the undisturbed values, and rapid leveling was expected further on. Three years later, however, balanced abundances between disturbed and undisturbed samples were only observed for the Tanaidacea, whereas the recovery of all other major taxa stagnated (e.g. Polychaeta, Bivalvia) or even retrograded (Isopoda). Seven years after impact, disturbed abundances of most groups still oscillated around undisturbed values (e.g. Polychaeta, Tanaidacea, Bivalvia).

Persisting effects of the disturbance impact over at least three years were evidenced by several parameters on different taxonomic levels: Vertical depth distributions of all major taxa were significantly shifted into deeper sediment layers, when the plow tracks were refilled with semi-liquid material. Abundances of subsurface deposit-feeding polychaetes (generally regarded as sensitive towards disturbances) were reduced. Polychaete diversity (Hurlbert rarefaction) on species level, and even on family level, was lower in disturbed sediments. The reestablishment of a semi-liquid top layer apparently plays a major role for recolonization after sediment mixing. Our data illustrate that the faunal composition in the plow tracks after three years was far from reaching the state of an undisturbed community.

Poster

Sensory Adaptations of Midwater Squids

CAREN E. BRABY^{1&2}, BRUCE H. ROBISON², JAMES C. HUNT³

¹Moss Landing Marine Labs, PO Box 450, Moss Landing, CA 95039

²Monterey Bay Aquarium Research Institute, PO Box 628, Moss Landing, CA 95039-0628

³Japan Marine Science & Technology Center, 2-15 Natsushima-Cho, Yokosuka, 237 JAPAN

Part I. GRAVITY: statocyst mediated photophore movement in *Chiroteuthis calyx* and *Galiteuthis phyllura*

In situ video images of *Galiteuthis phyllura* and *Chiroteuthis calyx* show that the ventral ocular photophore remains in a ventral position regardless of body orientation. Thin-sections of these counter-illuminating photophores elucidate the mechanical relationship between the photophore and the eye. In both species, the photophore is fused with the eye and thus provides a visual point of reference for measurements of eye movement on an otherwise radially symmetrical eye. Using *in situ* video footage taken by the ROV *Ventana*, image analysis reveals the angular displacement between the photophore and the body axis and thus the behavioral extremes of mobility in these midwater forms. This data is compared to previously published laboratory-derived data of both benthic and midwater species. The angular displacement found in the benthic species is more limited than that of the midwater species, indicating a lesser degree of three-dimensional movement in the benthic organisms.

Part II. SMELL: olfactory organ morphology of *Chiroteuthis calyx*

The olfactory organs of squid are often obvious structures, located posterior and ventral to the eye. Perched at the entrance to the mantle cavity, these organs are in a prime location to monitor the large volume of water that enters the mantle cavity for respiration, removing wastes and propulsion. Being paired and covered with chemosensory cilia, the olfactory organs are able to monitor not only the nature of water-borne chemicals but also the directionality of incoming chemical cues. Preliminary electron microscopy studies of these organs in *Chiroteuthis calyx* show the complexity of these structures in this mesopelagic squid and cause questions as to the multiple functions these organs may serve.

Poster

Biodiversity of Peracarida (Crustacea, Malacostraca) from the shelf to the deep Arctic Ocean (New results from an expedition with RV *Polarstern* in autumn 1995)

ANGELIKA BRANDT

Zoological Institute and Zoological Museum, University of Hamburg, Martin-Luther-King-Platz 3, D-20146 Hamburg, Germany

During three earlier expeditions with the RVs *Meteor* and *Polarstern* more than sixty thousand peracarids were sampled from the deep Arctic Ocean (northern North Atlantic) by means of an epibenthic sledge. Sampling areas were the Kolbeinsey Ridge north of Iceland (800-1100 m), in the Northeast Water Polynya, off Greenland (45-517 m) and at 75°N east of Greenland (197-2681 m). Until now, 288 species of Peracarida have been identified to species level. These 288 species comprise 152 genera and 59 families of Amphipoda, Cumacea, Isopoda, Mysidacea and Tanaidacea. 38 genera were very frequent and were sampled at each expedition (these were 22 species of Isopoda, 7 species of Cumacea, 3 species of Amphipoda and Mysidacea, each, and 2 species of Tanaidacea).

60 genera are eurybathic, occurring at least over a depth range of 1000 m, some even from the shelf up to 2681 m depth. Only 10 genera are stenobathic, occurring only in the deep sea. No significant decrease in species number with depth or latitude could be observed.

Due to an expedition with RV *Polarstern* to the deep Arctic Ocean off Greenland in September/October 1995, it is for the first time possible to compare deep-sea stations on the background of potential seasonal changes in these high latitudes.

***Thioploca* spp. from cold seep sites in Monterey Bay**

K. BUCK¹, J. ASHEN², S. MCHATTON³, D. NELSON³ & J. BARRY¹

¹Monterey Bay Aquarium Research Institute, P.O. Box 628, Moss Landing CA 95039

²Dept. of Biology, University of California - Santa Cruz, Santa Cruz CA 95064

³Section of Microbiology, ²University of California - Davis, Davis CA 95616

Beggiatoa sp. and *Thioploca* sp. are filamentous chemoautotrophic bacteria that oxidize hydrogen sulfide. They occur in high concentrations on the continental shelf of the western coast of South America and are presumed to have a major impact upon global C, N and S budgets. While *Beggiatoa* has been identified from various other marine sites, including cold seeps in Monterey Bay, marine *Thioploca* sp. are known only from the southern hemisphere site. Cold seeps in Monterey Bay are sites of low hydrogen sulfide and methane flow from the sediment. Vesicomyid clams, vestimentiferan worms and thick filamentous bacterial mats are common at these sites. In addition to *Beggiatoa* sp., we have now identified sheathed filamentous bacteria from these mats. The presence of a polysaccharide sheath around the trichomes of *Thioploca* is the only morphological character now used to differentiate these two genera. Within the genus *Thioploca*, trichome diameter is the morphological trait distinguishing the species. At cold seep sites in the Monterey submarine Canyon, we have identified *Thioploca auraceae* and a sheathed filamentous vacuolate bacteria with a diameter of approximately 80 nm, well outside the range of described species. Local access to both *Beggiatoa* and *Thioploca* will provide the opportunity to address some unresolved issues of phylogeny, morphology, and physiology of these two closely related organisms. As an initial step in this process, we will present some gross morphological and ultrastructural features of the *Thioploca* spp. from cold seeps in the Monterey submarine Canyon.

Poster

Explaining Edge-to-Center, Bed-to-Bed, and Site-to-Site Monotony of Non-Chemosynthetic Seep Associates at Five Upper Slope Hydrocarbon Seeps in the Gulf of Mexico

ROBERT S. CARNEY

Coastal Ecology Institute, Louisiana State University

Chemosynthetic communities at continental margin cold seeps and ridge system hot vents offer potentially rich food sources within a deep-sea habitat which is generally considered to be food limited. Thus, exploitation of these high biomass communities by some fraction of the surrounding faunae is to be expected, and the composition of non-chemosynthetic seep/vent associated species should reflect such exploitation. Of the few explanations for the composition of seep/vent associates that have been propose

As a test of the locally unique exploitation hypothesis five hydrocarbon seep sites lying between 400 and 1000m in the Gulf of Mexico off Louisiana were surveyed using grab samples from the submersible Johnson SeaLink. Surveying was restricted to mussel beds where sixty-one successful grabs were taken at five sites. Efforts to sample according to a balanced ANOVA model proved unsuccessful, but samples were collected from a variety of beds within sites and at the edges and centers of such beds.

It is not possible to select among alternate explanations given the data now available, and ancillary information tends only to complicate the picture. Surveys of seep fauna at deeper locations in the Gulf of Mexico have revealed different associated species. Thus, faunal heterogeneity appears to be a function of the distance or depth scales of comparison within a given basin. However, within a restricted depth an apparently restricted species association can persist for geologically long periods of time.

Temperature temporal variability within deep-sea hydrothermal-vent animal communities: a global overview

P. CHEVALDONNÉ^{1,2}, D. DESBRUYÈRES², T.M. SHANK¹, G. LÉVAI¹, AND R.A. LUTZ¹

¹*Institute of Marine & Coastal Sciences, Rutgers University, New Brunswick, NJ 08903, USA*

²*Département Environnement Profond, IFREMER Brest, B.P. 70, 29280 Plouzané, France*

Animal communities thriving around deep-sea hydrothermal vents benefit from the characteristics of the emitted fluid, since it is the basis for their food supply through chemoautotrophic processes accomplished by microbes. The success of a species' installation at vents, however, is the result of a trade-off between the search for food (or "fuel"), and the adaptability to the harsh environmental conditions. These conditions typically have been described as hot, acidic, anoxic, radioactive, and toxic due to the abundance of heavy metals and hydrogen sulfide. Since vent communities are actually established within the mixing zone between the hydrothermal fluid and the ambient seawater, they have been shown to primarily experience highly variable environmental conditions. The analysis of time-series obtained from temperature probes deployed in different environmental settings, is a particularly adequate approach since it allows the ability to apprehend both temporal and spatial characteristics of a parameter believed to be a good tracer of the degree of mixing between seawater and the fluid.

We report here the results and synthesis of 10 years of efforts to obtain such time-series from diverse hydrothermal settings. We have analyzed recordings from latitudes ranging from 22°S to 38°N, on two different ridge systems (EPR/Guaymas and MAR) and in two back-arc basins. More than 15 different locations were studied including vent sites from one of the deepest (3525 m) and the shallowest (865 m) vent areas known so far. The instruments deployed ranged from simple autonomous Hobo probes to multi-probe recorders and benthic stations. In one instance, the temperature recorder was coupled with a current meter. Deployments lasted from a few hours, to record at short time intervals, to up to a year. The entire range of the hydrothermal ecosystem's habitats was probed, from the hottest alvinellid worm colonies found on the walls of active smokers, to the peripheral communities where temperature anomalies are hardly detectable.

Our data indicate a tremendous temporal and spatial variability at almost all scales of time and space. Both processes are highly intricate and a change in space usually induces a shift in the temporal processes, thus demonstrating the need for studies integrating both aspects. Chaotic and random variability is important and primarily results from: (1) the turbulent mixing between the two fluids; (2) volcanic and tectonic processes; (3) the fragility of some of the populated substrates, such as sulfide chimneys. However, the most important feature detected by the spectral analysis of the series, is the omnipresence of a periodic variability of tidal origin. We therefore confirm earlier reports that had detected such a tidal influence on the vent environment, and we demonstrate that tidal periodicity is the rule rather than the exception, and that wherever vent communities are found, the primary periodic signal is derived from the tides and their harmonics (ca. 3, 6, 9, 12, 24 hours). It appears, however, that the tidal influence is dampened by non-periodic processes when communities are closer to the venting source.

The way temperature is affected by tides has been discussed in the past, and it has been proposed that it could result either from a direct pressure effect on venting, or from the action of tidal cross-currents on the emitted fluid. We here demonstrate, based on current meter data, that the latter hypothesis is much more likely. The impact of these results on the global hydrothermal fauna is discussed.

Topographic mismatching of the displaced amacrine and ganglion cell populations in the retinae of deep-sea lanternfish

SHAUN P. COLLIN AND ROBERT V. HOSKINS

Department of Zoology, University of Western Australia, Nedlands 6907, Western Australia, Australia

Optimizing sensitivity and spatial resolving power in mesopelagic deep-sea teleosts is crucial for the detection of predators and prey which are visualized by bioluminescent point sources of light. In order to assess this trade-off, the retinal topography of the ganglion cell layer of the lanternfish, *Lampanyctus macdonaldi* is examined. Topographic analysis of all neuronal profiles in the ganglion cell layer shows a concentric increase in density with a peripheral peak of 17.1×10^3 cells per mm^2 (centro-peripheral gradient of 1:4). This suggests either a need for increased spatial resolution in the peripheral field and/or a high degree of neurogenesis at the retinal margin. Subsequently, the contribution of the displaced amacrine cell (DAC) population was assessed by examination of the axonal population (70% of the cross-sectional area of the optic nerve) which showed that 137,580 neurons within the retinal ganglion cell (RGC) layer possess an axon (only 2% unmyelinated) within the optic nerve. This number confirms that over 80% of the total neuronal population in the ganglion cell layer are DAC's. Comparisons between optic axon and RGC counts (based on morphological criteria and confirmed by retrograde labeling from the optic nerve using a low molecular weight dextran-biotin-lysine conjugate in vitro) also shows the topography of the DAC and RGC populations are not matched. The topographic distribution of the DAC population matches that of the total cell population but not the RGC population which shows a relatively uniform distribution of 2.0×10^3 cells per mm^2 across the entire retina. Mismatched distributions of DAC and RGC populations have been found in 12 different species which suggest a large group of mesopelagic species rely on increasing sensitivity rather than high spatial resolving power. The orientation of tapetal reflecting cells and an unusual aggregation of retinal melanocytes surrounding the optic nerve head in some species are also thought to increase sensitivity in specific regions of the visual field.

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Gametogenic ecology of hydrothermal vent polychaetes from High Rise vent field, Juan de Fuca Ridge

J.T.P. COPLEY¹, P.A. TYLER¹ AND C.L. VAN DOVER²

¹ Department of Oceanography, University of Southampton, Southampton Oceanography Centre, UK

² Institute of Marine Science, University of Alaska Fairbanks, USA

Hydrothermal vent invertebrates display a range of developmental modes and reproductive patterns than may reflect phylogenetic constraints, but discontinuous recruitment has commonly been inferred from the size-frequency distributions of samples. Polychaetes collected from High Rise vent field (Endeavour Segment, Juan de Fuca Ridge) have allowed us to examine taxonomic variation in patterns of gametogenic development at vents. This suite of samples has also enabled an assessment of spatial variation in reproductive activity and population structure within the vent community. The difficulties of reliably interpreting population structures from the size-frequency distributions of samples are also explored.

- 3 species of polychaetes
- lecithotrophic or direct development
- ① *Amphisamytha galapagensis* - continuous or semi continuous reproduction. ~~Found to~~ be synchronous
 - ② *Piravindella palmiformis* - discrete breeding found to have patchy reproduction
 - ③ *Sulfoncola* - reproduction not described - found to be asynchronous development

* See Sarrazin et al 1997. - describe the successional sequence of the communities at Juan de Fuca vents

Laboratory Measurements of Metabolism and Swimming Speed during Routine Swimming and Vertical Migration in *Sergestes similis*

DAVID L. COWLES

Department of Natural Sciences, Loma Linda University, Loma Linda, CA 92350 USA

The metabolic rates and swimming speeds of freshly captured *Sergestes similis* were measured during routine swimming and simulated vertical migration in a computer-controlled swim tunnel. Experiments were conducted on shipboard off the coast of southern and central California. Subjects were placed into the swim tunnel, then allowed to swim undisturbed in semi-darkness for periods of approximately 24 hours. Water temperatures in the tunnel were cycled to match those which would be encountered during diel vertical migrations. Average swimming speed was around 4.5 cm/s; which is similar to speeds measured in situ. There was no significant difference in swimming speeds between the cool temperatures characteristic of daytime depths and the warm temperatures encountered in surface waters at night. Metabolic rate was significantly higher at warm temperatures, especially during the early evening hours. During times of vertical migration swimming speeds did not change with temperature, but downward migration speeds were significantly higher than upward speeds. Downward migration was not associated with a decrease or cessation of swimming. Swimming speed decreased when low oxygen pressures characteristic of the oxygen minimum layer were encountered.

Population Genetics and Biology in a Deep-Sea Spider Crab.

SIMON CREASEY^{1,2}, ALEX ROGERS¹, PAUL TYLER², CRAIG YOUNG³ AND JOHN GAGE⁴

¹Marine Biological Association of the U.K., The Laboratory, Citadel Hill, Plymouth, Devon, PL1 2PB, U.K.

²Department of Oceanography, Southampton University, Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, U.K.

³Harbor Branch Oceanographic Institution, 5600 U.S. 1 North, Fort Pierce, FL 34946.

⁴The Scottish Association for Marine Science, P.O. Box 3, Oban, Argyll, PA34 4AD, U.K.

Samples of the majid spider crab, *Encephaloides armstrongi*, were collected from six stations along the continental slope of the western Arabian Sea at depths of 150-650 m. The biology and genetics of horizontally and vertically separated populations were studied.

The overall sex ratio of crabs was male-biased ($p < 0.01$), although variation in sex ratio was observed in individual populations and between size classes of crab. Size frequency data indicated that male crabs comprised at least three instars. Female crabs comprised at least two instars, the second of which probably represented a terminal moult. Accumulation of female crabs in the terminal instar probably caused the variation of sex ratio with size classes.

Length frequency distribution differed significantly between the sexes ($p < 0.001$). Within sexes, length frequency distribution varied between populations. In both sexes of *Encephaloides armstrongi* individuals from the 150m population were significantly smaller than those from the remaining populations. It is concluded that the 150m population represents a juvenile cohort. Additional length frequency differences were observed between populations in male crabs, but none were detected in female crabs.

Eight enzyme loci were detected using starch gel electrophoresis from each population of *Encephaloides armstrongi*. Genetic identity (I) values were in the normal range observed ($I = 0.98 - 1.00$) for conspecific populations. Observed heterozygosity ($H_o = 0.080 - 0.146$) was lower than expected ($H_e = 0.111 - 0.160$), but consistent to the range detected in deep-sea decapods and crustacea in general.

Genetic structure of populations was examined using F -statistics. In both sexes of *Encephaloides armstrongi* significant genetic differentiation was detected between the 150m population and all other populations. When the 150 m population was excluded, the levels of within population and between population genetic structure were not significant in female crabs, but remained significant in male crabs as a result of significant heterozygote deficiency.

It is hypothesised that: (i) The 150m population represents a genetically distinct cohort of *Encephaloides armstrongi*, (ii) female *E. armstrongi* form a single panmictic population between 300 and 650 m, (iii) male crabs are from two or more genetically distinct populations at depths of 300-650m. This caused the observed differences in morphology and allele frequency between male populations. *E. armstrongi* may exhibit male gender-biased dispersal, with the 300-650m populations representing spawning aggregations.

Details of the morphometric comparison of two continental slope populations of the squat lobster *Munidopsis scobina* (Decapoda: Anomura: Galatheidae) from the North West Arabian Sea

SIMON CREASEY^{1,2}, ALEX ROGERS¹, PAUL TYLER² AND JOHN GAGE³

¹Marine Biological Association of the U.K., The Laboratory, Citadel Hill, Plymouth, Devon, PL1 2PB, U.K.

²Department of Oceanography, Southampton University, Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, U.K.

³The Scottish Association for Marine Science, P.O. Box 3, Oban, Argyll, PA34 4AD, U.K.

During October 1994, R.R.S. *Discovery* cruise 211 sampled the benthic fauna of the oxygen minimum zone, along a vertical transect on the continental slope off the coast of Oman. *Munidopsis scobina* was collected from two stations at 900m and 1,000m using an Agassiz trawl. Morphometric analysis was made upon approximately 1,500 individuals from both populations. Individuals were sexed and ten parameters measured. Examination for ectoparasites (either bopyrid copepod or rhizocephalan) was carried out in all individuals. Brood size and mean egg volume was also determined in ovigerous females. Parasitisation was observed to affect brood size in ovigerous females. Sexual dimorphism, sex ratio bias and evidence for synchronous reproduction was also found.

The overall sex ratio was male-biased and deviated significantly from an expected 1:1 ratio ($p < 0.01$). Size frequency analysis of carapace width showed that female *M. scobina* were significantly larger than males ($p < 0.01$), and that both sexes consisted of a single instar. Sexual dimorphism was observed to be significant in a number of parameters (carpus, merus, propodus, dactyl and total cheliped 1 lengths).

Approximately 10% of all specimens were parasitised by isopods or rhizocephalans. In ovigerous females, mean brood size (b) in non-parasitised individuals ($b = 35.8$) was significantly higher ($p < 0.01$) than in bopyrid- ($b = 3.4$) or rhizocephalan-parasitised ($b = 0$) individuals. Size-frequency analysis of egg volume yielded a bimodal distribution, with peaks at 0.32 mm^3 and 1 mm^3 . No correlation between brood size, or mean egg volume and size of female was observed. These results are discussed in relation to possible seasonality in reproduction, and to previous work on brood size in galatheids.

Poster

Genetic and morphometric comparison of two continental slope populations of the squat lobster *Munidopsis scobina* (Decapoda: Anomura: Galatheidae) from the North West Arabian Sea, with notes on the phylogeny of the Galatheidae

SIMON CREASEY^{1,2}, ALEX ROGERS¹, PAUL TYLER² AND JOHN GAGE³

¹ Marine Biological Association of the U.K., The Laboratory, Citadel Hill, Plymouth, Devon, PL1 2PB, U.K.

² Department of Oceanography, Southampton University, Southampton Oceanography Centre, Empress Dock, Southampton, SO14 3ZH, U.K.

³ The Scottish Association for Marine Science, P.O. Box 3, Oban, Argyll, PA34 4AD, U.K.

During October 1994, R.R.S. *Discovery* cruise 211 sampled the benthic fauna of the oxygen minimum zone, along a vertical transect on the continental slope off the coast of Oman. *Munidopsis scobina* was collected from two stations at 900m and 1,000m using an Agassiz trawl.

Approximately 200 specimens of *Munidopsis scobina* were obtained from each station. Each individual was screened using starch gel electrophoresis for 10 enzyme loci of which 4 were polymorphic (frequency of most common allele ≈ 0.99). Genetic variability was calculated for both populations using a number of parameters. F -statistics were used to estimate the between (F_{ST}) and within (F_{IS}) population genetic variance.

The number of genetically effective migrants per deme per generation ($N_e m$) was calculated using both F_{ST} and private alleles methods. $N_e m$ values were greater than 1 and are theoretically sufficient to prevent genetic differentiation between the populations sampled due to random genetic drift.

The genetic relationships of *Munidopsis scobina* to four other species of *Munidopsis* (*M. crassa*, *M. parhaiti*, *M. spinihirsuta* and *M. subsquamosa*) and one of *Galathea* (*G. squamifera*) were also examined using allozyme loci. Within the genus *Munidopsis* pairwise comparisons of genetic identity were within the normal range expected for congeneric species. Comparisons between *G. squamifera* and *Munidopsis* spp. were within the range expected for confamilial genera.

Morphometric analysis of individuals from the two populations of *Munidopsis scobina* was also undertaken. Individuals were sexed and ten parameters measured. Examination for ectoparasites (either bopyrid copepod or rhizocephalan) was carried out in all individuals. Brood size and mean egg volume was also determined in ovigerous females. Parasitisation was observed to affect brood size in ovigerous females. Sexual dimorphism, sex ratio bias and evidence for synchronous reproduction was also found.

Adaptation of the Deep Sea Multicorer for obtaining sediment samples with a ROV

T.C. **DAWE**¹, J. ERIKSON¹, J. HEDRICK², S. ETCEMENDY¹, J. MCFARLANE¹, J. BARRY¹, K. BUCK¹

¹*Monterey Bay Aquarium Research Institute, P.O. Box 628, Moss Landing CA 95039*

²*Ocean Instruments Inc., 5312 Banks St., San Diego CA 92110*

The Multicorer has been a mainstay of deep sea benthic sampling for more than a decade. It is capable of obtaining uncontaminated sediment samples with minimal disturbance of the sediment-water interface and returning these cores to the surface. In 1996 we adapted the sample tube holding assemblies of a Multicorer for use with the MBARI Remotely Operated Vehicle (ROV) *Ventana* as part of the benthic research program. The assemblies are mounted in individual quivers on hydraulically activated arms and are deployed, fired and retrieved through the use of the ROV manipulator arms. The principal advantages of this application of the Multicorer assemblies in exploring and sampling the deep sea with a ROV include precise positioning of cores with respect to pertinent biogeochemical features (e.g. cold seeps indicated by the presence of clams) and video recording of the coring process. In addition to the enhanced quality of the benthic samples, the use of Multicorer assemblies provides larger samples than core sizes typically deployed via ROV, thereby enabling ancillary measurements of physio-chemical parameters (e.g. H₂S, grain size) to be made on a routine basis.

Poster

Olfactory Search Tracks in an Antarctic Fish

CAROL DIEBEL, JOHN MONTGOMERY, MATTHEW HALSTEAD AND JOSHUA DOWNER

School of Biological Sciences, University of Auckland, New Zealand

Like the deep-sea, the high latitude Antarctic Basins are cold and dark. Antarctic fish resemble some deep-sea fishes in their reliance on non-visual sensory systems, so can serve as useful models for sensory processes occurring in the less accessible deep oceans. Olfactory source localization is an important part of the sensory repertoire of many fishes. In the deep-sea, for example, pheromone interactions are thought to play an important part in mate localization (Jumper and Baird, 1991). This study focused on olfactory source localization in a benthic fish species in McMurdo Sound, Antarctica. The olfactory stimulus was released from a point source on the bottom and video records made of individual fish tracks approaching the source. Next olfactory plumes generated by the source were visualized by co-release of a marker with the olfactory stimulus. Video images of the plume were processed to obtain representations of local plume concentration and local current vectors. Computer simulations produced approach tracks that would be obtained by following particular search rules and these simulated approach tracks were compared with the actual tracks taken by the fish.

Jumper, G. Y. and Baird, R. C. (1991). Location by olfaction: a model and application to the mating problem in the deep-sea hatchetfish *Argyropelecus Hemigymnus*. *Am. Naturalist* 138, 1431-1458.

Poster

Long-Wave Sensitivity in Stomiid Fish with Far Red Bioluminescence

R.H DOUGLAS¹ AND J.C. PARTRIDGE²

¹Department of Optometry & Visual Science, City University, 311-321 Goswell Rd, London EC1V 7DD, UK

²Department of Zoology, University of Bristol, Woodlands Road, Bristol BS8 1UG, UK

The visual pigments of most deep-sea fish absorb radiation most readily at wavelengths around 470-490 nm, matching both the wavelengths of solar radiation that most easily penetrate clear oceanic waters and the bioluminescent emissions of most deep-sea organisms.

However, three genera of stomiid fish (*Pachystomias*, *Aristostomias* & *Malacosteus*), which have suborbital light organs emitting much longer wavelengths (above 700 nm), have been shown to possess two visual pigments which are 'long-wave shifted' in comparison to those of other deep-sea fish, with I_{max} around 520 nm and 550 nm. Although such pigments give these species an enhanced ability to see the light generated by their suborbital photophores, they still provide a far from perfect match between the visual pigment absorption spectra and these long-wave bioluminescent emissions.

We have shown, using a novel retinal wholemount technique on fresh material, that the *Aristostomias* retina contains an additional visual pigment with I_{max} around 590 nm. Similarly, *Pachystomias* also has at least three visual pigments within its retina, one of which absorbs maximally around 590-600 nm.

Using fresh outer segment suspensions, we were unable to find a similar additional long-wave sensitive pigment in the retina of *Malacosteus niger*. The photoreceptor outer segments of this species have, however, been shown to contain a photostable pigment with an absorption maximum at 672 nm. We have shown that this pigment acts as a photosensitiser, resulting in *Malacosteus* visual pigments being bleached more by a 670 nm light than by some shorter wavelengths. Preliminary evidence indicates that this photosensitising pigment is a derivative of chlorophyll a.

Thus, different strategies have been adopted by the three genera of stomiid fish to visualise their own far red bioluminescence. While *Pachystomias* and *Aristostomias* employ at least three long-wave shifted visual pigments, *Malacosteus* has only two such pigments coupled to a long-wave, chlorophyll-derived, photosensitiser. These species therefore have a 'private' region of the spectrum which might be used for intraspecific communication undetectable by other species and/or for covert illumination of prey.

Seasonal variation in nutritional condition of *Coryphaenoides armatus* and *C. yaquinae* from the abyssal NE Pacific

JEFF C. DRAZEN

Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0202

Organic matter inputs to the abyssal ocean can be in large seasonal pulses of phytodetrital material. Previous research has shown seasonal variation in the responses of two macrourid fish, *Coryphaenoides armatus* and *C. yaquinae*, to bait in the North Pacific. These results suggested increased foraging behavior during the fall shortly after maximum phytodetrital input. In an attempt to determine if seasonal variation in feeding occurs, the nutritional condition of *C. armatus* and *C. yaquinae* captured in the abyssal NE Pacific (Sta. M, 4100 m) was determined. Fish were collected five times over a two-year period. The activities of the metabolic enzymes citrate synthetase (CS) and lactate dehydrogenase (LDH) were determined for fish white muscle. No significant variation in LDH activity was found for either species (Kruskal-Wallis ANOVA, $p > .05$). However, a significant decline in CS activity was found for *C. armatus* between February and October of 1996 (Mann-Whitney U test $p < .05$) suggesting that metabolic rate and feeding level were reduced. RNA/DNA ratios, indicative of relative growth rate, were determined in white muscle for fish collected in the last year of this study. Increases in RNA/DNA ratios were found for both *C. armatus* and *C. yaquinae* from February to October of 1996. Elevated RNA/DNA ratios suggest increased growth during the fall and coincide with previously observed increases in foraging activity. It is possible that these fish have increased their energy allocation for growth or energy input has increased via increased feeding level. Proximate analyses (lipid, protein, carbohydrate, % water) of white muscle and liver tissue are currently being completed to determine energy storage levels.

Poster

BENTHIC-PELAGIC COUPLING ON THE SHELF AND SLOPE OF THE OLIGOTROPHIC CRETAN SEA (E-MEDITERRANEAN)

G. DUINEVELD¹, A. TSELEPIDES², E. BERGHUIS¹, J. VAN DER WEELE¹, G. NIEUWLAND¹, R. BAK¹

¹*Netherlands Institute for Sea Research, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands.*

²*Institute for Marine Biology Crete, Iraklio, Crete, Greece*

During the EU-funded project CINCS, we studied the temporal and spatial variation of benthic biomass and respiration along a transect from the shelf of the island Crete to the deep basin of the Cretan Sea (1600m). This area is characterized by its extreme oligotrophy, attributed to phosphorus limitation, and by the relatively high temperature (14°C) of the deeper water layers. Measurements were carried out in two months (March, September) which according to satellite CZCS images have the most contrasting phytoplankton biomass. March is the most productive of the two periods due to winter mixing. Sediment community oxygen consumption (SCOC) was measured in-situ with a benthic lander. In conjunction with SCOC, we determined the biomass and abundances of sediment bacteria, heterotrophic nanoflagellates, meiofauna and macrofauna. The chlorophyll content in sediment was used a proxy for freshly deposited phytodetritus.

SCOC, microbial biomass and sediment chlorophyll displayed consistent spatial and temporal trends, i.e. a steady decrease with increasing water depth in both months, and lower values in September below 40m water depth. In March, SCOC ranged from 10.5 mmol O₂ m⁻² d⁻¹ at 40m depth to 0.9 mmol m⁻² d⁻¹ at 1600m. The SCOC values in September were about half the winter values except for the 40m where the opposite pattern was found. The reversed pattern at the shallow station is most likely caused by phytobenthic production as indicated by porewater oxygen microprofiles and the low fluxes of phytodetritus that we recorded in a sediment trap at all stations in summer. By contrast, no temporal differences were found in the biomass of meio- and macrofauna. Our results show pelagic-benthic coupling also to occur in the Cretan Sea with its oligotrophic water column and high temperatures causing organic particles to be rapidly degraded. However, the little extra energy that reaches the sea floor in winter appears to be mainly transferred to the microbial community which is able to quickly react again because of the high temperature. The reverse situation has been reported from arctic oligotrophic ecosystems where larger organisms mainly benefit from the annual food pulse while bacterial activity is permanently low due to the cold.

Poster

Ultrastructure of the ovary and oogenesis in the methane-seep mollusc *Bathynnerita naticoidea* (Gastropoda: Neritidae) from the Louisiana slope

KEVIN J. ECKELBARGER¹ AND CRAIG M. YOUNG²

¹*Darling Marine Center, University of Maine, Walpole, Maine 04573 and School of Marine Sciences, University of Maine, Orono, Maine 04469, USA*

²*Division of Marine Sciences, Harbor Branch Oceanographic Institution, Ft. Pierce, Florida 34946, USA*

The ultrastructural features of the ovary and oogenesis have been examined in the neritid gastropod *Bathynnerita naticoidea*, a bathyal species endemic to oil and gas seeps in the Gulf of Mexico. This is the first ultrastructural study of vitellogenesis in any "archaeogastropod". The ovary is an acinus organ containing oocytes in all stages of oogenesis. Oocytes are closely associated with hypertrophic follicle cells that may play a role in oocyte nutrition. Vitellogenesis is a complex process involving both autotrophic and heterotrophic pathways that contribute to the formation of at least three types of yolk bodies. Type I yolk bodies appear to be synthesized autotrophically through the combined efforts of the Golgi complex and rough endoplasmic reticulum. Type II yolk bodies have an uncertain origin but share many ultrastructural characteristics with mitochondria, suggesting that they may be derived from the latter organelles. Type III yolk bodies appear to form through the heterotrophic uptake of extra-oocytic precursors via receptor-mediated endocytosis. Oocytes also accumulate lipid droplets and glycogen granules. Vitellogenesis in this species shows similarities with that described previously in a caenogastropod and some Heterobranch (opisthobranchs and pulmonates) species. The ultrastructural features of oogenesis suggest that this species undergoes rapid egg production. The presence of all stages of oogenesis in every ovary examined also suggests that this species could be capable of non-seasonal reproduction.

Poster

Evaluating Impacts of Predation by Large, Motile Epifauna on Macrofauna and Meiofauna in the Deep Sea: A Test of Cage Performance

DAVID THISTLE¹, JAMES E. ECKMAN², GORDON L.J. PATERSON³, P.J.D. LAMBSHEAD³, WILLIAM C. BURNETT¹

¹Department of Oceanography, Florida State University, Tallahassee FL 32306, USA

²Skidaway Institute of Oceanography, 10 Ocean Science Circle, Savannah GA 31411, USA

³Department of Zoology, The Natural History Museum, London SW7 5BD, UK

From theories of deep-sea community organization and from empirical results obtained from shallow-water, soft-bottom communities, it has been argued that predation could play a major role in the organization of deep sea communities. Despite its conceptual importance, predation as an organizing force in deep-sea communities is essentially unstudied. Although a variety of species are known to be predators in the deep sea, the large, motile epifauna (LME) are the focus of our interest because they should be important predators and appear to be susceptible to experimental manipulations with cages. We are beginning a study that will assess effects of predation and disturbance by LME in San Diego Trough (a 1050 m deep basin located off the Southern California coast) on infaunal macrobenthos and meiobenthos. Our present efforts are devoted to investigating the performance of prototype exclusion cages. We are selecting cage mesh based on specific hydrodynamic criteria, and will use radiochemical and core-sampling techniques, plus *in situ*, time-lapse photography, to test the efficacy of LME exclusion and to evaluate and minimize potential cage artifacts. With the knowledge gained, we will carry out a follow-up study in which we will conduct experiments sufficiently free of artifacts to allow effects of LME to be seen. Results of our study should begin to clarify a major uncertainty in deep-sea community organization and should be widely applicable because of the presence of LME in most deep-sea communities.

Poster

Biomass patterns of deep-sea benthos in the Gulf of Mexico

ELVA G. ESCOBAR¹ AND G.T. ROWE²

¹*Laboratorio de Ecología del Bentos; ICMyL UNAM; A.P. 70-305; 04510 México, D.F.;
escobri@mar.icmyl.unam.mx*

²*Department of Oceanography; Texas A & M University; College Station, 77843; growe@ocean.tamu.edu*

Information from the deep-sea benthic communities in the Gulf of Mexico date back to the late 60's and early 70's; this earlier information characterized the Gulf as an oligotrophic basin. This recent information with an ample coverage of the western portions of the Gulf indicate a higher variability in the distribution pattern of the benthic biomass as had previously been described. As a tropical and relatively semi-isolated basin the Gulf of Mexico has been characterized oligotrophic based in its low primary productivity and earlier benthic biomass records. Varying environmental conditions along the western Gulf seem influence the community structure. Polychaetes, tanaid shrimps and bivalves contributed with >80% of macrobenthic biomass. Meiofauna biomass related to high densities of nematodes, foraminifera and harpacticoid copepods. Largest benthic biomass (0.70 ± 0.11 to 1.42 ± 0.32 ww/m²) was recorded at a depth range of 1200 and 1800m, values decrease into the abyssal plain. Higher or similar values were recorded at restricted locations off the Mississippi and Coatzacoalcos, and at the Bank of Campeche. These biomass values correlate with higher organic matter. Oligotrophic areas were recognized at the Campeche Scarpment. The responses of the biomass in a simplified benthic assemblage to different scenarios of organic carbon input were simulated. A steady increase that reaches a steady state with values similar to a continental shelf is recognized with a modest but continuous input that can simulate a trend recorded at sites with the largest biomasses.

Pelagic vs. vent carbon input in megafauna of the Guaymas Basin hydrothermal vents

ELVA G. ESCOBAR¹, L.A. SOTO², AND L.A. FUENTES³

¹Laboratorio de Ecología del Bentos; ICMYL UNAM; A.P. 70-305; 04510 México, D.F.;
escobri@mar.icmyl.unam.mx

²Laboratorio de Ecología del Bentos; ICMYL UNAM; A.P. 70-305; 04510 México, D.F.; lasg@mar.icmyl.unam.mx

³Department of Oceanography; Texas A & M University; College Station, 77843; cifuentes@ocean.tamu.edu

The complex hydrothermal vent system recorded in the Guaymas Basin has been recognized by its sedimentary conditions. Complexity can be expected in the food sources supporting the assemblage of megabenthic crustacea occurring in the different habitats. Expected sources being among others organic carbon of pelagic origin (POC) or vent related based on hydrocarbon, methane or sulfur, or directly linked to the chemosynthetic paths of symbiotic associations in the vents. Carbon and Nitrogen elemental and stable isotopic analyses carried out in sediment samples and tissue of megabenthic components allow to recognize three types of faunal assemblages. A vent assemblage of organisms hosting symbionts characterized by metabolic requirements based on sulfur chemosynthesis, ($\delta^{15}\text{N}$ -0.7 to 4.9; $\delta^{13}\text{C}$ -16 to -12.7). A second assemblage of Crustacea commonly recorded at the vents that have a diet dominated by a photoautotrophic signature ($\delta^{15}\text{N}$ 10 to 18; $\delta^{13}\text{C}$ -12 to -26). A third assemblage composed by diverse polychaete species that have a mixed diet and may be the most important carbon source to abyssal dwellers visiting the vent system. The complexity of the carbon sources in the vent system and the proportions of POC of pelagic vs vent origin should be considered when interpreting these values as mixing equations can depict.

Poster

Evolution in the deep sea: A molecular genetic approach

R.J. ETTER¹, M.R. CHASE¹, M.A. REX¹ AND J. QUATTRO²

¹*Biology Department, University of Massachusetts, Boston, MA 02125*

²*Department of Biology, University of South Carolina, Columbia SC 29208*

The origin of the extraordinarily diverse deep-sea benthic fauna is poorly understood and represents an enormous gap in our understanding of basic evolutionary phenomena. The main obstacle to studying evolutionary patterns in the deep sea has been the technical difficulty of measuring genetic variation in species that are typically minute, must be recovered from extreme depths and are fixed in formalin. We developed molecular genetic techniques to work with formalin-fixed macrofauna. Population genetic structure of several species of bivalves and gastropods revealed strong differentiation along a depth gradient from 500 to 4800m despite the lack of any obvious topographic or oceanographic features that would impede gene flow. Our findings indicate that the deep-sea macrofauna can have strong population structure over small spatial scales, similar to that observed in shallow-water and terrestrial organisms, with important implications for evolution in the deep sea. Our new genetic methods make it possible for the first time to use extensive available collections of deep-sea species to explore the evolutionary-historical basis of deep-sea biodiversity on global scales, and add a new dimension to the use of museum collections in general for spatial and temporal analyses of population structure.

Reproductive Periodicity in an Abyssal Sea Anemone

DAPHNE G. FAUTIN

*Division of Biological Sciences, and Natural History Museum, University of Kansas, Lawrence, KS 66045 USA;
fautin@kuhub.cc.ukans.edu*

Bathypheilia aust-ralis, originally described from the Pacific sub-Antarctic, is the most abundant species of sea anemone at 4100 m off the coast of south-central California. I studied gametogenesis in specimens collected several times a year from 1989 through 1995. Sexes are separate in *B. Australia*. Sperm bundles matured through the year, and males appeared to release sperm most years in the interval between collections of October and February. Eggs were released during the same interval but mainly on alternate years; I infer it takes an egg more than a year to mature. This cyclicity in gametogenesis and spawning appears to be triggered by an exogenous signal associated with the rain of organic material from surface waters.

***Ophiura bathybia*: An Enigmatic Ophiuroid from the Abyssal NE Pacific.**

ERIN C. FISHER AND LYNN M.L. LAUERMAN

Marine Biology Research Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0202; 619-534-4858; lm1@ucsd.edu

We examined several demographic parameters to determine the effects of a seasonally varying food supply on a population of brittle stars, *Ophiura bathybia*, from a long time series station in the abyssal NE Pacific (Sta M; 34°50' N, 123°00' W; 4100 m depth). Sta. M is characterized by increased sinking particulate organic matter (POM) flux in the summer and fall. Disc diameter was measured for *O. bathybia* trawled seasonally at Sta. M from 1989 through 1995. Individual disc diameters ranged from 5.4-21.6 mm, but the overall size frequency distributions varied little over the time span of this study; mean disc diameter (averaged for each collection) ranged from 14.7-16.7 mm (n=37 trawls). Growth bands on the vertebral arm ossicles and biochemical composition (protein, carbohydrate, and lipid) were examined for seven time points within a one year period (June 1994 through June 1995). Scanning Electron Microscopy of vertebral arm ossicles revealed distinct banding on the surface of the fossae; however, the bands could neither be confidently measured nor quantified. Mean values for biochemical components (n = 20 for each time point) ranged from 5.77 - 9.12 % AFDW (ash free dry weight) for protein, 4.31 - 5.68 % AFDW for carbohydrate, and 14.76 - 19.34 % AFDW for lipid. None of these components exhibited temporal variation, and neither size nor gender correlated with biochemical composition of individual specimens. During the time period examined, we were unable to detect a response by this population of *O. bathybia* to seasonal increases in the supply of POM to the sea floor at Sta. M using parameters such as size frequency distributions and biochemical composition.

Poster

Electrophysiologically Determined Spectral Sensitivities of Deep-sea Crustaceans

T.M. FRANK AND E.A. WIDDER

Harbor Branch Oceanographic Institution, Ft. Pierce, Fl.

The spectral sensitivities of several species of deep-sea crustaceans were determined by adapting an electrophysiological apparatus for shipboard use. An earlier study on members of the family Oplophoridae determined that 3 genera possessed two peaks of spectral sensitivity, including one in the near UV. These electrophysiologically determined peaks of sensitivity were later correlated with the presence of two visual pigments, one absorbing primarily in the blue, and one absorbing primarily in the near UV. Results of the current study indicate that this UV sensitivity is not a ubiquitous phenomenon among deep-sea crustaceans, as it has not been found in any of the species studied here in the families Euphausiidae, Sergistidae, Hyperiididae or Pasiphaeidae. All the species studied in these families have single spectral sensitivity peaks in the blue region of the spectrum, and no wavelength specific effect of a chromatic adapting light on either the shape of the spectral sensitivity curve or the individual response waveforms were found, indicating that these species possess a single visual pigment. However, the widths of the spectral sensitivity functions varied from species to species, and were often substantially broader than the visual pigment nomograms, which may be due to substantial differences in the amount of screening pigment present in the photoreceptors of the various species.

Does The Deep-Sea Function as the Ultimate Sink for Semivolatile POPS?

O. FROESCHEIS^{1&2}, R. LOOSER¹, K. BALLSCHMITER^{1&2}, W.M. JARMAN³, G. CAILLIET⁴

¹Department of Analytical and Environmental Chemistry, University of Ulm, D-89069 Ulm-Germany

²Center of Technology Assessment in Baden-Württemberg, D-70565 Stuttgart-Germany

³University of Utah, Civil and Environmental Engineering, Energy and Geoscience Institute, 421 Wakara Way, Suite 125, Salt Lake City UT 84108

⁴Moss Landing Marine Laboratories, POB 450, Moss Landing, CA 95039

The concept of an environmental multiphase distribution of persistent organic pollutants (POPs) regulated by the physicochemical properties of the respective compounds is well established. The theoretical aspects of it are discussed among other by D. Mackay at the University of Toronto (and his coworkers), whereas we have been investigating the actual problem in the field for several years.

The general principle of the interaction of global mass flow in the basic environmental compartments (atmosphere, hydrosphere, geosphere, and biota) and the molecular properties of persistent pollutants can be summarized by the old chemical statement "similia in similibus" - equal to equal.

While the stable and volatile fluorochlorohydrocarbons take the stratosphere as the ultimate environmental compartment, the semivolatile POPs will end up in the terrestrial environment in the upper soil of the forests, collected and carried off by the leaves and the needles. In the global marine environment their fate is to be collected in the fauna of the abyss. Transported by living (food cascades) or dead biota (absorbed to the detritus and marine snow) semivolatile POPs reach the deep-sea where they biomagnify in the food web.

We have analyzed a variety of fish and invertebrates collected in the Monterey Bay Canyon for POPs. We have found a variety of POPs, and some at relatively high concentrations, supporting the hypothesis of the contamination of the deep-sea by POPs.

Will the fauna of the abyss in its way mirror the accumulation of long-term of persistent anthropogenic chemicals as we observe it for the volatiles in the stratosphere, and eventually accumulate to levels that are detrimental to deep-sea ecosystems?

Poster

Quantitative analysis of rhodopsin densities in rod outer segments of deep-sea fish retinae: an electron microscopic immuno-gold study

E. FRÖHLICH¹, W. DE GRIP² AND H.-J. WAGNER¹

¹Anatomisches Institut, Universität Tübingen, Germany

²Institute of Cellular Signalling, Katholieke University, Nijmegen, The Netherlands

In deep-sea fishes with multi-bank retinae high densities of visual pigment have been measured by spectrophotometry of retinal extracts or of single cells. With this method it is difficult to identify the origin of outer segments from different banks of . The different banks may be bleached differently by light and only the most distal banks have contact with the retinal pigment epithelium. It was proposed that not all banks are equally functional. To test this hypothesis it is necessary to investigate the outer segments in the different banks separately.

We used a morphological method (immuno-electron microscopy) which allows to determine the density of rhodopsin separately. Outer segments in the retinae of eight mesopelagic and one bathybenthic deep-sea fishes, of the shallow-water fish *Rutilus rutilus* and of cattle were investigated.

Retinae were embedded in a hydrophilic plastic resin and an antibody directed against bovine rhodopsin was used. The binding of the primary antibody was quantified with Protein A coupled to gold particles (15 nm). Gold particles were counted over outer segment profiles totalling an area of at least 1 mm² in each location (proximal and most distal bank).

Rutilus rutilus and cattle outer segments showed roughly the same densities of gold particles (60-70/μm²), whereas densities in deep-sea fishes ranged from 65-156/μm². The densities were not correlated to the number of the banks but possibly to the depth of the habitat because the bathybenthic fish showed highest densities. Outer segments of proximal banks had slightly but not statistically significantly higher densities than distal banks. For four deep-sea fish species belonging to the same genus as our specimens spectrophotometry data are available. Direct comparison of these data with rhodopsin densities is difficult but the differences between surface-dwelling fishes and three of the deep-sea fishes were similar for spectrophotometry and for rhodopsin densities.

From our experiments we conclude that i) deep-sea fishes differ markedly in the density of immunoreactive rhodopsin, ii) these interspecies differences correlate with differences in spectrophotometry data, iii) deeper living species tend to contain higher densities of rhodopsin and iv) in multi-bank retinae all banks of outer segment contain similar densities of rhodopsin suggesting that all banks are functionally equivalent.

Shell morphometry in the deep-sea protobranch bivalve *Ledella pustulosa* in the Rockall Trough, N.E. Atlantic

LEE A. FUIMAN¹, JOHN D. GAGE² AND PETER A. LAMONT²

¹University of Texas at Austin, Marine Science Institute, 750 Channelview Drive, Port Aransas, Texas, 78373, USA

²Scottish Association for Marine Science, Dunstaffnage Marine Research Laboratory, P.O. Box 3, Oban, Argyll, Scotland, PA34 4AD

The deep-sea protobranch bivalve species *Ledella pustulosa* has been recently described as comprised of four subspecies, differentiated on subtle differences in shell morphology. Two of these, *L. p. pustulosa* and *L. p. marshalli*, possess overlapping geographic distributions, *L. p. pustulosa* occurring on the continental slope, and *L. p. marshalli* occurring on the continental rise and at upper abyssal depths in the N.E. Atlantic. Principal components analysis was applied to six collections of *Ledella pustulosa* from the Rockall Trough in order to explore patterns of variation and to test if the variability follows a depth-related cline which might be under environmental control. The distributions of shell shapes at each depth overlapped broadly with the distributions of those from other depths. None of the animals from the different depths had uniformly distinct shells. However, the mean shapes of the six collections divided into two clusters: a shallow cluster characterised by a lower dorsal profile (smaller "shoulders") and a deep cluster with larger "shoulders." No bathymetric trend in shape was found within these clusters. A discriminant function based on training samples of *L. p. pustulosa* and *L. p. marshalli* correctly identified 84% of the shells in the training samples and was applicable over a wide range in shell size. It showed that the subspecies differed primarily in aspects of the anterior shoulder. The discriminant function was applied to 598 shells from depths of 1,632 m to 2,900 m in the Rockall Trough in order to test the hypothesis of depth-related segregation of the subspecies. Although individual variability was high, the results indicated a gradual transition from *L. p. pustulosa* dominance at about 2,000 m to *L. p. marshalli* dominance at 3,000 m depth, but not marked segregation. A collection from 1,632 m depth with large proportions of both subspecies suggested a latitudinal gradient in distribution, rather than a bathymetric gradient. Environmental factors, such as bottom currents, acting on a common genotype to cause the observed pattern of differentiation, may also be involved in causing the pattern of differentiation. For example, differences in current energy may influence the growth of the shell. Certainly a depth-related pattern in bottom strength of currents may be inferred from various other data which correlates well to the observed depth-related pattern in shell shape.

Poster

Community ecological characteristics of the seep community at the Off Hatsushima Site, Sagami Bay, Japan

KATSUNORI FUJIKURA¹, YOSHIHIRO FUJIWARA¹, JUN HASHIMOTO¹ AND TAKASHI OKUTANI²

¹Deep Sea Research Department, Japan Marine Science and Technology Center, 2-15 Natsushima Yokosuka, Kanagawa 237, JAPAN

²College of Bioresource Sciences, Nihon University, 1866 Kameino Fujisawa, Kanagawa 252, JAPAN

The bathyal chemosynthetic community called Off Hatsushima Site (OHS) at a depth ranging from 830 to 1,200 m in Sagami Bay contains a cold seep theoretically created by a complicated geologic setting including plate convergence and deep groundwater lateral migration. This study compared the community ecology between the OHS and three reference communities: Okinoyama Bank Site (OBS) in Sagami Bay (1,050 - 1,180 m deep, cold seep, 35 km from OHS), Minami-Ensei Knoll (MEK) in the Okinawa Trough (700 - 740 m deep, hydrothermal vent, 1,350 km from OHS); and a bathyal community (570 - 1,340m deep) near the OHS which is non-chemosynthetic; all are in Japanese waters.

Twenty-three chemosynthetically obligate mega- and macro-benthic species occurred at the OHS, 13 species at the OBS, and 24 species at the MEK. Based on analyses of the fauna at these sites, several invertebrate taxa characteristic of Pacific vent and seep systems are present. These include vesicomylid clams, deep-sea mussels and vestimentiferan tubeworms. In contrast, 69 species occurred from the non-chemosynthetic bathyal community near the OHS.

Only one or two species exist in high density within the three chemosynthetic sites. OHS and OBS were dominated by dense beds of the vesicomylid clam, *Calyptogena soyoae*, and the provannid snail *Provanna glabra*. MEK was dominated by the deep-sea mussel *Bathymodiolus japonicus* around its vents. Faunal composition of the OHS was similar to that of the OBS owing to 12 common species. Despite this similarity, community characteristics (rank-relative abundance series and similarity) of the OHS differed from OBS, and were instead very similar to those of the MEK.

In Situ Spawning of a Deep-Sea Vesicomid Clam by Increasing the Water Temperature

YOSHIHIRO FUJIWARA¹, JUNZO TSUKAHARA², JUN HASHIMOTO¹, AND
KATSUNORI FUJIKURA¹

¹ *Deep-Sea Research Department, Japan Marine Science and Technology Center (JAMSTEC),
2-15 Natsushima, Yokosuka 237 JAPAN*

² *Faculty of Science, Kagoshima University, 1-21-35 Kohrimoto, Kagoshima, 890 JAPAN
(Visiting Researcher of JAMSTEC)*

The vesicomid clam, *Calyptogena soyoae*, is a conspicuous species at deep-sea seep sites in Sagami Bay, Japan, and is thought to depend on a chemoautotrophic symbiosis with bacteria as do other vesicomid clams. The spawning behavior of the clam was observed in situ over 12 days between December 1993 and June 1995. Observations were made using a deep-sea observatory off Hatsushima Island in Sagami Bay. Spawning events occurred independently of season or lunar period, which are known to be related to the spawning of some marine invertebrates. We tried to correlate spawning data from the observatory with some environmental factors. Only water temperature showed any correlation. An increase of more than 0.1 degree C from initial temperature readings always coincided with the beginning of spawning behavior, although spawning did not occur with every temperature increase. A heating experiment was performed on a vesicomid clam bed during Shinkai 2000 dive. Spawning commenced 5 minutes after heat was applied. Water from the heating device was collected after the spawning of several males. Many spermatozoa were observed in the precipitates from heated water. They were approximately the same size and shape of the spermatozoa in the testes of the clam. The potential benefit derived from synchronized spawning induced by water temperature changes suggests that this strategy may be widespread in deep-sea chemosynthetic communities.

Ecology and demographic characteristics of a dense brittle star population on the Scottish continental slope

JOHN D. GAGE AND PETER A. LAMONT

Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, P.O. Box 3, Oban, U.K. PA34 4AD

Populations of the small bathyal ophiurid brittle star *Ophiocten gracilis* (G.O. Sars. 1871) are well developed on the upper continental slope off Scotland. Although still little known, these populations seem to be a part of a semi-continuous, ribbon-like distribution on the upper slope and submerged banks around 500-1,000 m depth throughout the northern North Atlantic. Counts of brittle stars visible in oblique-view seabed photographs show population densities up to 695 m⁻². Analysis of the nearest neighbor distances between individuals using a Canadian grid superimposed on the photographs shows individuals have a non-random, overdispersed distribution. This was caused probably by the need for adequate arm spread during feeding, because overdispersion was most pronounced in the densest populations at about 700 m depth. The diet of the brittle stars is probably phytodetritus, as the gut is filled with amorphous material with high chlorophyll content. It is still uncertain whether the animals intercept suspended particles in the current or take in material lying on the bed.

Study based on natural skeletal growth marks present in the arm ossicles, and on disc size frequencies in samples taken at different times of the year, have provided data for a demographic model for this species. The skeletal growth banding shown on the surface of the arm ossicle using SEM is assumed to reflect annual variation in growth. This is probably related to the seasonal changes in dietary intake, the bag-like stomach being squeezed into a very small space by the gonads which develop through the autumn and winter and almost completely displacing it in ripe individuals. The species reproduces in late spring with early development as an ophiopluteus larva that is widely dispersed in the oceanic surface plankton in the North Atlantic. Disc size frequencies of *Ophiocten gracilis* were measured in four epibenthic sled samples from 1,000 m depth. When arranged according to date over a notional single year, these frequencies show a clear trend of increasing modal size for two distinct peaks covering the smallest sizes in the multimodal size structure. We here fit a demographic model to these frequency distributions for *Ophiocten gracilis*. This is achieved by means of non-linear optimisation of a suite of model parameters, including those determining growth and survivorship. This represents an astonishingly high rate of production by deep-sea standards.

Megafauna distributions on the Hebridean continental slope from sea bed photographs provide an integrated expression of hydrodynamic forcing of sediment processes

JOHN D. GAGE¹, LYNDA MITCHELL¹ AND JOHN D. HUMPHERY²

¹*Scottish Association for Marine Science (SAMS), P.O. Box 3, Oban, Argyll PA34 4AD U.K.*

²*Proudman Oceanographic Laboratory, Bidston Observatory, Birkenhead, Merseyside L43 7RA U.K.*

Studies by the SAMS during the 1980s based on extensive benthic sampling using benthic sleds and trawls have described the depth-related distribution of megafauna on the Scottish continental slope off the Hebrides. These studies showed that the maximum rate of change in species composition of the megafauna occurs at around 700-1,000 m depth, and again at about 2,000, depth.

Many hundreds of photographs of the sea bed on the Hebridean continental slope have been recently taken in the course of a multidisciplinary study of oceanographic processes in the Shelf Edge Study (SES), a component part of the U.K.'s Natural Environment Research Council's Land-Ocean Interaction Study (LOIS). Study of the fauna visible in these high quality images have provided corroboration of these depth-related patterns and provide indications for controlling processes. The photographs were taken along depth transects using an 80-mm camera system owned by the Proudman Oceanographic Laboratory, Birkenhead.

The photographs show dramatic depth- and declivity-related changes in composition and densities that appear to be associated with the changing downslope environment, particularly that associated with the flow regime at the seabed. The distribution of species, particularly those utilizing currents for intercepting food particles, seem to be associated with flow conditions. Knowledge of the distribution of such organisms may be very useful in broadscale mapping of physical forcing in sediment processes on the slope. In this respect they may be at least as useful as sediment bedforms in interpretation of integrated flow conditions over long timescales. The faunal 'breaks' observed in faunal distributions mapped from the trawl samples seem to fit in with major downslope changes in the sea bed environment that are visible in the photographs. For example, at 700-1,000 m the bottom changes from a variable sandy to cobbly deposit to a sandy mud, reflecting changes in hydrodynamics. Below this depth physical forcing becomes much reduced until about 2,000 m where seabed currents become stronger again as a consequence of boundary currents.

The photographs show an oblique view about 1 m wide and 2 m deep and offer insights into the ecology of individual species of the surface-living motile, sessile epifauna (dominated by echinoderms) and other species, and also of the source organisms for sediment traces that are visible on the surface.

Poster

Bottom fauna in the area of Paramushir gas-hydrate seepage (Sea of Okhotsk)

S.U. **GALKIN** AND Q.P. KUZUETSOV

Institute of Oceanology, Russian Academy of Science, Nakhimovskii pr., 36, Moscow 117218, Russia; Tel. (095)1292118, Fax. (095)1245983, email: galkin@bentos.ioras.ssk.ru

The study was performed using two submersibles Pisces (R/U Akademik Mstislav Keldysh). Direct observations in the area of gas seeping were carried out as well as photography, videotape recording and sample collection. Gas emergence (methane 90%) was discovered on the field around 50 meters across (750-800 m depth). It has been found that the benthic population there is a new specific community-ecosystem confined by territory near seepage existing due to photo and chemosynthetic food sources. Thyasirid mollusks *Conchocele* n.sp. dominate the community. Normal digestive tract containing common planktonic diatoms suggests that filter feeding is possible. Besides gills are extensively developed (29% - 31% of net width in adult specimens). TEM-analysis shows the presence of intracellular bacterial symbionts in gill tissues. The amount of organic carbon derived from CH_4 and CO_2 varies from 4,4 (mantle) to 12,8 (gills) mg per 1 g of protein per 1 hour. Besides methane derived organic carbon amount from 687 to 767 in different tissues. Stable isotope composition, microbiological and anatomical investigations suggest mixotrophic feeding type of *Conchocele* n.sp. The second peculiar species is ampharetid polychaete of a new genus *Parvelliussushakovi*. Presumable feeding source of these polychaete are free-living bacteria of Beggiatoa-type. The density of mollusk amount 15-20 specimens per m^2 (biomass at least 2,5-3 kg per m^2); density of polychaetes — 5000 - 6000 specimens per m^2 . Such high indexes have not been recorded previously from similar depth in Okhotsk Sea.

Origin and Evolution of the Asellote Isopod Crustacea in the Atlantic Deep-Ocean Environment with Emphasis on the Eurycopid genus *Storthyngura*"

ROBERT Y. GEORGE

Department of Biological Sciences, University of North Carolina at Wilmington, Wilmington, North Carolina 28403

The deep-sea environment of the Atlantic ocean, that is younger than the Pacific ocean in geologic ages, still exhibits a high species diversity of the asellote isopod crustaceans which appear to be an order of magnitude less diverse in the shallow water environment anywhere in the world oceans. Asellote isopods are primitive in morphology in comparison with other marine isopods such as Anthuridea, Gnathidea, Valvifera, Epicaridea, Calabozoidea and Microcerberidea. This paper deals with a rich collection of asellote isopod species that were collected by this author under the sponsorship of the UNCW Deep Sea Biology Program (DSBP) over a period of three decades. The data suggest that the evolution of infaunal deep sea isopods such as the genera of the family Ischnomesidae is very different from the evolution of the genera of the family Eurycopidae which contain species that have posterior paraeopods modified for limited swimming. A detailed morphometric analysis, involving 36 characters and 142 character states in the genus *Storthyngura*, revealed a phylogeny that suggests that the genus originated in the Antarctic ocean and radiated and speciated into the abyssal plains and trenches in the world oceans except the Arctic ocean. The pattern of sympatric speciation in the abyssal depths of the Atlantic ocean throws light on the evolution of this eurycopid genus *Storthyngura* different from other eurycopid genera such as *Eurveope*, *Svneurveope* and *Acanthocope*. Based on preliminary results, the application of molecular tools in studying the genomic DNA with the use of the RAPD technique and the nucleotide sequences of mitochondrial 16 rRNA is discussed in relation to patterns of evolution in the deep sea asellote isopods in the Atlantic deep-sea environment.

Inorganic nitrogen assimilation and utilization by the tubeworm *Riftia pachyptilla*

PETER GIRGUIS

The hydrothermal vent tubeworm *Riftia pachyptila* lives in association with chemolithoautotrophic bacteria which are housed deep within its trunk. The worm lacks a digestive tract and thus relies upon its symbionts to fulfill its nutritive requirements. The association's carbon and sulfur metabolism have been well documented, however nitrogen metabolism has not been thoroughly addressed. In the vent environment, ammonia and free amino acid concentrations are below 2.7 mM and 2 nM respectively, making them unlikely sources of nitrogen to the association. Nitrate, however, is present at higher concentrations (40 mM) and can be utilized by the symbionts. Here we report that nitrate is assimilated at a substantial rate ($> 4\text{mM/g}^* \text{ hr}$), with a concomitant production of ammonia. In addition, under steady state conditions there is a discrepancy between the total nitrogen assimilated via nitrate uptake and the total nitrogen lost via ammonia excretion, indicating the existence of a nitrogen "sink." Previous research (Lee, 1996) has demonstrated the presence of ammonia assimilatory enzymes in the tissues of the host. We suggest that the end-product of nitrate reduction by the symbionts, ammonia, is the primary source of nitrogen for the host. In light of this phenomenon, *Riftia pachyptila* may represent an association which is "autotrophic" with respect to carbon and nitrogen.

Poster

Sulfide Acquisition by the Vent Worm *Riftia Pachyptilia* Appears to be via Uptake of HS⁻, Rather than H₂S

SHANA K. GOFFREDI, JAMES J. CHILDRESS, NICOLE T. DESAULNIERS, AND FRANCOIS H. LALLIER

Oceanic Biology Group, Marine Science Institute and Department of Biological Sciences, University of California, Santa Barbara, CA 93106, USA

Deep sea hydrothermal vents are home to a variety of invertebrate species, many of which host chemosynthetic bacteria in unusual symbiotic arrangements. The vent tubeworm *Riftia pachyptilia* relies upon internal chemoautotrophic bacterial symbionts to support its large size and high growth rates. Because of this *Riftia* must supply sulfide to the bacteria, which are far removed from the external medium. Internal SH₂S can reach very high levels in *Riftia* (2⁻¹² mmol l⁻¹ in the vascular blood), most of which is bound to extracellular hemoglobins. The animal can potentially take up sulfide from the environment either via H₂S diffusion, mediated uptake of HS⁻, or both it was expected that H₂S diffusion would be the primary sulfide acquisition mechanism, paralleling the previous demonstrated preferential uptake of CO₂. Our data show, however, that the uptake of HS⁻ is the primary mechanism used by *Riftia* to obtain sulfide and that H₂S diffusion into the worm apparently proceeds at a much slower rate than expected. This unusual mechanism may have evolved because HS⁻ is less toxic than H₂S and because HS⁻ uptake decouples sulfide and inorganic carbon acquisition, which occurs via the diffusion of CO₂ at very high rates due to the maintenance of an alkaline extracellular fluid pH. Thus H₂S accumulation is limited to that which can be bound by the hemoglobins, protecting the animal from sulfide toxicity and the symbionts from sulfide inhibition of carbon fixation.

Feeding ecology of the copepod *Lucicutia grandis* near the lower interface of the Arabian Sea oxygen minimum zone: implications for carbon flux

MARCIA M. GOWING¹ AND KAREN F. WISHNER²

¹*Institute of Marine Sciences, University of California, Santa Cruz, CA 95064*

²*Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882*

Feeding ecology of the calanoid copepod *Lucicutia grandis* collected in the Arabian Sea at one station during the inter-monsoon in March-April and during the southwest monsoon in September 1995 was studied with transmission electron microscopy of gut contents. Highest abundances of these animals occurred from ~400-1100 m, near the lower interface of the oxygen minimum zone and at the inflection point where oxygen starts to increase. We hypothesized that their gut contents would include particles and cells that had sunk relatively undegraded from surface waters as well as those from within the oxygen minimum zone, and that gut contents would differ between the inter-monsoon and the more productive SW monsoon. Overall, in both seasons *Lucicutia grandis* was omnivorous, and had consumed a variety of metazoans as well as detrital particles, prokaryotic and eukaryotic autotrophs, gram-negative bacteria including metal-precipitating bacteria, aggregates of probable gram-positive bacteria, microheterotrophs, virus-like particles and large virus-like particles. Few significant differences in types of food consumed occurred between life stages within or among various depth zones. Amorphous and detrital material were significantly more abundant in guts during the inter-monsoon than during the SW monsoon, and recognizable cells made up a significantly higher portion of gut contents during the SW monsoon. This is consistent with the inter-monsoon as a time when organic material is considerably re-worked by the surface water microbial loop before leaving the euphotic zone. In both seasons *Lucicutia grandis* had consumed what appeared to be aggregates of probable gram-positive bacteria, similar to those we had previously found in gut contents of several species of zooplankton from the oxygen minimum zone in the eastern tropical Pacific. By intercepting sinking material, populations of *Lucicutia grandis* act as a filter for carbon sinking to the sea floor. They also modify sinking carbon in several ways: enhancing pelagic-abyssal coupling of carbon from cyanobacteria, eliminating part of the deep-sea microbial loop by direct consumption of bacterial aggregates, and redistributing particulate manganese and iron from association with suspended cells or aggregates to containment in rapidly sinking fecal pellets.

Poster

Migration and bioturbation of benthic deep-sea foraminifera

ONNO GROSS

Institute and Museum of Geology and Paleontology, University of Tübingen, Sigwartstr. 10, 72076 Tübingen, Germany; Tel. ++49 (0) 7071-2974683, Fax. ++49 (0) 7071-2976990; Email. Onno.Gross@uni-tuebingen.de

Benthic deep-sea foraminifera are largely fueled by organic matter arriving from the sea-surface and they respond rapidly to incoming phytodetritus. In order to study such response of benthic deep-sea foraminifera, laboratory experiments with special microcosms have been conducted. Living foraminifera from down to 2880 m water depth were successfully maintained and observed. Microspheres were used to record the mode of foraminiferal movements - in the following termed migration - and the impact of foraminiferal bioturbation on the sediment.

Deep-sea foraminifera are not slower in their migration speeds than shallow water species. No differences in speed for epifaunal or infaunal foraminifera were observed. In contrast, factors such as temperature, food concentration and oxygen content clearly influenced the benthic foraminifera. For example, an increase of 5°C in temperature (from 10°- 15°C) resulted in an increase of 35 % in migration speed for *Allogromia* spp. Differences in food concentration within the substrate resulted in a difference of migration speed for *Adercotryma glomerata* (40 %). A low oxygen content within the sediment did not greatly affect migration speed significantly for *Quinqueloculina seminula* but generally resulted in migration of individuals to the sediment surface.

Particle displacement (e. g. tracer particles, $d_m = 10 \mu\text{m}$) by benthic foraminifera was achieved either by burrowing or pseudopodial activity. Sediment ingesting species showed accelerated particle transport. Cementation by secondary tests removed grains from the bioturbation cycle. The bioturbation rate was elevated close to the sediment-water interface (0-0,5 cm) as compared to deeper sediment horizons (0,5-1,5 cm). A biological mixing coefficient (D_b) of $0,4 \text{ cm}^2 \text{ d}^{-1}$ was calculated.

Assuming a model population of 100 individuals/ 10 cm^2 of foraminifera ($d_m = 1 \text{ mm}$) a sediment displacement rate of $400 \text{ cm}^3/\text{y}$ was calculated. Oligotrophic conditions may result in higher bioturbation rates, whereas balanced food concentrations would show low sediment turnover. The rate of bioturbation thus seems to be directly related to the response of benthic foraminifera to the prevailing trophic conditions in the deep-sea.

Three categories could be recognized due to the migrational behavior. So called "lazy" foraminiferal species were characterized by mean migration speeds of maximal $2,5 \mu\text{m}/\text{min}$, "active" species exhibited mean migration speeds of up to $5,0 \mu\text{m}/\text{min}$ and "steady-vagile" foraminiferal species moved with mean speeds greater than $5,0 \mu\text{m}/\text{min}$. By video documentation a maximal value of $87,76 \mu\text{m}/\text{min}$ was found for *Hoeglundina elegans*, followed by *Cibicides floridanus* ($83,33 \mu\text{m}/\text{min}$) and *Cassidulina leavigata* ($82,76 \mu\text{m}/\text{min}$). Migration speeds of the miliolids *Pyrgo murrhina* ($66,67 \mu\text{m}/\text{min}$) and *Quinqueloculina laevigata* ($55,87 \mu\text{m}/\text{min}$) were also documented to have high values.

Starting from a model population of 100 individuals (10cm²) *Allogromia* spp. (dm: 1 mm) a rate of 400 cm³/y sediment displacement was calculated. Oligotrophic conditions result in higher bioturbation rates, whereas balanced food concentrations showed low sediment turnover. Thus the rate of bioturbation seems to be directly related to trophic conditions.

There are different modes of cyst production (also termed secondary tests). Growth of new chambers, feeding, reproduction and hypoxic conditions lead to formation of secondary tests. Sporadic encystment after feeding (*Chlorella*) were observed for some species (*Gavelinopsis transluscens*, *Cibicidoides wuellerstorfi*, *Spiroplectinella wrightii*). Stationary cysts were formed under hypoxic conditions (*Glomospira gordialis*, *Rosalina* spp., *Trochammina squamata*).

Miliolids (*Quinqueloculina seminula*, *Pyrgo murrhina*) were observed to live more than 3 years and calcareous forms (*Gavelinopsis transluscens*) show an age of 2 1/2 years.

Reproduction takes place in special cysts, in which the juvenile schizonts may profit from the offered sediment particles (*Textularia porrecta*), or the juveniles are sheltered in a brood chamber (*Gavelinopsis transluscens*).

The juveniles grow up to adult size within several weeks (*Textularia porrecta*, *Bulimina marginata*) or some month (*Rosalina* spp.). The test of *Bathysiphon* spp. double their size within 1 month.

A feeding experiment under *in situ* original pressure conditions (12 °C, 300 bar; removed from box core samples) showed that *Uvigerina mediterranea* increased the test size by adding a chamber after 2 weeks of incubation and feeding with algae (*Chlorella*).

Box core samples of deep-sea foraminifera showed higher enzymatic activities (Esterase) as the surrounding standing stock of sediment bacteria. Maximal FDA (Fluorescein-Diacetat) activity of 6,78 nmol/Ind./h of the total esterase pool was measured for *Quinqueloculina* sp.1. Specific FDA-activity reached a maximum level of 0,2 nmol/h/ug C. *Hoeglundina elegans* showed a positive correlation of enzymatic activity with test size and biomass.

Laboratory experiments showed that the activity of other enzymes (API-ZYM test) revealed a high content of phosphatase and hydrolase, which possibly corresponds to the active pseudopodial network in benthic foraminifera.

Migration speed of benthic foraminifera were neither linked to oceanic provinces nor water depth. No differences in speed for epifaunal or infaunal foraminifera were observed. Differences in bioturbation rate are obvious for varying trophic levels. A long lifespan, secondary tests, mode of reproduction and enzymatic activity in the observed foraminifera are indicators of a highly adaptativ strategy (K-strategy) to the deep-sea environment.

Locomotory activity patterns in deep-sea crabs (Crustacea, Decapod, Bythograeidae) collected from hydrothermal vent sites in the western Pacific

JUN HASHIMOTO, YOSHIHIRO FUJIWARA, KATSUNORI FUJIKURA AND JAMES C. HUNT

Deep Sea Research Department, Japan Marine Science and Technology Center (JAMSTEC), 2-15 Natsushima, Yokosuka 237 Japan

Bythograeid crabs are known as typical members of deep-sea hydrothermal vent communities. The locomotory activities of undescribed bythograeid crabs collected from hydrothermal vent communities were examined under atmospheric pressure. Specimens were collected from the Kaikata, Suiyo and Nikko Seamounts located along the eastern edge of the Philippine Sea Plate between 430m and 1400m and tested individually. The locomotory activity pattern of the crabs synchronized with the light-dark cycle, and the activity was highest during the dark period of an imposed light-dark cycle. However, no specific diel pattern was found under constant darkness. Therefore, we operated to impair vision within the eyestalks. After the operation, no clear diel pattern was exhibited. This result suggests that bythograeid crabs have light receptors proximal to the eyestalks and can use light for diel synchrony even though they do not have compound eyes and inhabit low-light environments.

Response of deep-sea benthic foraminifera from the Gulf of Tarrent (Mediterranean Sea) to phytoplankton

P. HEINZ AND C. HEMLEHEN

Living deep-sea benthic foraminifera from about 1000 m from the Gulf of Tarrent (Mediterranean Sea) were transferred into aquariums. Grazing, experiments were conducted to analyze the effect of a phytodetritus pulse on these foraminifera under laboratory conditions (in situ temperature, 1 at). The influence of food on the vertical distribution in the sediments, the activity and the reproduction of the living foraminifera in the aquariums were observed. Additionally, oxygen profiles of the sediments were measured.

The number of living foraminifera in the fed part of an aquarium was higher than in the unfed part. There were no differences in the activity of the observed foraminifera between the fed or unfed part. Regularly feeding (with deep frozen dried *Chlorella* and with different living algae) raised the number of foraminifera that exist on or in the first half centimetre of the sediment (epifaunal) in contrast to those deeper layers. Stop of the feeding or low oxygen supply lead to decrease of the number of the so-called epifaunal foraminifera.

Poster

The effects of the oxygen minimum on the distribution of the mesopelagic fauna in the Gulf of Oman

P.J. HERRING, H.S.J. ROE, G.GRIFFLTHS, B. BOORMAN AND A.T. MUSTARD

Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, UK

The Gulf of Oman is characterized at its eastern end by an intense midwater oxygen minimum layer, similar to that in the northern Indian Ocean. The intensity and extent of this minimum declines westward into the Gulf as the depth decreases. A series of day/night samples were taken with a multiple midwater trawl system at three sites within the Gulf (ranging from about 200-2500m depth) and the catches were compared with concurrent multifrequency acoustic data. The samples showed that the oxygen minimum had a dramatic effect, greatly reducing the biomass of both macroplankton and micronekton at mesopelagic depths, although the epipelagic macroplankton densities were very high. Below the oxygen minimum layer the biomass increased again very sharply, with the sudden appearance of a typical bathypelagic fauna.

The faunal composition was very restricted but the micronekton undertook regular diet vertical migrations from their daytime depths (in the oxygen minimum) to the surface layers at night. Myctophid fishes and decapod shrimps dominated this fauna, but the former were grossly undersampled by the trawl according to the acoustic data. We present profiles of biomass and acoustic backscatter from each of the three stations and illustrate some of the key species.

Flashing anglerfish; an unexpected signalling system

P.J. HERRING¹, E.A. WIDDER², O. MUNK³

¹Southampton Oceanography Centre, Empress Dock, Southampton SO14 3Z, UK

²Harbor Branch Oceanographic Institution, 5600 U.S. 1 N. Fort Pierce, Fla 34946, USA

³Zoological Institute, 15 Universitetsparken, DK-2100 Copenhagen D, Denmark

Female anglerfishes (Ceratiodei) are classically regarded as the ultimate ambush predators, attracting their prey with a (usually) luminous lure. Histological and molecular studies have shown that the esca "lure" contains symbiotic non-culturable luminous bacteria. Culturable luminous bacteria glow steadily and it has been assumed that the symbionts behave similarly, resulting in little or no changes in the light output from the esca. Observations on live specimens of several different species of anglerfish have made it clear that this is not always the case. Mechanical stimulation of species of *Haplophryne*, *Linophryne*, *Dolopichthys*, and *Cryptopsaras* may result in a flash or pulse of light from an apparently dark esca or a sudden increase in intensity from an illuminated one. The mechanism for this light increase is not known, but studies of esca structure have shown the presence of smooth muscle which may have a role in the control of light output. The mechanism and function of these signals are discussed and illustrated with a video sequence of *Cryptopsaras couesi*.

Phylogenetics and Taxonomy of *Brisaster*, a Genus of Deep Water Schizasterid Spatangoids

S. HOOD AND R. MOOI

Dept. Invert. Zool. & Geol. Acad. Sci., Golden Gate Park, San Francisco, CA 94118-4599

The genus *Brisaster* is a group of deep water schizasterid spatangoids found in cooler waters worldwide except the Indian Ocean. Previous work suggested that *Brisaster* contained eight nominal taxa: *B. fragilis*, *B. capensis*, *B. latifrons*, *B. townsendi*, *B. kerguelenensis*, *B. antarcticus*, *B. moseleyi*, and *B. owstoni*. Our preliminary findings, based on both qualitative and quantitative comparisons, suggest that *B. moseleyi* actually consists of two taxa, and that *B. antarcticus* is a senior synonym of *B. kerguelenensis*. A principal component analysis on 17 measurements from over 300 specimens (including *Tripylaster philippi*, a suspected sister taxon to *Brisaster*) was run for 6 of the species. In spite of previous difficulties in telling them apart, *B. latifrons* and *B. townsendi* were shown to be distinct taxa. A preliminary phylogenetic analysis was run on PAUP using 13 morphological binary characters. A single shortest tree was produced with a consistency index of 0.87. Using *Schizaster* as a more distant outgroup, it was found that *Tripylaster* is an extant sister group to *Brisaster*, and that *Brisaster* is a monophyletic group supported largely by features of the pedicellariae. The phylogeny suggests 2 major vicariant events within *Brisaster*: the first in the south Atlantic and a second in the eastern Pacific separating northern Pacific taxa from South American ones.

Brisaster is a genus of deep water spatangoids. Spatangoids are irregular heart urchins with bilateral symmetry. Burrowing in sand and mud, spatangoids have adapted to this lifestyle by having specialized spines, fascioles, and petaloids. They are sediment swallowers with no need for an Aristotle's lantern. The species of *Brisaster* are excellent biogeographic subjects, and have been collected on many trips including the "Albatross", "Challenger", and the "Ingolf" expeditions as well as during environmental surveys.

In spatangoids, bilateral symmetry and easily identified homologous points make their tests ideal subjects for morphometric studies. One of two goals of this project is to straighten out aspects of alpha taxonomy. There has been much confusion over the species in *Brisaster*, especially with the 2 species *B. latifrons* and *B. townsendi*. In fact, many museum collections seem to have unidentified material or specimens not identified at all. There has not been any phylogenetic work done on *Brisaster*. That constitutes the second goal of this project--to develop a preliminary phylogenetic tree.

Poster

Assessment of Midwater Mesozooplankton by an Optical Plankton Counter Mounted on an ROV

RUSSELL HOPCROFT

Monterey Bay Aquarium Research Institute, PO Box 628, Moss Landing, CA 95039-0628; 408-775-1828, FAX 408-775-1620, hopcroft@mbari.org

The optical plankton counter (OPC) is one of several emerging technologies to assess the distribution, density and size frequency of small 'particles' *in situ*. The potential, and limitations, of this device for quantifying changes in particle fields observed during submersible operations are discussed. Combined with other technologies, the OPC allows determination of the relative availability of mesozooplankton and marine snow/detritus as food resources for larger organisms within pelagic environments.

Does not see Salps & probably other gelatinous organisms. Good for MICROCRUSTACEAN

Submersible Observations of the Meso-Pelagic and Benthic-Pelagic Fauna in Japanese Waters

JAMES C. HUNT AND DHUGAL J. LINDSAY

Japan Marine Science & Technology Center, 2-15 Natsushima-Cho, Yokosuka, 237 JAPAN

The meso-pelagic and benthic-pelagic fauna have been observed and analyzed using the submersibles Shinkai 2000, Dolphin 3K, and Shinkai 6500. Live observations and video records coupled with physico-chemical data taken from a CTD/ δO meter have allowed preliminary characterization of the water column in areas such as Sagami Bay, while observations from less frequently sampled areas including the Bonin Islands, Okinawan Trench, and Japan Trench have provided behavioral information on species which have rarely (or never) been seen alive. Shipboard and laboratory observations supplement field records about the behavioral ecology of meso-pelagic species.

This presentation will review what has been learned thus far by a recently expanded meso-pelagic survey program of the Japan Marine Science & Technology Center. An overview of the meso-pelagic fauna including dominant forms, similarities and differences between regions of Japan, and between the Sagami Bay in Japan and the Monterey Bay in California will be given. Specific observations of novel species or of novel behaviors will also be discussed.

Atolla drags 1 long Tentacle
of have seen it captures Nanomia
with it

Found Periphylla with brooded
eggs & actually got them to
release small juvenile Periphylla

Living Far from Oxidative Stress: Adaptation of Meso- and Bathypelagic Fish to Reduced Oxygen Toxicity

**BERNADETTE JANSSENS¹, JIM J. CHILDRESS², FERNAND BAGUET¹ AND
JEAN-FRANCOIS REES¹**

*¹Animal Physiology Lab, University of Louvain, B-1348 Louvain-la-Neuve, Belgium; contact e-mail:
janssens@bani.ucl.ac.be*

²University of California at Santa Barbara, Santa Barbara, CA USA

From the oxidative point of view, the deep waters of the oceans constitute a somewhat protected environment. Reactive oxygen species (ROS) faced by marine organisms originate from two main sources. At first, photochemical reactions are a well known source of hydrogen peroxide and superoxide anion in the upper layers (> 100 m) of the oceans. Since solar irradiance decreases with increasing depth, ROS are no longer detectable below the euphoric zone. The second source is endogenous and essentially redates to the incomplete reduction of oxygen by the mitochondrial respiratory chain. Since the oxidative metabolism of the marine necton (fish and crustaceans) decreases with increasing depth of occurrence, it is likely that the importance of this endogenous production should also decrease. Thus the threat linked to the oxidants, whose high reactivity with many cellular constituents is highly toxic for cells, decreases at higher depth. In this context, the limited resources available in deep waters could have favored a reduction in the antioxidative arsenal of deep-sea fishes.

This hypothesis prompted us to study the influence of the depth of occurrence on the activities of superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx), three major oxygen detoxifying enzymes. These were analysed in various tissues of fishes collected off the coast of Southern California, and their eventual link with the metabolic activity were tested. In parallel, the contents of vitamins C and E, two major non-enzymatic antioxidants, have been measured. Our results indicate that some antioxidative mechanisms were adjusted to the reduced pro-oxidant dangers as depth increases. This adaptation to a reduced stress could also be a limiting factor in the vertical distribution and the migratory behavior of deep sea fish, and could maybe explain the inability of deep-sea fishes, as well as possible other organisms, to survive at atmospheric pressure.

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Shifting Targets: Anti-Oxidative Mechanisms as an Origin of Bioluminescent Anti-Predation Systems in the Deep-Sea

B. JANSSENS, M. DUBUISSON, B. DE WERGIFOSSE, O. NOISET, A. TROUET, F. BAGUET AND J.-F. REES

University of Louvain, Animal Biology Unit, B-1348 Louvain-la-Neuve, Belgium (e-mail:Reesjf@bani.ucl.ac.be)

The capacity to produce light for protection against predators and communication is a widespread property of animals thriving in the dysphotic zone of the oceans where it plays essential roles in the ecosystem. Coelenterazine, an imidazolopyrazine molecule, is the luminescent substrate (luciferin) of most marine organisms, ranging from protozoa to fish. The occurrence of the same molecule in many phylogenetically-unrelated bioluminescent organisms suggests that dietary transfer of this luminescent substrate could occur. Nevertheless, the widespread utilization of coelenterazine by the vast majority of marine organisms remains puzzling. In an attempt to solve this evolutionary dilemma, we previously suggested that coelenterazine's first function was not that of a luciferin, and that it played some roles in the general physiology of many marine organisms. This could also explain the presence of coelenterazine in most non-luminescent marine organisms. Since coelenterazine can react with reactive oxygen species (ROS) such as singlet oxygen and the superoxide anion, we postulated that coelenterazine's primary function could have been that of an antioxidant involved in antioxidative defense mechanisms of organisms living in the epipelagic environment (In: *Biochem. Molec. Biol. Fishes*, Hochachka and Mommsen (eds.), vol 4 (1995), pp. 435-466, Elsevier) where ROS are being produced both exogenously (photochemical reactions) and endogenously (metabolic activity). The functional change towards its bioluminescent functions would have been allowed by the reduction of the pro-oxidant threat associated with the migration towards greater depths as deep-sea organisms have a reduced metabolic activity and the residual solar irradiance does not allow photochemical processes to occur at a sufficient rate. On the other hand, the ability to produce light offers major selective advantages in these dark areas of the oceans.

We now have experimental evidences of a very high antioxidative ability of coelenterazine when applied *in vitro* on cells subjected to an oxidative stress. The antioxidative potency of coelenterazine is superior to that of α -tocopherol and ascorbic acid, two major antioxidant substances of cells, thus making coelenterazine one of the best antioxidant known. Also, we have data showing that the antioxidative arsenal of deep-sea fishes adjusted to the reduction of the oxidative dangers in these waters. Beside the new light that this sheds on the evolutionary history of marine bioluminescence, these results suggest that the limited ability of deep-sea fishes to resist oxidative stress could be an essential factor in their mortality at surface conditions.

This work was funded by the Fonds de Développement Scientifique of the UCL, Belgium to J.-F.R., who's a senior researcher associate of the FNRS.

Rapid dispersal of a dolphin carcass in the deep-sea

E.G. JONES, M.A. COLLINS, S. ADDISON, P.M. BAGLEY, I.G. PRIEDE

University of Aberdeen Department of Zoology, Tillydrone Avenue, Aberdeen, AB24 3TZ, Scotland, UK.; e-mail: e.g.jones@aberdeen.ac.uk

Coastal strandings of large marine animals such as whales, sharks and squid evoke considerable public interest, but most mortalities occur in the open ocean and sinking is probably a significant pathway for rapid removal of organic carbon from the surface layers of the oceans. Such material becomes permanently buried, or recycled, perhaps ultimately returning to the surface. The significance and frequency of these episodic enrichments of the deep-sea environment have long been speculated upon (Stockton and Delacca 1982), and whale carcasses may act as oases, aiding the dispersal of sessile deep fauna between sites such as hydrothermal vents (Smith et al. 1989).

Here we report the first direct observations of the immediate fate of a cetacean carcass at abyssal depths. In August 1996, we placed a 60 kg half dolphin carcass (*Lagenorhynchus acutus* (Gray, 1846)) at a depth of 4800m in the Northeast Atlantic. Scavenging fish, principally *Coryphaenoides* (*Nematonurus*) *armatus* (Hector, 1875) and amphipods arrived within 50 minutes. These were joined by four other putative fish species and two species of decapods. By day 6 nearly all soft tissue had been consumed and after 13 days over 50% of the bone surface had been stripped down to the mineralised matrix. At the end of the experiment, zoarcid fishes, amphipods and galatheid crabs remained at the skeleton.

An estimated 500 g C organic content, equivalent to 325 years average daily flux of carbon m^{-2} , remained within the bones, which might support the development of a localized, persistent microbial and encrusting community as observed on some whale skeletal remains (Smith et al. 1989). The consumption of the soft tissue was rapid (0.4 kg h^{-1}). Staying times of the grenadier were short and evidence is discussed for large-scale dispersal of the soft tissue fraction of organic carbon from the carcass across the N. Atlantic basin. If migrations of cetaceans are coupled with the movements of the abyssal scavengers, the potential for organic carbon dispersal across oceans has significant implications for the role of the deep-sea as a sink in the global carbon-cycle.

Smith, C. R., Kukert, H., Wheatcroft, R. A., and Jumars, P. A., 1989. Vent fauna on whale remains. *Nature*. 341, 27-28.

Stockton, W. L., and Delacca, T. E., 1982. Food falls in the deep-sea: occurrence, quality and significance. *Deep-Sea Research*. 29, 157-169.

Visual Pigments in Deep-Sea Crustaceans

JEREMY KENT¹, JULIAN PARTRIDGE¹, PETER HERRING², TOM CRONIN³

¹*School of Biological Sciences, University of Bristol, Woodland Road, Bristol, BS8 TUG, UK; (email: j.c.partridge@bristol.ac.uk)*

²*Southampton Oceanography Centre, Empress Dock, Southampton, S014 3ZH, UK.*

³*School of Biological Sciences, University of Maryland Baltimore County Campus, Catonsville, Maryland 21228, USA*

The deep-sea presents a unique visual environment. Due to filtering by overlying water, the downwelling light is reduced to homochromatic blue light. At greater depths and at night, downwelling sunlight is insignificant and the visual environment is limited to bioluminescent emissions. The suggestion that deep-sea animals have their retinal spectral sensitivities matched to the light available at depth, the Sensitivity Hypothesis, has largely been investigated using species of deep-sea fishes. To test the hypothesis further it has now been applied to another taxon which inhabits the same environment. This poster presents a comparative study of the visual pigments of deep-sea crustaceans, concentrating on the Carid and Penacid decapods.

During RRS Challenger cruise 122 (September to October 1995) and a cruise on the RV New Horizon (May 1996) a total of thirty six species of deep-sea crustaceans were collected. Specimens included twenty nine species of decapods, six mysids and a single amphipod. On board ship, specimens were sorted under dim red illumination and the eyes were removed and preserved by rapid freezing. Following the cruises, at the University of Bristol, frozen eyes were sectioned on a cryostat and the spectral absorbances of the rhabdomeric visual pigments measured using a purpose-modified microspectrophotometer. Computer spread-sheet based analysis methods were used to fully characterise the visual pigments present.

Most deep-sea crustaceans investigated have a single visual pigment with a wavelength of peak absorbance (I_{\max}) between 482 and 509 nm, on average ca. 10 nm longer than those of the deep-sea fishes. Thus, on first investigation, deep-sea crustacean visual pigments are not matched to the spectrum of downwelling sunlight available in the deep-sea, nor to the wavelength of maximum bioluminescent emissions. No correlation is apparent with depth and the total range of pigments is limited. However, simple models that use bioluminescent spectra rather than downwelling irradiance suggest that the visual pigments of crustaceans are spectrally located to maximise bioluminescent photon catch. This model also reveals a correlation between rhabdom length and rhodopsin pigment which may explain differences in visual pigment complement between species. In contrast to the majority of species, four Ophiophorid species also have a second, short wavelength sensitive visual pigment (I_{\max} ca. 414), conferring broader spectral sensitivity and the potential for hue discrimination. The demonstration of such a pigment in a bathypelagic, non-vertically migrating species which lacks photophores questions the use of such a pigment in mediating daily migrations and conspecific recognition.

Poster

Faunal characteristics of deep-sea benthopelagic zooplankton in Sagami Bay and Okinawa Trough, Japan

TOMOHIKO KIKUCHI, M. TERAZAKI, J. HASHIMOTO AND T. TODA

Department of Biology, Faculty of Education, Yokohama National University 79-2 Tokiwadai, Hodogaya-ku, Yokohama 240 Japan; Phone & Fax: +81-45-339-3413, e-mail: kikuchi@ed.ynu.ac.jp

A survey of deep-sea benthopelagic organisms by means of a multiple plankton sampler attached to the Deep-Tow System (DT-MPS) of the Japan Marine Science and Technology Center (JAMSTEC) have been carried out in Sagami Bay and Okinawa Trough. Sagami Bay and Okinawa Trough are typical cold-seep and hydrothermal fields in Japan, respectively. Samplings were made as close to the sea floor as the terrain would allow, maintaining a distance of 0.5 - 3.0m above the bottom. Sampling depths ranged from about 600 to 1300m in Sagami Bay and 700 to 1400m in Okinawa Trough. Between two locations obvious difference in faunal composition are observed. Copepods, Ilyarachnid isopods, and Gammarid amphipods are the dominant components in Sagami Bay. Copepods and Lophogastrid mysids are the dominant in Okinawa Trough. Faunal composition, distributional characteristics in two different fields and some potential implications in biogeography of deep-sea benthopelagic organisms will be discussed.

A new multiple plankton sampler (DT-MPS) to collect deep-sea benthopelagic organisms was developed. The DT-MPS is attached to the deep-tow system of the Japan Marine Science and Technology Center (JAMSTEC), and had four plankton nets that are closed at the desired locations by commando relayed through a conductivity cable. Collection of the deep-sea benthopelagic organisms were made in Sagami Bay and Okinawa Trough, the western Pacific.

Reproductive Biology and Population Structure of Commensal and Free-Living Polynoid Polychaetes at the Lucky Strike Hydrothermal Vent Field

ANN L. KNOWLTON, JENNIFER TRASK, AND CINDY LEE VAN DOVER

*Institute of Marine Science, University of Alaska, Fairbanks AK 99775;
e-mail (Knowlton): ftalk@aurora.alaska.edu*

Polynoid polychaetes are commonly found in hydrothermal vent communities in the Pacific and Atlantic Oceans. We examine the reproductive biology of two polynoid species—one commensal in mussels and one free-living—from the Lucky Strike hydrothermal vent field on the Mid-Atlantic Ridge. Commensalism provides a species with a relatively stable environment, which may be reflected in the population structure and reproductive strategy of the species. Polychaetes living in a symbiotic relationship with mussels are offered the advantage of an abundant food supply and a consistent, protected environment, and therefore can be expected to spend less energy on food gathering and predator avoidance than free-living individuals. Instead, commensals can allocate more energy to reproductive effort, resulting in high fecundity, large egg size, and increased reproductive potential. In order to succeed at hydrothermal vents, both species must be able to maintain individuals and populations at active vent sites as well as to readily colonize newly formed sites. Commensal polychaetes must also insure that their offspring find and occupy the correct hosts.

Reproductive strategies can be deduced by investigating the morphological characteristics of reproductive tissues. We use size-frequency analyses of individuals and oocytes, mean and maximum oocyte diameter, and estimates of fecundity of the commensal polynoid, *Branchipolynoe seepensis*, and an unidentified free-living polynoid to describe the reproductive ecology and population structure of these vent polychaetes.

Ten clumps of mussels (approximately 2 liters each) were collected from hard-substrate mussel communities during the LUSTRE '96 cruise to the Lucky Strike hydrothermal vent field using the *ROV JASON*. All polynoids were counted, weighed, measured, and sorted according to sex-based dimorphic characteristics. Population size-frequencies and sex ratios were determined for each species at each of two sites within the vent field.

We review reproductive and population correlates associated with commensalism *versus* free-living species reported in the literature and test whether these correlates apply to two polynoid species from Lucky Strike.

Poster

Calyptogena (Bivalvia) around Japan: taxonomy, distribution, and speciation process

S. KOJIMA¹, S. OHTA¹, Y. FUJIWARA², K. FUJIKURA², J. HASHIMOTO², T. OKUTANI³

¹*Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo 164, Japan*

²*Japan Marine Science and Technology Center, 422-1 Natsushima, Yokosuka, Kanagawa 237, Japan*

³*College of Bioresource Science, Nihon University, 1866 Kameino, Fujisawa, Kanagawa 252, Japan*

Bivalves of the genus *Calyptogena* are one of the dominant groups among the chemosynthesis-based communities in the deep-sea reducing environments. Around Japan, their habitats of various types, such as seep areas, hydrothermal vents and submarine volcanoes have been discovered. Eight species of the genus *Calyptogena* were described and two are now under description. In addition, there is at least one undescribed species that has been discovered.

Although two species of *Calyptogena* inhabits two areas (about 1,400 km apart), the geographical range of other species is limited to a single area. Clear bathymetrical zonation was revealed for the distribution of each *Calyptogena* species. Other dominant groups of the deep-sea reducing environments around Japan, such as vestimentiferans and *Bathymodiolus* bivalves, were distributed over wider geographical range. Limitation of range of *Calyptogena* is thought to attributed to their low larval dispersal ability.

Phylogenetic relationships among all Japanese *Calyptogena* species were analyzed on the basis of nucleotide sequences of mitochondrial DNA. The geographical distribution, shell morphology and nucleotide sequence of intron region of nuclear gene were compared for two species, which form species complex. Morphological and genetic differentiation was detected not only between the sibling species but also between a population coexisting the sister species and populations in the area where the sister species is absent.

Deep Arabian Sea mesozooplankton distribution and its respiratory potential

ROLF KOPPELMANN

Institut für Hydrobiologie und Fischereiwissenschaft, Zeiseweg 9, 22765 Hamburg, Germany

Little is known about the vertical distribution of deep-living mesozooplankton in the Arabian Sea. I will present data obtained by vertically fine-stratified MOCNESS hauls down to a depth of 4000 m at four stations in the Arabian Sea using a mesh of 333 μm .

The highest mesozooplankton biomass concentrations (wet weight m^{-3}) were measured in the surface layer during night. A secondary maximum was situated between 150 and 450 m, with maximum concentrations at daytime. This layer coincided with the daytime residence depth of the deep scattering layer. The standing crop of the mesozooplankton in the upper 1000 m was highest at station WAST at 16°N60°E (ca. 47 000 mg m^{-2}); station CAST at 14°N65°E ranked second (ca. 22 500 mg m^{-2}), followed by station SAST at 10°N65°E (11 420 mg m^{-2}). The differences can be related to different productivity regimes at the sea surface generated by the Findlater Jet during the SW monsoon. The differences in surface production were also reflected below 1000 m depth, in the bathypelagic zone, with mesozooplankton wet weights of 5330 mg m^{-2} at WAST, 3210 mg m^{-2} at CAST, 3390 mg m^{-2} at EAST (15°N65°E) and 2690 mg m^{-2} at SAST. The rate of decrease of mesozooplankton biomass with depth in the bathypelagic zone was statistically similar between the sites, even though the absolute zooplankton biomass at the sites was different.

The respiratory potential of the deep-living mesozooplankton taken by horizontal hauls was measured by the ETS method. These potential values were transformed into respiration rates using a factor derived from upper ocean zooplankton and converted into CO_2 utilisation rates. The carbon requirements of deep-living zooplankton were calculated for the examined stations in the Arabian Sea.

The fauna of mid-slope seamounts off southern Tasmania: impacts of deepwater trawling and its conservation

TONY KOSLOW AND KAREN GOWLETT-HOLMES

CSIRO Division of Marine Research, GPO Box 1538 1538, Hobart, Tasmania 7001, Australia

A cluster of >50 seamounts is found at depths of 1000 to 2000 m south of Tasmania. Most seamounts that peak at depths of 600 to ~1200 are commercially trawled for orange roughy (*Hoplostethus atlanticus*) and oreos (*Pseudocyttus maculatus* and *Allocyttus niger*). These seamounts provide a distinct environment for a diverse sessile fauna, including several groups of deepwater corals. This fauna has extremely limited regenerative capacity and is likely characterized by a high degree of endemism. However, details of its species composition, depth distribution and zoogeography are not known. Due to concern about the impact of trawling on this fauna, an interim protected area was established in 1995 around a group ~12 relatively deep seamounts (Peaks at depths of 1150-1800m) that had not been previously fished.

A survey was carried out in January 1997 to assess the impact of trawling on the seamount fauna and to determine its diversity, depth distribution and zoogeography. Sampling was carried out with a still camera, benthic sled, dropline, and traps. Preliminary results indicate that many species represent new records for Australia or are undescribed. While some species have very wide distributions, there are marked differences in species composition from seamounts on either side of the Tasman Sea, which has interesting biogeographical and conservation implications, as do the apparent differences in faunal comp.

Population Dynamics of Deep-Sea Benthic Foraminifera in the Arabian Sea (India Ocean)

F. KURBJEWIT, P. HEINZ AND C. HEMLEBEN

On six stations in the Arabian Sea (WAST top, WAST plain, NAST, CAST, SAST, EAST) the distribution, population dynamics and reproduction of deep-sea benthic microforaminifera ($> 28 \mu\text{m}$) were investigated. Additionally, grazing and bioturbation experiments under in situ and semi in situ conditions were conducted to evaluate the impact of deep-sea benthic foraminifera on sedimented phytodetritus and the turnover of sediment.

On the shallowest station, WAST-top (1916 m depth), where about 1 cm of phytodetritus covered the ocean floor and highest nutrient concentrations ever recorded for deep-sea sediments could be found, large Allogromiids of 0.5 to 1.2 cm in length dominated the epifaunal community with up to 1 specimen per 10 cm^2 . In contrast on the other stations agglutinated species of the genera *Reophax*, *Hormosina*, *Lagenammina* and *Rhizammina* and calcereous species of the genera *Epistominella*, *Melonis*, *Astrononion* and *Uvigerina* were dominant.

Population dynamics and contribution of these dominant benthic foraminifera to the overall benthic biomass, their grazing impact as well as their influence on the bioturbation is discussed.

Poster

Benthic Size Structure and the Oxygen Minimum Zone (OMZ) in the Arabian Sea

P.A. LAMONT¹, J.D. GAGE¹ AND L.A. LEVIN²

¹Scottish Association for Marine Science, P.O. Box 3 Oban, Argyll, PA34 4AD, U.K.

²Marine Life Research Group, Scripps Institution of Oceanography, La Jolla, CA 92093-0218

Core samples, bottom trawls and photosled studies were undertaken on a month-long cruise in October-November 1994 on the British research ship R.R.S. *Discovery* in order to describe the response of the benthic system to the OMZ along a transect on the Oman margin. As markers of hypoxic conditions the associated biofacies are important in reconstructing ancient ocean basins and climatic regimes. The deep-sea benthic fauna within the oxygen minimum zone on the continental slope off Oman was almost completely unknown. The community was found to be extremely impoverished in numbers of species, although rich in numbers of individuals. Those present were mainly polychaetes (95.6%), with two species, the spionid *Prionospio (Minuspio) sp. A* and the cirratulid *Aphelachaeta sp. A*, forming 90% of the total macrofauna. The remaining fauna included six polychaete species, nemertean, and a thin-shelled mytilid mussel. Cnidarians, echinoderms, and crustaceans were notably absent. Most of the individuals (94%) were tentaculate surface feeders and many construct dwelling structures such as tubes, cocoons or mudballs. The majority are found near the sediment surface and bioturbation is minimal.

Bulk statistics, such as mean biomass/mean abundance were compared to depth-comparable quantitative deep-sea samples from the North Atlantic in order to assess the overall benthic response to hypoxia in terms of body size. However, differences deriving from sample processing, such as washing and sieve size, are notoriously difficult to control and no clear pattern emerged. Body mass and body surface area of the benthic biota were studied in relation to the predominantly depth-related gradient in oxygen concentration along the transect. Changes in body size and shape parameters within species were addressed in various species of spionid and paraonid polychaete. Measurements of body parts important in dissolved oxygen exchange, such as the branchiae indicate that these structures are greatly developed compared to those of congeners from slope environments not subjected to hypoxia. Counts and measurements of length and area on many individual specimens are interpreted as adaptation for enhancing oxygen diffusion by increasing body area/mass ratio. Furthermore, when samples of individual species are compared along the transect, this is expressed as increased development of body appendages, especially the branchial cirri, compared to specimens from higher oxygen concentrations along the transect. A model was developed (Fig. 6) which shows the response in terms of branchial length and number in relation to the ontogenetic development and growth of the (as yet undescribed) spionid *Prionospio (Minuspio) sp. "A"*. At present it is not known whether these differences represent a genotypic or phenotypic response to the oxygen environment. The results indicate that, for taxa whose occurrence may be limited by oxygen, there are powerful constraints on morphological adaptation aimed towards enhancing O₂ diffusion by increasing body area/mass ratio. Such data may provide sensitive predictors of prevailing bottom-water oxygen concentration.

Poster

Estimates of growth and production in a deep-sea Lumbrinerid polychaete from jaw mandible growth banding

PETER A. LAMONT AND JOHN D. GAGE

Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, P.O. Box 3, Oban PA34 4AD U.K.

Polychaete worms typically comprise around half the numbers of individuals of invertebrate metazoans of the macrobenthos in the deep-sea sediments. This numerical dominance is also expressed in terms of biomass and species richness. Yet virtually nothing is known of the demographic characteristics of deep-sea polychaetes.

In the polychaete families Nephtyidae and Lumbrineridae it has been known for some time that growth lines can be observed with little preparation in the jaw mandibles of inshore species. We have investigated if growth marks can be visualised in specimens from deep-sea samples from the Rockall Trough (northeastern Atlantic), and to see if any such patterns can be used to understand the growth and population age structure in deep-sea polychaetes. Various species of polychaetes from sta. "M" in 2,200 m depth were examined and growth band patterns most clearly seen in the jaw mandibles of a species of *Lumbrineris* (family Lumbrineridae, order Eunicida). The pattern appeared as wide pale-coloured bands separated by dark brown, narrow bands. Animals collected in autumn (September) and at the end of winter (February) exhibited a dark band at the terminal (posterior) growing edge of the mandible, while those from spring and the end of summer (April & August) showed a pale or partly pale terminal edge. No worms examined from those collected in spring and summer had a dark band at the terminal edge. This is interpreted as reflecting an annual variability in growth rate where jaw growth was most rapid in spring/summer, and slowest in autumn/winter. We also assume that body growth closely tracked that of the jaw elements.

The number of dark bands was positively related to measures of size as estimated from the anterior fragments of adults available. Specimen age was assumed to approximate closely (± 1 year) to the maximum number of dark bands plus one making the oldest specimen an estimated fifteen. The juvenile to adult ratio was determined at approximately 600:1, thus adults were rare with, on average, less than five found per epibenthic sled sample. Jaw mandibles were extracted from 17 adult specimens collected between 1980 and 1990, and the jaw bands measured. Plots of cumulative sequences of bandwidth were cross matched by inspection while maintaining agreement of estimated age between the specimens. Parameters of a Gompertz growth curve were fitted to these size-at-putative age data by non-linear regression. The size data consisted of the distance of each band from the estimated growth primordium and its estimated corresponding age, assuming one dark band was formed each year during growth. Secondary production was calculated from a fitted size-to-mass relationship based on estimates of total size standardised from measurements of the tenth setiger width.

Poster

Deep-sea epibenthic echinoderms and a temporally varying food supply: a time series from the abyssal NE Pacific

LYNN M. L. LAUERMAN¹ AND RONALD S. KAUFMANN

¹Marine Biology Research Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0202; 619-534-4858; lml@ucsd.edu

²Marine and Environmental Studies Program, University of San Diego, San Diego, CA 92110; 619-260-4600; kaufmann@acusd.edu

Abundance and distribution of epibenthic echinoderms and detrital material on the sea floor at an abyssal site in the NE Pacific (Sta. M; 34°50'N, 123°00'W; 4100 m depth) were examined between June 1994 and June 1995. Sta. M is characterized by a variable food supply to the sea floor: sinking particulate organic matter (POM) flux generally increases in the summer and fall, resulting in visible patches of organic detritus on the sea floor. Camera-sled surveys, time-lapse camera photographs, and observations from the submersible *Alvin* were analyzed to describe the sequence of detrital deposition events as well as the residence time of detritus on the sea floor. Six different types of detrital material were observed on the sea floor during this time period and all types were most abundant between September and October 1994. However, a carpet of flocculent material remained visible on the sea floor from July through November 1994, and mats of detritus composed mainly of phaeodarian radiolarians were observed from August 1994 through February 1995. We evaluated the distribution and abundance of echinoderm species from camera-sled surveys and found few consistent temporal patterns. Abundance varied spatially, and distributions were predominantly random at along-transect distance scales of 1, 2, 4, 8, 16, 32, 64, and 128 m, in contrast to the patchy distribution observed for detrital aggregates. The spatial distributions of several echinoderm species correlated significantly with the distributions of detrital aggregates, but these correlations were not consistent among taxa or across transects. The lack of consistent correlation between echinoderm distribution and abundance and the presence of detrital aggregates is not surprising when the residence time of the material on the sea floor is considered. Patches of detrital material can persist, and thus impact the benthos, for many months after initial deposition.

Relations Between the Distribution of Benthic Fauna and Food Input on the Slope and in Canyons of the Celtic Margin

M.S.S. LAVALEYE, G.C.A. DUINEVELD, E. M. BERGHUIS, P.A.W.J. DE WILDE

NIOZ, Netherlands Institute of Sea Research, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands. E-mail duin@nioz.nl

During the CEC-funded OMEX-I project, *in-situ* measurements of sediment community oxygen consumption (SCOC) were combined with a study of the distributions of macro and megafauna and phytopigments in order to determine, and if possible to explain, the distribution of labile particulate organic matter on the NE-Atlantic continental slope (Goban Spur, SW Ireland). A major issue concerned the existence of depocenters of labile POM on the slope caused by lateral transport, a phenomenon that has been found previously in the NW-Atlantic. For this latter purpose, we specifically looked for deviations from expected bathymetric trends. However, none of the parameters that we studied provided firm indications for a depocenter on the slope. In May there was a clear spring bloom signal in terms of sediment concentrations and fluxes of phytopigments, and of settlement of juvenile ophiuroids. This signal rapidly attenuated with increasing water depth. Strikingly, there was no clear response of SCOC after the spring bloom input. Concurrent sampling of the water column indicated a transport of phytodetritus on the upper slope in a bottom nepheloid layer (BNL). It was concluded that an important part of the spring input into the upper slope sediment consisted of degraded phytodetritus which had been laterally transported. In late summer, we observed a decoupling of food input to the upper and lower slope. While pigment concentrations on the former were quite low, the latter area had received a strong pulse of fresh phytodetritus forming a mucous layer on the sediment. Pigment and sterol markers showed that the pulse originated from an offshore deep bloom of coccolithophores and dinoflagellates. The occurrence of large motile "vacuum-cleaning" sea cucumbers at stations covered by the mucous carpet was regarded as typical for areas which receive a strongly pulsed supply of fresh food. While concluding that there was no evidence on the Goban Spur for a major export of POM from the upper slope sediments to the ones on the lower slope and continental rise, it was realized that the numerous steep canyons intersecting the NE Atlantic margin could present transport routes and deposition areas.

As a follow up of OMEX-I, a cruise was made to the Whittard Canyon system (in concert with GEOMAR, Germany) where the benthic community structure, sediment respiration and sediment biochemistry were studied. These data were compared with those from the OMEX-I transect across the Goban Spur. The benthic communities in the canyon had a clearly different composition with high percentages of filter feeding organisms indicative for a higher suspended load. Respiration rates of canyon sediments were only locally enhanced but concentrations of carbon, nitrogen and nucleic acids in the surface sediment in the canyon were distinctly higher than on the Goban Spur. By contrast, at the time of the cruise there was no difference in the characteristics (pigments, SPM) of the bottom water of the canyon and the Goban Spur. The data indicate that over longer periods a higher load of labile organic material reaches the canyon system. This fits into the hypothesis that the canyon acts as a direct passage for organic matter from shallow water to the deep-sea.

(A video (VHS) with pictures of the *in-situ* sampling by multicorer and boxcorer, and with images of the deep-sea bottom and benthic community of the Whittard Canyon and the Goban Spur will be shown during the Video Film Sessions.)

Preliminary Trophic Studies of the Hydrothermal Vent-Endemic Fish *Thermarces cerberus* (Zoarcidae)

G. LÉVAI, W. WAKEFIELD, T. M. SHANK, P. CHEVALDONNÉ, AND R. A. LUTZ

¹Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ 08903 USA

Few trophic studies have been conducted on the mobile megafauna inhabiting deep-sea hydrothermal vents. The vent-endemic eelpout *Thermarces cerberus* (Zoarcidae) has been observed at numerous sites along the East Pacific Rise (EPR) and on the Galapagos Rift. We present preliminary investigations of gut content analysis and extensive video image analysis in an effort to define the ecological role of a primary predator, *T. cerberus*, in the dynamic hydrothermal vent community. The capture of three specimens, one from 20° 49.8'N (1990) and two from 9° 49.8'N (1994) on the EPR, provided an opportunity to assess questions regarding the feeding and general behavior of this vent-endemic fish. Gut content analysis was conducted via the removal of the stomach and the complete intestine, the identification and enumeration of prey items, and construction of indices of relative importance (I.R.I.) to characterize the diet of *T. cerberus*. The results of the gut content analysis indicate a predominance of the lysianassid amphipod *Ventiella sulfuris*, as well as the leptostracan *Dahlella caldariensis*. Other prey items included lysianassid amphipods, lepidodrilid limpets, brachyuran crabs, and siphonostomatoid copepods. Acanthocephalan parasites (*Hypoechinorhynchus thermarceri*) were discovered among the prey items of the 9°N specimens (predominantly in the middle and posterior thirds of the intestines). To our knowledge this represents only the third record of an acanthocephalan parasite in an abyssal fish, and the first documentation of a parasite in the 9°N hydrothermal vent area.

Video analysis using a high resolution 3-chip color CCD camera mounted on the arm of the submersible *Alvin* was conducted to observe the feeding behavior of *T. cerberus*. Feeding was observed in several microhabitats: in dense swarms of the amphipod, *Halice hesmonectes* (23 observations); around the base of the vestimentiferan tubeworms, *Riftia pachyptila* (3 observations); and amongst dense aggregates of mussels (10 observations). The video footage illustrates few instances of aggressive behavior between zoarcids and no aggressive behavior toward any other fauna within the vent community. Eighteen separate sightings of a 'juvenile' *T. cerberus* were noted on the video. Further analysis, as well as the aid of more specimens, is needed to attain a better understanding of the role of *T. cerberus* within the hydrothermal vent community.

Poster

Macrofaunal Processing and Bioturbation of Phytodetritus On the North Carolina Continental Slope: An In Situ, Time Series Approach

LISA LEVIN¹, CHRIS MARTIN¹, NEAL BLAIR², DAVE DEMASTER², GAYLE PLAIA², AND CARRIE THOMAS²

¹Marine Life Research Group, Scripps Institution of Oceanography, La Jolla, CA 92093-0218, USA

²Dept. Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695-8208, USA

A series of experiments were conducted to examine the fate of freshly-deposited diatoms (*Thalassiosira pseudonana*) and other particles at 850 m on the continental slope off Cape Fear (Site I) and off Cape Hatteras (Site III), North Carolina, USA. ¹³C-labeled diatoms, old slope sediments and glass beads (each tagged with a radiotracer) were introduced to the seabed surface by submersible to examine the fate of freshly deposited organic matter and mechanisms of particle mixing. Sediments and macrofauna were sampled by coring 30 min, 1.5 da, 3 mo (III only) and 14 mo after tracer deposition. Assays were conducted to evaluate the concentration of diatom C (¹³C) in sediments, porewaters and macrofaunal tissues and to look at the vertical distribution of other tracers within the sediment column. The roles of site, taxon, lifestyle, body size and vertical position in determining macrofaunal access to surface organic matter were examined.

Vertical distributions of tracers indicated substantially more mixing within the sediment column at Site III than I after both 1.5 d and 14 mo. These patterns were attributed to site-specific differences in animals accessing the tracer material. Diatom C was ingested within 1.5 days by metazoan macrofauna (mainly annelids) at Site III. Some deep-dwelling taxa traditionally considered to be subsurface-deposit feeders (e.g., paraonid and maldanid polychaetes) ingested large amounts of tracer. Rapid deep subduction of tracer to below 10 cm was observed; non-selective hoeing of surface sediments by maldanid polychaetes (*Praxillella* sp.) appeared to be responsible. Isotopic signatures of many deep-dwelling infauna indicate tracer diatom ingestion after 1.5 d. Maldanid subduction activities are hypothesized to introduce freshly deposited, reactive organic matter into deep sediments, fueling microbial processes and providing food for smaller infauna. Deep mixing by maldanids can account for 25-100% of mixing expected on 100-day time scales at Site III, based on Th-²³⁴ estimates. After 14 mo. only 2% of the introduced tracer remained at this site, but 95% of this was mixed below 2 cm.

At Site I diatom C was initially (after 1.5 d) ingested primarily by large, agglutinated protozoans (*Hyperammia*, *Bathysiphon*, *Rhizammia*, xenophyophores), and by surface-deposit feeding annelids, groups which cause little bioturbation. After 14 mo. most annelid groups obtained access to tracer, but only 23% of the remaining diatom C in sediments was mixed below 2cm. Our results suggest (a) there is significant spatial heterogeneity in the fate of organic material reaching the North Carolina slope seabed, (b) this heterogeneity is driven by differences in animal assemblage composition, and (c) downward mixing of fresh organic material into slope sediments can be extremely rapid in some locations, with potential consequences of geochemical and ecological significance.

Oxygen and Organic Matter Controls on Macrobenthic Diversity in the Bathyal Indian and Pacific Oceans

LISA A. LEVIN¹ AND JOHN D. GAGE²

¹*Scripps Institution of Oceanography, La Jolla, CA 92093-0218, USA, llevin@ucsd.edu*

²*Scottish Association of Marine Sciences, PO Box 3 Oban, PA34 4 AD, United Kingdom, jdg@wpo.nerc.ac.uk*

The influences of bottom-water oxygen concentration and sediment organic carbon content on measures of community diversity [Es(100), H', dominance - D, and evenness - J'] were examined for macrobenthic data from 8 regions (23 stations) in the eastern Pacific and Indian Oceans (200-3300m). Stepwise multiple regression revealed that depth, latitude, organic carbon and oxygen concentration are significant factors which together explained over 80% of the variance in Es(n), H', D, and J', respectively. Organic matter appears to exert greater control than oxygen on most community measures, and on polychaetes more than on total macrobenthos. However, when only stations with oxygen < 1 ml/l were considered, oxygen concentration became the dominant parameter. These results suggest a threshold above which oxygen effects are negligible relative to organic matter influences on community structure, but below which oxygen becomes a critical factor.

Examination of rarefaction curves for Indo-Pacific stations revealed that total macrobenthos, polychaetes, crustaceans and molluscs all exhibit reduced species richness within oxygen minimum zones (OMZs). However, representation under conditions of hypoxia varies among taxa, with polychaetes being most tolerant. Molluscs and crustaceans often (but not always) exhibit few individuals and species in OMZs, and sometimes disappear altogether, contributing to reduced macrobenthic diversity and elevated dominance in these settings. A negative relationship was observed between bathyal species richness and sediment organic carbon content (used here as a proxy for food availability). There appear to be a strong influence of both organic matter and oxygen on the structure of bathyal macrobenthic communities, especially in the Indo-Pacific Ocean.

Poster

Excitability and electrical signalling in hexactinellid sponges

SALLY P. LEYS AND GEORGE O. MACKIE

Biology Department, University of Victoria, Victoria, B.C. V8W 3N5, Canada

Sponges arose very early in metazoan evolution and lack a nervous system but some hexactinellids respond to touch by turning off their feeding currents. This response spreads through the body of the sponge at about 0.2 cm. per second on an all-or-none basis, much like the neuronally-mediated ciliary arrests seen in the branchial sac of ascidians and in other filter-feeders.

Earlier attempts to record propagated electrical events from sponges have been unsuccessful largely because of technical problems associated with attachment or insertion of electrodes in the delicate, porous, filamentous tissues of these animals.

We have adopted a new approach. This involves dissociating sponge tissue, letting it reaggregate to form a compact mass, and grafting this back on to the original sponge. The graft fuses with the sponge, and serves as a "handle" for attachment of recording electrodes. Recordings from such preparations made from *Rhabdocalyptus dawsoni* show action potentials (the first to be recorded from any member of the Porifera) spreading into the graft following stimulation at remote points (S.P.Ley & G.O.Mackie, 1997, *Nature* 387, 29-30). The pathway for impulse spread is probably the trabecular reticulum, a syncytial tissue permeating all parts of the sponge including the flagellated chambers, where the feeding currents are generated.

Arrests of the feeding current are seen following any mechanical disturbance of the sponge, and also when excessive particulate matter is present in the ambient water. Cessation of pumping presumably helps to prevent clogging of the internal water passages.

These results show that this group of sponges is capable of responding protectively to potentially harmful environmental conditions, and that they make use of propagated electrical impulses like higher animals, despite their lack of a nervous system. It appears likely that contact-excitability and electrical impulse conduction arose in the Metazoa prior to the evolution of nerves.

Manifestations of fluid flow and biogeochemical turnover at cold seeps of the Aleutian subduction zone

PETER LINKE, KLAUS WALLMANN, ERWIN SUESS, GERHARD BOHRMANN,
HEIKO SAHLING, ANKE DÄHLMANN

GEOMAR, Research Center for Marine Geosciences, Dept. of Marine Environmental Geology, Wischhofstr. 1-3, Kiel, 24148, Germany

Along 3 sectors of the eastern Aleutian Trench characteristic manifestations of fluid flow were observed and sampled. In one area, in situ oxygen fluxes were measured at a water depth of 5000 m using a TV-guided benthic flux chamber. The obtained fluxes were two orders of magnitude greater than the normal benthic consumption on the continental margin off Alaska. Pore water profiles obtained from sediments below a seep site indicated high concentrations of sulphide, methane, and ammonia. These reduced inorganic compounds were transported to the seep site by fluids expelled from deeper anoxic sediment layers by the force of plate convergence. The tectonically driven Darcy flow of these fluids was determined from the biogeochemical turnover in vent communities and found to be $3.4 \pm 0.5 \text{ m y}^{-1}$. A model was used to quantify the transport of silica, Ca^{2+} , and sulfate via diffusion, advection, and bioirrigation through the surface sediments of a seep site. By fitting the model curves to the measured pore water profiles a nonlocal mixing coefficient of 20-30 y^{-1} was determined which demonstrates that the transport of solutes within the surface sediment and across the sediment-water interface is dominated by the activity of the seep fauna. From these data it becomes evident that the seep biota shape their immediate environment, control the sediment-water exchange, and the benthic flux at seep sites.

new seeps in Aleutian Chain
at base of continental slope from
Kodiak to Shumagin Islands. Fauna
includes Calyptraea, Solemya sp., pagurophorans
1.11 5,000 m. Acharax digs U-shaped burrow
near surface of sediment (Not clear to me if
The solemyid mentioned is Acharax or if there
is another Solemyid present.
The pagurophorans are at ~~side~~ side of
clams - Don't know if the clams force them.

Large-area imaging of hydrocarbon seep habitats

I.R. MACDONALD, R. SASSEN AND A. PICHABCHY

*Geochemical and Environmental Research Group Texas A&M University College Station, TX 77843
ian@gerg.tamu.edu*

Hydrocarbon seepage on the Gulf of Mexico slope nourishes extensive chemosynthetic communities, which are characterized by visually distinctive colonies of tube worms, seep mussels, and bacterial mats—as well as geological formations such as carbonate pavements and gas hydrates. Laser line scan image strips from four separate seeps were joined into geo-referenced mosaics that covered areas of up to 150 by 250 m.

Mosaicking was accomplished by use of ER-Mapper, a remote-sensing and geophysical image-processing application. Spatial resolution was on the order of 1 to 2 cm and spectral resolution was sufficient to delineate all major seep components. Comparison of the mosaics demonstrates the differences between two major forms of seepage: sediment diffusion and brine pooling; in particular, the dynamics of the two processes are evident from comparison of seeps with different activity levels. These sessile biological aggregations are indicators of persistent seepage through discrete seafloor areas over time-scales of tens or hundreds of years.

Measurement of their precise area can provide low-order estimates for the localized scale and distribution of seepage over time.

PHYLOGENY AND TAXONOMIC REVISION OF THE BRISINGIDA

CHRISTOPHER MAH

Department of Invertebrate Zoology, California Academy of Sciences
Golden Gate Park, San Francisco, CA 94118-4599

Brisingidans comprise a clade of unusual deep-water forcipulatacean asteroids with a cosmopolitan distribution. *Gymnobrisinga* Studer and *Hymenodiscus* Perrier, two historically problematic taxa, were re-examined. *Gymnobrisinga sarsii* is a senior synonym of the Antarctic *Labidiaster annulatus* and should be suppressed. *Brisingella* Fisher is a junior synonym of *Hymenodiscus* Perrier.

Labidiasterid and pedicellasterid forcipulataceans were both considered and rejected as choices for the outgroup. Relative to the Brisingida, both groups possessed either plesiomorphic or autapomorphic characters, neither of which are useful for determining phylogenetic relationships between taxa. The Antarctic brisingidan, *Odinella* was ultimately determined as the outgroup to the crown brisingidan clade.

Preliminary results of a cladistic analysis of 17 brisingidan taxa using 25 characters is presented. The following terminal taxa were included in the analysis: *Astrolirus*, *Astrostephane*, *Brisinga*, *Brisingaster*, *Brisingenes*, *Hymenodiscus* (formerly *Brisingella*), *Midgardia*, *Novodinia*, *Stegnobrisinga*, *Parabrisinga*, *Astrocles*, *Belgicella*, *Colpaster*, *Freyastera*, *Freyella*, *Freyellaster*, and *Odinella*.

A PAUP 3.1.1. search generated 102 trees with a minimum length of 53 steps, a CI of 0.68 with several well supported clades. Data support the monophyly of the Freyellidae (Downey, 1986), but the family Brisingidae *sensu* Clark and Downey (1992) appears to be paraphyletic. *Novodinia* and *Brisingaster* are basal brisingidans and show closest relationship to the outgroup. *Astrolirus*, *Hymenodiscus* and *Parabrisinga* form a strongly supported clade that is the sister taxon to the Freyellidae. Changes in the taxonomy of brisingidans are proposed.

The penetration of brisingidans into deeper water is concurrent with morphological changes. The phylogeny suggests shallow water ancestry for the Brisingida with a shift in feeding behavior from benthopelagic predation to suspension feeding. Because freyellids appear to be so highly differentiated, certain aspects of their morphology may be interpreted as adaptations to inhabiting hadal depths

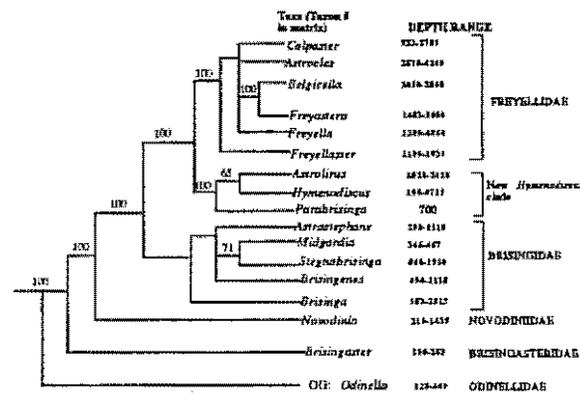


Figure 1. 50% Majority Rule Consensus Tree shown with depth range.

PAEDOMORPHOSIS, RANGE EXTENSIONS AND AN ANSWER TO THE QUESTION: CAN BRISINGIDANS SWIM?

CHRISTOPHER MAH

Department of Invertebrate Zoology, California Academy of Sciences, Golden Gate Park San Francisco, CA 94118-4599

This poster summarizes data from collections-based and observational research on various aspects of brisingidan natural history. Newly discovered juveniles of *Freyella* sp. permit examination of ontogenetic stages in brisingids and suggest progenesis in the freyellid *Freyastera*. Examination of characters in *Hymnodiscus* (formerly *Brisingella*) suggest that this genus is either progenetic, or that at least some species of *Hymnodiscus* are the juveniles of other adult brisingid species.

Material from Oregon State University and CAS collections shows several significant, and in some cases dramatic, range extensions. *Astrolirus panamensis*, known previously from Central American waters has been collected from Southern California and Oregon. *Brisinga* (= *Craterobrisinga*) *synaptoma* previously known only from British Columbia is now known from the central California Coast (Mendocino Ridge). *Freyastera benthophila* previously known from coastal California is now known to range north to Oregon. *Astrocles actinodetus* known previously from British Columbia, now known to range south to Oregon.

Three specimens of cf. *Hymnodiscus* sp. collected during the summer of 1993 from Monterey Bay, California were observed in aquaria for three weeks. cf. *Hymnodiscus* sp. moves like other asteroids, with all arms on the substrate. The suggestion that brisingids can swim (Inst. of Oceanog. Sci., Wormley, 1979) was not confirmed.

Poster

BioDiversity Professional Ecological Analysis Package

NEIL MCALEECE¹, JOHN LAMBSHEAD, GORDON PATERSON AND JOHN GAGE²

¹*Natural History Museum, Cromwell Road, London SWB 5BD, U.K.*

²*Scottish Association for Marine Science, P.P. Box 3, Oban, Argyll, PA34 4AD, U.K.*

The last 30 years have seen an increasing reliance on numerical techniques in community ecology and biodiversity research, particularly in marine biology where accurate quantitative sampling is the norm. IT developments have supplied modestly priced desk-top and portable PCs operating interactive business software through a Windows environment. Environmental scientists have been slow to exploit this potential. Most numerical environmental programs have utilised command prompt interfaces, inflexible outputs and limited functionality.

The Biodiversity Professional package builds on the success of BioDiversity Test version to address these issues.

Program Specification

- Simple to use
- Modest hardware requirement
- Familiar operation
- Windows compatible
- Flexible data input
- Comprehensive and powerful
- Flexible output
- Camera-ready facility
- Future proof

Key Program Functions

- Data management
- Statistical analysis
- Ecological analysis -Alpha diversity -Beta diversity -Multivariate
- Graphic editing
- Advanced user options

BioDiversity On The Web

<http://www.nhm.ac.uk/zoology/bdpro/>

BioGrowth, a computer work bench for analysis of the demographic characteristics of deep-sea invertebrates from measurements of body size frequencies and growth markers

NEIL MCALEECE¹, JOHN D. GAGE² AND TOM BREY³

¹*Natural History Museum, Cromwell Road, London SW8 5BD, U.K.*

²*Scottish Association for Marine Science, P.P. Box 3, Oban, Argyll, PA34 4AD, U.K.*

³*Alfred Wegener Institute, Bremerhaven, Germany*

The computer package *BioGrowth: a Computer Workbench* has been developed by Neil McAleece for the PC Windows 95/NT environment. It has been written to provide for the first time a user-friendly set of tools for analysis of the dynamics of invertebrate populations, including those from the deep sea. It has been developed from programs written in BASIC by John Gage over several years and incorporates elements of the structure of a course in marine invertebrate population dynamics taught by Tom Brey at Bremen University.

Although fisheries scientists have developed mainframe and microcomputer packages capable of assisting with these problems, these usually require some mathematical knowledge and computing skills. Furthermore, such software has primarily been developed for analysis of catches of exploited populations, such as fish and shellfish, for stock management purposes. Hence, these programs may incorporate assumptions and tools that may not be helpful to those attempting to understand the demographic characteristics of natural, unexploited populations such as those of deep-sea invertebrates.

The package combines sophisticated graphics simulation with optimisation, using advanced non-linear search algorithms as the Nelder-Mead Simplex, for fitting demographic models to observed data. These data typically consist of body size frequencies measured from large unbiased samples, and/or estimates of size-at-age measured from analysis of skeletal growth marks in individuals. The program is able to assist with the analysis of demographic characteristics by exploring the implications of particular function parameters using graphics displays combined with rapid optimisation of multiple parameter sets in order to fit a demographic model. This may be used to test the relative fit against competing models, in order to analyse age class composition from size frequencies and fit growth and survivorship functions to these data and to size-at-age data.

Essentially the problem may be one such as that posed by a size frequency distribution measured from a sample, where a series of peaks may be discerned. One may want to estimate demographic characteristics such as age composition, growth and mortality with proper regard to error associated with sample size and taking into account other data (such as growth marks) and what seems biologically reasonable from other information. The ability to rapidly explore the consequences to population size structure of changing values of parameters determining growth and survivorship also make this software a useful teaching tool.

This presentation aims at providing a multimedia presentation of the capabilities of the package along with demonstration using the graphics display by screen projection of working program modules, using data from deep-sea populations. It is planned to make the package available to users on the Internet as freeware.

Nitrate by Seep Populations of *Beggiatoa* from Monterey Canyon

SARAH C. MCHATTON¹, AZEEM AHMAD¹, JAMES P. BARRY² AND DOUGLAS C. NELSON¹

¹Section of Microbiology, University of California, Davis, CA 95616, USA

²Monterey Bay Aquarium Research Institute, Moss Landing, CA 95039, USA

Mats of conspicuous sulfur bacteria belonging to the genus *Beggiatoa* have been found in Monterey Canyon cold seeps. Individual disk-shaped cells, roughly 75 micrometers in diameter, form filaments one to several centimeters long. These bacteria have been recently described as sulfur oxidizing, nitrate respiring autotrophs that contain a central vacuole accounting for roughly 80% of the cellular biovolume. Nitrate is concentrated 400-fold over ambient concentration and is presumably stored in the vacuole. In these traits, as well as the extraordinary biomass achieved in surf-ial marine sediments, these *Beggiatoa* filaments show striking parallels with those of the extensive *Thioploca* mats found off the western coast of South America. Ribosomal RNA sequence analyses of *Beggiatoa* spp and *Thioploca* spp. support the view that the nitrate-accumulating, vacuolate phenotype is monophyletic. In cores from Monterey Canyon seeps, the vertical distribution of the *Beggiatoa* filaments is bimodal with dense populations in the top 3 cm of sediment and between 5 to 7 cm. Studies of sediment chemistry over the depths occupied by *Beggiatoa* filaments have revealed pronounced sulfide depletion and an ammonia maximum. In vitro enzyme assays for a nitrite reductase ($\text{NO}_2^- \rightarrow \text{NH}_4^+$) yielded specific activities of 0.5 to 16 micromoles NH_4^+ formed/min/mg protein in washed *Beggiatoa* samples. This, coupled with a previous demonstration of high activity of a membrane-associated nitrate reductase ($\text{NO}_3^- \rightarrow \text{NO}_2^-$), strongly suggests that these bacteria are using nitrate stored in the vacuole to oxidize sulfide and that they are forming NH_4^+ as the product. At sediment depths well below any possible penetration of oxygen, this postulated use of internally stored nitrate provides a likely explanation for the observed sulfide depletion. Our proposal that nitrate respiration by vacuolate, filamentous, sulfur bacteria results in ammonia as a waste product is in contrast to the literature view that *Thioploca* species are denitrifiers ($\text{NO}_3^- \rightarrow \text{N}_2$)

Poster

Food selection by deep-sea megafaunal surface deposit feeders as indicated by ^{234}Th , chlorophyll, and amino acid measurements

ROBERT J. MILLER¹, CRAIG R. SMITH¹, AND DAVID J. DEMASTER²

¹*Department of Oceanography, University of Hawaii at Manoa, 1000 Pope Rd., Honolulu, Hawaii 96822*

²*Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, North Carolina, 27695*

"Age-dependent mixing" hypothesizes that deep-sea deposit feeders selectively ingest newly sedimented, nutritionally rich particles, and mix them into the sediment column faster than older particles. In principal this differential may be traced using ^{234}Th , which is scavenged by particles in the water column and has a short half life (24 days). To test whether excess ^{234}Th activities and the food values of sediment are correlated, we have measured excess ^{234}Th activities and concentrations of chlorophyll a and labile proteins in sediments from San Diego Trough (1200 m) and the Hawaiian Slope (2000-3000m). We have also measured concentrations of Benth in the guts of deposit feeders from these sites. Chlorophyll and labile amino acids are considered to be indicators of nutritional food such as newly sedimented phytodetritus. Excess ^{234}Th activities in the guts of surface deposit feeders was 10-100X greater than surface sediments (0-5mm), while chlorophyll a in the guts of San Diego Trough deposit feeders was 80-1500X the concentration in surface sediment (0-1mm). Selection for chlorophyll was weak at the Hawaiian Slope, suggesting that phytodetritus is not as important a food source in that more oligotrophic area. This is supported by the very low chlorophyll concentrations in surface sediment there. Labile amino acid concentrations also are much higher in surface sediments rich in ^{234}Th . These results provide strong evidence that deep-sea deposit feeders select for newly sedimented, food-rich particles, and that these particles can be traced by their high average ^{234}Th activity.

Origin and fate of organic carbon at the Hebridean shelf edge, west of Scotland

L. MITCHELL¹, K.D. BLACK¹, E. BRADBEER¹, R. CARRIE¹, A.E. FALLICK², J.D. GAGE¹, S.M. HARVEY¹ AND K. JONES¹

¹Scottish Association for Marine Science, Dunstaffnage Marine Laboratory, P.O. Box 3, Oban, Argyll PA34 4AD

²Scottish Universities Research and Reactor Centre, East Kilbride, Glasgow G75 0QF

What is the ultimate fate of carbon in the oceans? How important is the role of the benthic fauna in the recycling of organic matter? Continental slopes have been thought to represent major depocentres for carbon. To test this hypothesis, a benthic transect was established across the Hebridean Shelf Edge consisting of four stations at 700, 1000, 1500 and 2000m depth. The transect was seasonally sampled 9 times by multicorer during 1995-96. Samples from within the surface mixed layer were analysed for organic and inorganic carbon content, stable carbon isotope ratios, diagnostic fatty acids, chlorophyll/phaeopigments, sediment community oxygen consumption (SCOC) and meiofaunal population dynamics.

The organic carbon content is consistently low, always <1% total dry weight. Surprisingly, there is no significant seasonal variation in either the organic or inorganic carbon content in the sediment despite changing productivity in the overlying water column. This suggests that most of the bloom material is not buried, but remains above the sediment-water interface. Indeed, a large amount of phytodetrital >fluff= was seen resting on the surface of some cores.

Carbon isotope data show a strong seasonal variation reflecting changes in the origin of the detritus. Summer values (around -221) are typical of organic material in oceanic sediments and reflect a predominance of phytoplankton detritus (typical value -211). Winter values (around -251) are consistent with a smaller phytoplankton input and a correspondingly larger proportion of more isotopically depleted material, probably land plant detritus (typical value -271). Assuming that the terrestrial input stays constant (though this is not necessarily the case), a simple mixing model shows that the >pool= of organic detritus above the sediment-water interface must increase in size by a factor of about four during the summer, due to a tenfold increase in the influx of phytodetrital detritus.

Fatty acid and pigment analyses of the organic matter can yield more detailed information about its origin. Diagnostic fatty acid associations indicate that there is a phytoplankton bloom in spring followed by a larger bloom in autumn, and that the bacterial biomass appears to show a small spring peak followed by an increase later in the year to a maximum in autumn/winter. The overall lack of longer chain fatty acids is consistent with a predominantly marine input. Chlorophyll and phaeopigment analysis further supports a seasonal variation in phytoplankton input, but also shows that much of this material is already in a partially degraded state, as if it may have already been transported some distance downslope.

If it is not buried, what is the fate of this material? Seasonal variation in both SCOC and benthic meiofaunal counts suggest that a significant amount of the material is consumed by the benthos. Any remainder may continue to be transported downslope.

This work forms part of the NERC LOIS (Land Ocean Interaction) SES (Shelf Edge Study) programme.

The Mechanosensory Lateral Line in Deep-sea Fishes: Functional Considerations

JOHN MONTGOMERY AND CAROL DIEBEL

School of Biological Sciences, University of Auckland, New Zealand

Recent progress in understanding lateral lines provides insight into the nature of mechanosensory interactions in the deep-sea. The functional unit of the lateral line system is the neuromast, which consists of a patch of hair cells with an overlying gelatinous cupula. There are two main forms of the lateral line: superficial neuromasts on the surface of the skin, and canal neuromasts located within rigid subdermal canals. These morphologies can be interpreted as mechanical filters that influence the functional response of the neuromast (Montgomery et al. 1994). Deep-sea fishes have some extreme lateral line morphologies including stalked superficial neuromasts and large membranous canal systems (Marshall, 1996). This diversity of structure predicts an equally diverse range of mechanosensory function. The key to understanding lateral line is that it is a noise limited system. In the deep-sea, environmental noise is likely to be very low, and the most potent noise source will be the animal's own movements. We have shown that fish have a range of strategies to address the problem of self-generated noise, including behavioural strategies, receptor location, mechanical filters at the periphery and central sensory processing mechanisms (Montgomery and Bodznick, 1994). The raising of the neuromast onto stalks seen in deep-sea anglerfish will have the effect of increasing sensitivity to low frequencies and slow flows. We argue that this increase in sensitivity only makes "sense" within the whole adaptive complex seen in these fishes of neutral buoyancy, low metabolic rate, and consequent reduced movement with an associated reduction in self-generated noise.

Reduction in self-generated noise will carry the added benefit of reducing lateral line "visibility" to other animals. In principle one would expect that given the elaborate development of visual camouflage mechanisms there should be a parallel world of mechanosensory camouflage mechanisms to be discovered. One possible example is the rat-tail morph so common in deep-sea fishes. This body form is expected to produce much less of a mechanosensory "footprint" than the typical teleost homocercal tail (Montgomery and Pankhurst, 1997). Recent experiments show that the superficial neuromast system of fish provides information for rheotactic orientation. From first principles it can be argued that one important use of this information will be to help interpret olfactory signals carried by water currents. Appropriate search strategies can be employed when a fish factors-in information about the water currents dispersing an olfactory stimulus. On this basis we might expect an interaction between olfactory stimuli and mechanosensory endorgans adjacent to olfactory nares. The recent report of specialised superficial neuromasts in association with the nares of some deep-sea species (Marshall, 1996) is circumstantial evidence for this proposal.

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The Challenges of Deep-sea Fisheries

JON A. MOORE

Division of Vertebrate Zoology, Peabody Museum of Natural History, Yale University, P.O.Box 208118, New Haven, Ct. 06520-8118 or Director of Undergraduate Studies, Program in Organismal Biology, Yale Inst. for Biospheric Studies, P.O. Box 208104 New Haven, CT 06520-8104; email: Jon.Moore@Yale.edu, fax: 203-432-9816 voice: 203-432-6040

As shallow water resources continue to decline, fishers are venturing into deeper waters to search for underexploited resources. Underexploited deep-sea animals hold the promise of providing alternative income to fishers and alternative protein for consumption. However, a number of biologic and economic difficulties must be overcome before reasonable fisheries management of deepwater animals can proceed. Because of these difficulties, it may turn out that small-scale deep-sea fisheries can potentially supplement the annual marine harvest, but will not likely replace a large share of the shallow-water harvest.

Distribution density and relative abundance of benthic invertebrate megafauna from three sites at the base of the continental slope off central California as determined by camera sled and beam trawl

JAMES NYBAKKEN, LISA SMITH-BEASLEY, GUILLERMO MORENO, ANNE SUMMERS AND LISA WEETMAN

Moss Landing Marine Labs, PO 450, Moss Landing, CA 95039

Distribution, density and relative abundance of benthic invertebrate megafauna at three sites at the base of the continental slope off central California were investigated by trawls and camera sleds over a two year period. A total of 29 successful trawls returned a total of 133 species of invertebrates. The dominant taxa by number in the trawls were holothurians, ophiurans, pennatulids and one species of sea star and one species of corallomorpharian. There was considerable variation in rank order of abundance of the dominant invertebrates among the three sites and within one of the sites between years. Thus the percent similarity among the three sites as also low. Three of the five most abundant species were burrowers and were not detected in the camera sleds. Comparisons of rank order of abundances between the camera sleds and the trawls was done for 18 taxa. Results indicated no significant differences between the two methods and a total percent similarity of 78.8%. Comparison of the densities per 100 square meters between the two methods revealed that the densities estimated from the camera sleds were about 4 times those of the trawls.

The spectral sensitivities of deep-sea fish visual systems

JULIAN C. PARTRIDGE

School of Biological Sciences, University of Bristol, Woodland Road, Bristol, BS8 1UG, UK (email: j.c.partridge@bristol.ac.uk)

Most deep-sea fishes well developed eyes, suggesting that vision is an important sensory-modality for fish that live in the deep oceans. Nevertheless, the deep-sea is essentially a photon limited environment and numerous visual adaptations have been identified that serve to increase photon catch, including modifications to gross ocular anatomy, photoreceptor morphology and retinal spectral sensitivities. Almost all deep-sea fishes have a single type of rod photoreceptor in their retinas and a single visual pigment which is more short-wave sensitive than that found in shallow living fishes. It is generally accepted that the evolution of such short-wave sensitive pigments is correlated with the spectral transmission properties of oceanic waters, and a link has often been suggested between the spectral distribution of the dim, blue downwelling irradiance found at depth and the spectral sensitivities of deep-sea fish visual pigments. Indeed, the match between the ambient daylight at depth and visual pigment spectral absorption has become a much cited example of how a sensory system can be tuned to some feature of the environment in which it operates; in this case to maximise sensitivity.

However, such conclusions may be based on a misconception about the nature of the light environment at depth and do not adequately consider the visual tasks of deep-sea animals. This paper presents computer models that optimise visual pigment I_{\max} for maximum sensitivity. These models indicate that spectral tuning to downwelling light may not, in fact, be the main selection pressure operating on the visual pigments of deep-sea fishes. Instead the visualisation of bioluminescence may be more significant, with eye design and visual task interacting to determine the optimal (i.e. most sensitive) visual pigment. This conclusion may not only provide a new understanding of the selection pressures acting on deep-sea fish visual systems but, by stressing the importance of interaction distances in visualisation tasks, may also present new insights into communication and community structure in the deep-sea.

Responses of Deep-Sea Benthos to Sedimentation Patterns in the North-East Atlantic

O. PFANNKUCHE¹, A. BOETIUS¹, K. LOCHTE², U. LUNDGREEN³

¹*GEOMAR, Forschungszentrum für Marine Geowissenschaften, Universität Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany*

²*Institut für Ostseeforschung, Seestr. 15, 18119 Rostock-Warnemünde, Germany*

³*Institut für Meereskunde an der Universität Kiel, Dsternbrooker Weg 20, 24105 Kiel, Germany*

In an extended deep-sea study the response of the benthic community to seasonally varying sedimentation rates of organic matter were investigated at one fixed abyssal site in the NE Atlantic (BIOTRANS station or JGOFS station L2 at 47°N-20°W, water depth >4500 m) on four cruise legs of METEOR expedition 21 between March and August 1992. Vertical flux in 3500 m depth and temporal variations in the sediment of chloroplastic pigment concentrations, as a measure for phytodetritus deposition, of total adenylates and total phospholipids, as measures for benthic biomass, and of activity of hydrolytic enzymes were observed. The flux patterns in moored sediment traps of total chlorophyll, POC and total flux showed an early sedimentation maximum in March/April 1992, followed by intermediate flux from June to August. Thus, in 1992 no distinct seasonal signal in sedimentation was found. In the sediment unusually high concentrations of chloroplastic pigments were found in March reflecting the early sedimentation peak. This early influx was matched by slightly higher biomasses and activity of hydrolytic enzymes compared to values from March 1985 and to the following months. In May and August pigment concentrations in the sediment were lower than previously observed depositions of phytodetrital matter in summer. Biomass and activity parameters followed the pattern of the pigment concentrations, although there seemed to be some time lag in response to sedimentation pulses. The data imply that the deep ocean benthic community reacts to small sedimentation events with transient increases in metabolic activity and only small biomass production. The coupling between pelagic and benthic processes obviously is so closely geared that interannual variability in surface water production is "mirrored" by deep-sea benthic processes.

BIGSET A New German Deep-Sea Programme

O. PFANNKUCHE

GEOMAR, Forschungszentrum für Marine Geowissenschaften, Universität Kiel, Wischhofstr. 1-3, 24148 Kiel, Germany

BIGSET (Biogeochemical transport of matter and energy in the deep sea) is a joint programme within the new federal research focus "Deep Sea Research" sponsored by the German Federal Ministry of Education, Science, Research and Technology. BIGSET is concerned with the biogeochemical processes in the ecosystem of the deep sea. The objective is the fate of sedimenting organic matter. Investigations concentrate on the abysso-pelagic and benthic environment with the benthic boundary layer (BBL) as a focal point. The BBL is defined as a zone which extends from the clear water minimum to about one metre into the sediment, contains the nepheloid layer, the bottom contact water, and the bioturbated zone in the sediment. The activity of various groups of organisms inhabiting the BBL, from bacteria to the megabenthos and nekton generates the chemical fluxes and also partly the physical mixing processes. The quantification of biochemical and geochemical fluxes (esp. carbon compounds and opal) within the BBL, the identification of the role of different ecological groups and their interactions are key questions to be dealt with. These investigations will enhance our knowledge of deep ocean fluxes and the early diagenesis of pelagic sediments, thus also contributing to a better interpretation of the geological record. The main objectives are:

- I. Investigations on the functional interrelations within the ecosystem deep sea.
- II. Parameterization and quantification of the benthic-pelagic coupling to ascertain the net fluxes of inorganic and organic matter, especially carbon compounds and opal, on different time and space scales within the benthic boundary layer.
- III. Enhancement of our knowledge by modelling of diagenetic processes in deep sea sediments.
- IV. Development and use of advanced deep sea technologies.

Expeditions are carried out in oceanic regions which are characterized by large periodic sedimentation pulses of organic and inorganic matter to the sea bed (Arabian Sea, NE Atlantic) following plankton blooms caused by monsoon activity or spring plankton blooms caused by deep winter mixing. This joint program is coordinated by GEOMAR.

Poster

Characteristics of Hydrothermal Vent Communities Along the Southern East Pacific Rise, 17°15' to 17°40' S

TYNAN PFINGST¹, CINDY LEE VAN DOVER¹, RACHEL HAYMON², KEN MACDONALD², DAWN WRIGHT³

¹*Institute of Marine Science, University of Alaska, Fairbanks, AK 99775*

²*Department of Geology, University of California, Santa Barbara, CA 93106*

³*Geology Department, Oregon State University, Corvallis, OR 97331; e-mail (Pfingst): pfingst@ims.alaska.edu*

The Southern East Pacific Rise (SEPR) is a superfast spreading center with a large magma budget and high density of hydrothermal sites. The close spacing of vents on the SEPR represents one end-member in a continuum, with the other end-member represented by widely-spaced hydrothermal systems of slow spreading centers such as the Mid-Atlantic Ridge. Using the camera sled ARGO, we mapped the distribution of vent communities on a 40-km segment of the SEPR. More than 100 active hydrothermal sites were identified based on observation of high densities of vent-specific organisms. Sites ranged in size from very small (2-4 m maximum dimension) to large (>100 m maximum dimension) and were hosted by basalts of varying ages. Twenty-one sites were selected for detailed mapping and analysis of patterns of distribution of dominant megafauna. This database will be used to prepare a regional-scale account of faunal diversity and will serve as baseline data for return visits by Alvin in 1998 as part of a proposed chronoseres study.

Poster

Studies on Behaviour of the Abyssal Demersal Grenadier Fish, *Coryphaenoides (Nematonurus) armatus* in North Atlantic and Pacific Oceans

I.G. PRIEDE¹, S. ADDISON¹, P.M. BAGLEY¹, M.C. COLLINS¹, A. SMITH¹ AND N.R. MERRETT²;

¹University of Aberdeen, Department of Zoology, Tillydrone Avenue, Aberdeen. AB24 2TZ. Scotland UK; email: i.g.priede@aberdeen.ac.uk

²Department of Zoology, Natural History Museum, Cromwell Road, London SW7 5BD England. UK.

Using the AUDOS series of lander vehicles, equipped with time lapse cameras, and acoustic tracking systems investigations have been carried out on the behaviour of scavenging *Coryphaenoides (Nematonurus) armatus* at trophically contrasting locations in the NE Atlantic and Pacific Oceans.

The abundance of *C.(N.) armatus* varies between 10 km⁻² on the Madeira Abyssal Plain to 800 km⁻² at 3000m depth in the Porcupine Sea Bight. Arrival time of fish at baits is related to abundance, with 138 min on the Madeira Abyssal Plain and 13 min in the Porcupine Seabight. Staying time of fish at baits is inversely related to fish abundance and a model is presented that predicts the total number expected to be present at baits given variations in fish abundance. The relationship is dome shaped with a peak at 200 fish.km⁻².

Grenadiers departing from the bait source have been tracked using ingestible pingers and transponders. In the Porcupine Seabight there is an increase in swimming speed from 5 cm.s⁻¹ at 2000m depth to 12 cm.s⁻¹ at 4000m depth on the abyssal plain; this is related to bigger-deeper trend in fish size. In the North Pacific Ocean at 4100m depth off the California coast a seasonal change in speed has been recorded between 7cm.s⁻¹ in October and 2.6cm.s⁻¹ in February. The fish move independently of one another and independent of the bottom currents. Meandering tracks result in a dispersal speed of 1.03 to 1.23m.min⁻¹.

On the Porcupine Abyssal Plain major changes have been observed in the size-frequency distribution of fish between repeat visits to this station in August 1989, April 1994 and August 1996. In April there were many small fish on the abyssal plain that are normally associated with the ocean margin continental rise and slope regions during summer sampling. This implies that major seasonal migrations of *C.(N.) armatus* occur around the North Atlantic basin. Sampling in the deep-sea in temperate regions is highly biased towards the summer months. There is clear evidence of seasonal changes in behaviour and distribution of fish; future studies must endeavour to achieve all year round sampling. Seasonal change in terrestrial anis regulated by cycles of secretion of the pineal hormone melatonin, investigations of the brain of *C.(N.) armatus* show a very unusual distribution of melatonin receptors sites possibly related to adaptation to life in darkness at the bottom of the sea.

Feeding behaviors and vertical distribution of the medusa, *Solmissus* (Narcomedusae): *In situ* studies with the MBARI ROV *Ventana*

KEVIN A. RASKOFF

Monterey Bay Aquarium Research Institute, Moss Landing, CA 95039 and Department of Biology, University of California, Los Angeles, Box 951606, Los Angeles, CA 90095-1606

The narcomedusa *Solmissus* is a dominant predator in the mesopelagic zone of Monterey Bay, CA. Foraging behavior, prey capture, and diet composition were examined from *in situ* observations made by the MBARI ROV *Ventana*. The characteristic tentacle-first swimming behavior of the narcomedusae is shown with numerous variations on the theme. It is thought this posture facilitates the capture of large bodied gelatinous prey, which are hypothesized to be its principle diet. Gut content observations show that gelatinous organisms make up almost 90% of the identifiable prey items. Of the gelatinous component, ctenophores are the largest group comprising over 70% of diet. Analysis of the vertical distribution of *Solmissus* show that although this medusa has a wide range of occurrence (surface-1000+ meters), the meters depth. Preliminary day vs. night averages suggest a daily vertical migration of the population, as has been shown for *Solmissus* in other locations.

Poster

The Ecology and Stable Isotopic Composition of Living (Stained) Deep-Sea Benthic Foraminifera from the California Current System

ANTHONY E. RATHBURN¹ AND KYGER C. LOHMANN²

¹Marine Life Research Group, Scripps Institution of Oceanography, La Jolla, CA 92093-0218

²Department of Geological Sciences, University of Michigan, Ann Arbor, MI 48109-1063

Faunal and stable isotope analyses of living (Rose Bengal stained) deep-sea benthic foraminifera from two sites on the Southern California margin reveal spatial and temporal changes in foraminiferal assemblages. Replicated multicorer samples were collected from two sites during CalCOFI cruises in October, 1995, and February, May, August, and October, 1996. The more northern site (located near CalCOFI site 83-55, west of the Santa Barbara Basin at a water depth of 1000 m) has bottom-water oxygen values ranging from 0.41 to 0.47 ml/l, and bottom-water temperatures of about 4°C. *Uvigerina peregrina*, *Bolivina spissa*, and *Hoeglundina elegans* are present in significant densities in the 0-1 cm interval of each sampling. *Epistominella smithi* is present in significant, but variable, numbers in all sampling times except August, whereas *Nonionella fragilis* appears in significant densities in surficial samples only in May and October, 1996. Changes in the abundances of these opportunistic taxa correspond to changes in inferred phytodetrital flux. The southern site (located west of the CA-Mexico border at a water depth of 1300 m) has bottom water oxygen levels of about 0.86 to 0.96 ml/l and bottom water temperatures of about 3°C. *Uvigerina proboscidea*, *U. peregrina*, *Cibicides* species, and *H. elegans* dominate the 0-1 cm samples from this site. Results from $d^{13}C$ analyses of the tests (shell material only) of selected taxa from both sites indicate expected differences between species. Abundant taxa show little temporal variation in $d^{13}C$ despite the possibility of a direct or indirect phytodetrital influence on stable isotopic composition. Variability of $d^{18}O$ is high for several species despite the relative uniformity of temperature and other bottom-water properties at a given site. Comparisons of these results with concurrent water column productivity data (generated by CalCOFI) and previous foraminiferal studies suggest that the faunal differences between sites and temporal assemblage changes observed in this study result from spatial and temporal differences in the availability of organic flux. Opportunistic species exist on the CA margin, and may provide a valuable tool in which to infer changes in paleoproductivity and seasonality in the benthos. Changes in inferred phytodetrital input do not appear to influence the carbon isotope values of taxa selected for study. These inferences about the relationship between living benthic foraminifera and water column productivity have important consequences for the interpretation of paleoproductivity and the history of upwelling in the region (and in other areas of the world). These results reconfirm the idea that benthic foraminifera respond rapidly to the influx of fresh organic material, and provide a means to examine the linkage between modern and ancient water column productivity and benthic ecosystems.

Zooplankton community structure and seasonal dynamics in the Greenland deep-sea

CLAUDIO RICHTER

Institut für Polarökologie, Wischhofstr. 1-3, Geb. 12, D-24148 Kiel, Germany

present address: Zentrum für Marine Tropenökologie, Fahrenheitstr. 1, D-28359 Bremen, Germany

In spite of the extreme seasonality in primary productivity, the near-absence of a vertical density stratification and the overall low temperatures, the Greenland Sea harbors a surprisingly rich and vertically stratified zooplankton community. Integrated biomass values are high and vary only little between seasons (14 ± 3 gDW m^{-2} between the surface and 3000m). However, a considerable vertical translocation of biomass occurs during this period between the surface and the deep-sea, due to the seasonal vertical migrations of herbivorous species, notably among the calanoid copepods. These species crowd into the surface for a very brief feeding period in early summer (June) and descend into the deepsea as early as July, where they overwinter in density maxima located as deep as 1500-2000m. Well above these wintering depths a diverse assemblage of omni- and carnivorous copepods, ostracods, chaetognaths and jelly fish occupies the meso- and lower bathypelagial. Lack of food specialization appears to have resulted in a vertical partitioning of the limited resources with a stepwise arrangement of species with regard to depth and a large generic radiation among the characteristic families, e.g. Aetideidae among the copepods. These mesopelagic scavengers and captors are active year-round and are likely to inflict severe predation losses on overwintering prey populations. Deep wintering thus appears as a necessary strategy to escape prolonged exposure to predation in mid-water.

Poster

Invertebrate predator control of zooplankton seasonal vertical migration in the Greenland Basin

CLAUDIO RICHTER

Institut für Polarökologie, Wischhofstr. 1-3, Geb. 12, D-24148 Kiel, Germany

present address: Zentrum für Marine Tropenökologie, Fahrenheitstr. 1, D-28359 Bremen, Germany

Three species constitute about half the zooplankton biomass in the Greenland Sea, where the herbivorous *Calanus hyperboreus* (Calanoida, Copepoda) takes the biggest share (34+8%), followed by the raptorial *Eukrohnia hamata* (Chaetognatha; 13+5%) and the omnivorous halocyprid ostracod *Conchoecia maxima* (6+2%). *C. hyperboreus* performs extensive seasonal vertical migrations (SVM) between the surface and the deep-sea (>1000 m), while the latter two species remain more or less stationary in the upper and lower mesopelagial with biomass peaks between about 300 and 800m. Spawning of *E. hamata* occurs both in spring and in fall, i.e. right after the SVM of its potential prey. The by polar standards unusual timing indicates that reproduction in arctic midwater predators might be fuelled by their transient prey and geared to their migration cycle. On the herbivore side, deep wintering appears as avoidance response to potential vertebrate and invertebrate predation in the epi- and mesopelagic zone. This is compounded by the observation that in other arctic areas with only low concentrations of chaetognaths, the same herbivores perform only shallow SVM, e.g. <500m for *C. hyperboreus* in the Arctic proper. Predation pressure triggers other intra- and interspecific responses: The rise of young 4-6mm long *E. hamata* from mesopelagic spawning depths to the near-surface can be seen as adaptation to both, higher concentrations of adequately sized food (cyclopid copepods and calanoid nauplii) and lower mortality losses due to the parent generation. Small 0.6-0.8mm sized recruits of *C. maxima* take the opposite route. While the spawning females concentrate in the upper mesopelagial, the young sink out into the bathypelagial where they reach their highest concentrations between 1000-1500m. A slow developmental ascent completes their annual life cycle. The resulting by all means unusual reverse size gradient, with large individuals in the upper water column and small individuals below, is further evidence of the pivotal role of the deep-sea as a refuge for migratory and resident mid-water zooplankton.

Poster

Real in Situ measurements of respiration and metabolism of the deep sea shrimp *Heterocarpus grimaldii*

WOLFGANG RIESS

Max-Planck Institute of Marine Mikrobiology, Celsiussu. 1, 28359 Bremen/Germany

Oxygen consumption rates of the pandalidae deep-sea shrimp *Heterocarpus grimaldii* were measured in 1360-m depth in the eastern Atlantic Ocean north west of Africa during the cruise 37/1 with R/V Meteor. The free falling chamber lander ELINOR, designed for studies of the biogeochemistry of the sediment/water interface, was used to capture four individuals of *H. grimaldii*. The lander is equipped with a coated titanium chamber. An area of 870 cm² is enclosed with approximately 20 cm of the overlying water that is stirred by a stirrer so that a DBL comparable to the natural conditions is created. Due to the absence of other fauna and the possibility to recalculate microbial activity of the sediment measured by the simultaneously deployed lander PROFILUR, rates of respiration and metabolism of *Heterocarpus* could be measured *in situ* without major disturbing effects.

Two Clark type oxygen microelectrodes (stirring effect <1%, 90% response time <1 sec) were used to measure oxygen uptake of the animals which led to respiration rates of 0,047 mmol O₂ / mg fw d. With a motor driven water sampling system water samples for the analysis of CO₂, NH₄⁺, NO₃⁻, and other components were taken over the entire incubation time of 18 hours. After recovery of the lander the still living animals were fixed for examination of gut content. Sediment samples were also taken for the analysis of possible food supply. The diet of the animals consisted not only of benthic but also of planktonic prey.

With these measurements the many problems of other techniques (e.g., pump driven traps, food traps or even decompression effects by bringing animals to the surface) have been avoided.

Sediment distribution, enzyme profiles and bacterial activities in the guts of *Oneirophanta mutabilis*, *Psychropotes longicauda* and *Pseudostichopus* sp. — What do they tell us about digestive strategies of abyssal holothurians?

D ROBERTS¹, H M MOORE¹, J PATCHING², M CARTON²

¹*School of Biology & Biochemistry, The Queen's University, Belfast BT9 7BL, Northern Ireland.*

²*Marine Microbiology, Ryan Institute, University College, Galway, Ireland*

Gut morphologies can be used to infer the digestive strategies of animals and can be substituted for differences in diet in analyses of resource partitioning (Penry 1993). These premisses form the basis for our developing studies into the nutrition of and resource partitioning amongst sympatric abyssal deposit-feeding holothurians. Based on the application of chemical reactor models to digestive strategies in deposit feeders promoted by Penry and Jumars (1987), our previous studies (Moore, Manship & Roberts, 1995) inferred that the gut of *Oneirophanta mutabilis* may act as a plug-flow reactor whereas the guts of *Pseudostichopus* sp. and *Psychropotes longicauda* may show predominantly fore- and hind-gut fermentation respectively.

To further test these ideas, a comparative study of different regions of the guts of the three species was undertaken. The three approaches adopted involved investigation of:

1. sediment distribution in the gut, to provide quantitative support for previous anatomical interpretations
2. enzyme profiles in the gut and gut contents, to identify holothurian and possible sedimentary sources of hydrolytic enzymes
3. bacterial profiles and activities in the gut which might support the concept of fermentation in specific regions of the gut.

Preliminary results indicate clear interspecific differences in sediment partitioning in the gut which supports previous interpretations. Profiles of 19 hydrolytic enzymes determined using API Zym assays (BioMerieux) were similar for both gut tissues and contents although higher values were recorded for the former. Total bacterial counts and profiles of cell-specific rates of bacterial thymidine incorporation also revealed interspecific differences but these are more difficult to interpret.

Acknowledgement

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Advances in Midwater Biology

BRUCE H. ROBISON

Monterey Bay Aquarium Research Institute, PO Box 628, Moss Landing, CA 95039-0628

Continuing developments in the technology, instrumentation, and methodology of research with undersea vehicles have enabled significant advances in our understanding of mesopelagic ecology. Direct observations of behavior patterns, interspecific associations, trophic interactions, predator-prey relationships, and spatial distribution patterns of the mesopelagic fauna in Monterey Bay provide a unique perspective on community structure and function. Comparative studies with other regions (e.g. Sagami Bay, Galapagos) also reveal fundamental or common aspects of ecological structure. MBARI's time-series data set of quantitative midwater transects adds to this new understanding by providing information on the seasonal and inter-annual variability of these ecological patterns. Together, these integrated lines of research are contributing to an improved structural and dynamic model of midwater community ecology.

Faunal community structure at cold seeps of the Aleutian subduction zone

HEIKO **SAHLING**, PETER LINKE, NIKOLAUS VON MIRBACH, ERWIN SUESS,
GYONGYVER LEVAI, RICH LUTZ

GEOMAR, Research Center for Marine Geosciences, Dept. of Marine, Environmental Geology, Wischhofstr. 1-3, Kiel, 24148, Germany

Benthic communities dominated by *Calyptogena* sp., *Solemya* sp. and Pogonophorans are observed and sampled in the eastern Aleutian trench. Stable carbon isotopic composition of soft tissue indicate a nutrition based on sulphide oxidation for the bivalves, and a mixed biogenic methane or sulphide oxidation between species of Pogonophora. Dense colonies of Actiniaria attached to *Calyptogena*-shells rely on particles produced chemosynthetically. Aggregation of suspension feeding Crinoids could be observed around areas with active seepage indicating enhanced particle supply.

Poster

Aplacophoran Molluscs of Seamounts

AMELIE H. SCHELTEMA

Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA

Seamounts often arise thousands of meters above the seabed. Their height and conical form enhance the large-scale unidirectional currents impinging upon them and their summits are affected by tidal currents. Many are found beneath or at the edges of highly productive surface waters. The combination of a ready source of food particles and swift, oscillating currents provides unique habitats for both hard bottom suspension feeders and benthic macrofauna.

Aplacophoran mollusks are primarily carnivores, the creeping neomenioids feeding upon cnidarians and the burrowing chaetoderms on small organisms or organic detritus. Many species found on seamounts appear to be endemics, although net tows above seamounts have captured both infaunal and epifaunal forms, suggesting the possibility for dispersal. Benthic aplacophorans on Fieberling Guyot were found by Levin et al. (1994, *J. Mar. Res.* 52:489) to form the second most numerous taxon after polychaetes, with up to 324 individuals m².

Nutritional patterns of mesopelagic copepod species in the Arctic Ocean - Indications for selective feeding

TILL SCHERZINGER

Alfred-Wegener-Institut for Polar and Marine Research, Columbusstraße 27568 Bremerhaven / Germany

Abundance and vertical distribution of Arctic zooplankton were determined from stratified samples collected during summer 1996 in the Eurasian Basin. The ratio of carbon and nitrogen (C/N) and stable isotope ratio ($\delta^{15}\text{N}$) were determined from six mesopelagic calanoid copepods dominating the biomass including the epipelagic species *Calanus glacialis* as reference for a herbivorous, and *Pareuchata* spp. for a carnivorous feeder. Gut contents were analyzed by different techniques of light microscopy.

Four species (*Spinocalanus antarcticus*, *Scaphocalanus magnus*, *Chiridius obtusifrons*, *Gaidius tenuispinus*) are exclusively ingesting detritus. However, the structure of the gut contents is species specific and sometimes dependend also on the developmental stage. *Gaidius tenuispinus* is the only exception with a high versatility in its gut content. It also feeds on other planktonic crustaceans. This is a strong indication for food selection within the group of detritus feeders. *Aetideopsis rostrata* and *Gaidius brevispinus* have mostly crustacean remains in their stomachs.

According to $\delta^{15}\text{N}$ measurements the six species are grouped into three trophic levels. *Sp. antarcticus* was in the range of the herbivorous *C. glacialis*, four species identified as detritivorous from gut contents, are between *C. glacialis* and the carnivorous species *Pareuchaeta* and *Ae. rostrata*. Species specific gut contents together with the isotope data are clearly showing selective feeding at different trophic levels in the mesopelagic calanoids.

The C/N ratio of most species, with the exception of *Sp. antarcticus*, was rather low (between 4,5 and 5,5) and suggests low fat contents in these species.

Poster

Midwater Observations using the ROV Ventana

B.M. SCHLINING^{1&2}, B.H. ROBISON², AND K.R. REISENBICHLER²

¹*Moss Landing Marine Labs, PO Box 450, Moss Landing, CA 95039*

²*Monterey Bay Aquarium Research Institute, PO Box 628, Moss Landing, CA 95039-0628*

Ninety-five research dives were conducted over the axis of the Monterey Submarine Canyon between January 1990 and December 1994. Measurements were made using a remotely operated vehicle (ROV) and consisted of salinity, temperature, oxygen, and percent light transmission, as well as video recordings of each dive.

Analysis of hydrographic data between 1990 and 1995 shows seasonal uplifting of the California Undercurrent (CUC) and the deeper North Pacific Intermediate waters. This uplifting coincides with upwelling. Contours of temperature, density, and oxygen also show this trend. Reduced upwelling is observed in 1992 coinciding with an El Niño Southern oscillation.

Using data from both quantitative transects and from ascents, descents, and non-transect observations provides information about the vertical distribution and relative abundance of different species. Distributions of organisms calculated from video records typically show seasonal or episodic patterns with reduced abundance during 1992.

Poster

Does an anthropogenic alteration of sediment parameters induce a shift in deep-sea meiofauna composition

GERD SCHRIEVER¹, AHMED AHNERT¹, BERND GRUPE², WILFRIED LANGNER² AND KAY VOPEL³

¹ *BIOLAB Forschungsinstitut, Kieler Str. 51, D-24594 Hohenwestedt, Germany*

² *Alfred-Wegener-Institut fuer Polar- und Meeresforschung, Columbusstr., D-27568 Bremerhaven, Germany*

³ *Versuchsanstalt fuer Wasserbau und Schiffbau, Technische Universitaet Berlin, Mueller-Breslau-Str., D-10623 Berlin, Germany*

In early 1989 a large scale DISturbance and reCOLonisation experiment (DISCOL) was conducted in a manganese nodule field of the tropical south eastern Pacific. In the experiment a plough-harrow device was repeatedly dragged along the seabed in 4150 m water depth, thus creating a severe physical disturbance in the circular DISCOL Experimental Area (DEA). The sediment in the DEA is characterised by a 5 - 10 cm thick surface layer of semi-liquid ooze with low shear strength, followed by compact clayish sediments displaying increased shear strength. Due to the disturbance the semi-liquid layer was totally removed from within the disturber tracks and lumps of clay were deposited beside the tracks. Inside the disturber tracks the clayish sediment was exposed to the sediment surface. The suspended material from the semi-liquid layer formed sediment plumes which drifted away, resettled within some hours, and blanketed large areas within the DEA. A baseline survey was conducted before the experiment, and four post-impact studies followed for monitoring the recolonization process, immediately after the experiment, six months, three years, and seven years later respectively. Meiofaunal data were obtained from multiple corer samples from ten locations inside the DEA and a reference site. During the last cruise (seven years after impact) interdisciplinary research of biologists, geologists and engineers was performed and sediment parameters, like grain size spectra, shear strength and water content were recorded. As a consequence of the experiment three different sedimentary situations can be distinguished:

- comparatively hard sediments within and along the plough-harrow tracks,
- blanketed semi-liquid sediments
- semi-liquid sediments, unaffected by the experiment.

This presentation focuses on the morphological composition of the nematode and harpacticoid copepod community of the DISCOL area. Special attention is given to possible correlations between the occurrence of different "Lebensformtypen" and the sediment qualities mentioned above.

A morphological approach to the phylogeny of Vestimentifera

ANJA SCHULZE

University of Victoria, P.O. Box 3020, Victoria, B.C., V8W 3N5, Canada' e-mail: aschulze@uvic.ca, Tel: (250) 721-8858, Fax: (250) 721-7120

There has been a lot of confusion about the systematic status of vestimentiferan tube worms (=Obturata) in the past. These animals have been switched continuously between the protostomes and the deuterostomes and their rank varied from class to subphylum to phylum. Recent molecular studies supported by some morphological data indicate that Vestimentifera as well as Pogonophora s. str. (also named Perviata) are derived polychaete annelids. The present study comprises two objectives: 1) What is the relationship between vestimentiferans, pogonophorans and tubicolous polychaetes? 2) How are the vestimentiferan species (presently 12 species are known) related to each other? This study is restricted to morphological characters.

The species *Ridgeia piscesae* was examined by light and electron microscopy. The structure of the excretory system reveals a set of important characters. The musculature, nervous system and setal ultrastructure in the opisthosome were also found to be phylogenetically informative. The data are compared to existing data from polychaete and pogonophoran taxa and other vestimentiferan species. Datasets for both of the above mentioned analyses will be presented. Ultimately it is hoped that my results can be combined with existing molecular data to produce an overall picture of vestimentiferan phylogeny.

Poster

An Illustrated Guide to Lucky Strike Hydrothermal Vent Fauna

JENNIFER **SCHURMEIER**, JENNIFER TRASK AND CINDY LEE VAN DOVER

*Institute of Marine Science, University of Alaska Fairbanks, Fairbanks AK 99775
e-mail (Schurmeier): fsjgs@aurora.alaska.edu*

Lucky Strike is a recently discovered hydrothermal system located at 37°N on the Mid-Atlantic Ridge. Its close proximity to the Azores, moderate depths (1700 m), and abundant invertebrate communities make it the focus of international field research. The faunal community at Lucky Strike has been described as one of five hydrothermal biogeographic provinces known to date and is dominated by a new species of mussel. Comprehensive sampling of mussel community fauna was undertaken at two Lucky Strike sites (Sintra and Eiffel Tower) in 1996, using the remotely-operated vehicle *JASON*. We present here an illustrated and annotated guide to this fauna.

Poster

Flight of the Vampire Squid: Scaling of metabolism and aquatic "flight" in *Vampyroteuthis infernalis* (Vampyromorpha: Cephalopoda)

BRAD A. SEIBEL, J. J. CHILDRESS AND E. V. THUESEN

University of California, Santa Barbara, CA 93106, seibel@lifesci.ucsb.edu, (805) 893-3659, FAX (805) 893-8062

Vampyroteuthis infernalis is a cosmopolitan cephalopod that lives in the heart of the oxygen minimum layer below 600 m depth. Morphometric and physiological studies have indicated that *V. infernalis* has little capacity for jet propulsion and has the lowest metabolic rate ever measured for a cephalopod. Because fin swimming is inherently more efficient than jet propulsion, some of the reduction in energy usage relative to other cephalopods may result from the use of fins as the primary means of propulsion. *V. infernalis* undergoes a rapid metamorphosis that includes changes in the position, size, and shape of the fins. This suggests that there are changes in the selective factors affecting locomotion through ontogeny. The present study describes these changes in relation to models for underwater "flight". Citrate synthase (CS) and Octopine dehydrogenase (ODH) activities, indicative of aerobic and anaerobic metabolism respectively, were measured in fin, mantle and arm tissue across four orders of magnitude size range. Results indicate that fin swimming is the primary means of propulsion at all post-metamorphic sizes. Negative allometry of CS activity in mantle and arm muscle is consistent with scaling of oxygen consumption previously measured for *V. infernalis* and with the scaling of aerobic metabolism observed in most animals. The unusual positive allometry of fin muscle suggests that the use of fins is more costly in larger sized animals. Positive scaling of ODH activity in all tissue suggests that fin propulsion, jet propulsion and medusoid "bell-swimming" are all important for burst escape responses. The observed scaling patterns and morphological changes at metamorphosis appear to function as an ontogenetic "gait-transition".

Deep dwelling cephalopods opt for
fin swimming rather than
jet propulsion because more
efficient

In ontogeny the Vampire squid starts out
with 2 pairs of fins & as develop the
posterior fins degenerate & anterior ones
take over. Seems juveniles use jet propulsion
& when adult use fins

Post-spawning egg care in the mesopelagic squid, *Gonatus* (Teuthoidea: Cephalopoda)

BRAD A. SEIBEL¹, F. G. HOCHBERG², D. CARLINI³, J.J. CHILDRESS⁴

¹University of California Santa Barbara,

²Santa Barbara Museum of Natural History

³Virginia Institute of Marine Science

⁴University of California, Santa Barbara

A novel reproductive strategy consisting of deep-water spawning and egg-care was observed for the mesopelagic squid, *Gonatus* spp. Brooding females and associated hatchlings and eggs, captured between 1250 and 1750 m off southern California, are described. Brooding females appear to be senescent and are lacking tentacles. The loss of tentacles in Gonatid species is discussed in relation to this unusual life-history characteristic. Metabolic estimators and chemical composition of *G. onyx* and *G. pyros* are also reported and discussed in relation to buoyancy and energy reserves required for an estimated 9 month post-spawning brood period.

Poster

Biological Succession Following Eruptive Initiation of Deep-Sea Hydrothermal Venting

T. M. SHANK AND R. A. LUTZ

Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ 08903 USA

The April 1991 discovery of newly-formed hydrothermal vents in areas of intense volcanic activity along the East Pacific Rise (EPR) between 9° 45' and 9° 52'N afforded the unique opportunity to follow temporal changes in biological community structure from the "birth" of numerous deep-sea hydrothermal vents. In March 1992, *DSV Alvin* was used to deploy an on-bottom observatory, the Biologic-Geologic Transect (Transect), along a 1.37-km segment of the axial summit caldera between 9°49.61' and 9°50.36'N. Subsequent megafaunal colonization was photo- and videographically documented in March 1992, December 1993, October 1994, and November 1995. Chemical analyses of fluids associated with venting areas within the Transect initially revealed extremely high concentrations of H₂S (up to 8.5 mmoles/kg in diffuse vent fluids and 47 mmoles/kg in high-temperature vent fluids). A decline in the concentration of this chemical compound in diffuse vent fluids was concomitant with the sequential recruitment of numerous vent-endemic species (*e.g.*, the vestimentiferan tube worms *Tevnia jerichonana* and *Riftia pachyptila*, and the mussel *Bathymodiolus thermophilus*) between April 1991 and November 1995. This sequential pattern of colonization, *T. jerichonana* to *R. pachyptila* to *B. thermophilus*, suggests that successful colonization of the dominant megafaunal vent species may be separated in time by their relative tolerance to geochemical conditions. Several of the newly-formed biological assemblages suffered a rapid death coincident with abrupt geochemical changes and the local refocusing or cessation of vent flow in discrete venting areas.

We observed the following sequence of events. (1) Immediately following the eruption, H₂S and Fe concentrations were extremely high (>1 mmole/kg) and microbial debris from a subsurface source covered vigorously venting areas of the seafloor in the form of thick mats. (2) Mobile vent fauna (*e.g.*, amphipods, copepods, brachyuran and galatheid crabs) and non-vent fauna (*e.g.*, nematocarcinid shrimp) proliferated in response to the increased microbial production. (3) Within 1 year of the eruption, the areal coverage of microbial mats was markedly reduced and larvae of *Tevnia jerichonana* settled gregariously in the most intense areas of diffuse flow. (4) Within 2 years, levels of H₂S and other chemical species decreased appreciably and colonies of *Riftia pachyptila* dominated vent openings previously inhabited by dense thickets of *Tevnia jerichonana*. (5) Within 3 years, H₂S levels declined further and mussels began to colonize basaltic substrates. (6) Within 4 years, galatheid crabs and serpulid polychaetes increased in abundance and were observed close to active vent openings as H₂S levels continued to decrease; mussels began to colonize tubes of *Riftia pachyptila*. (7) Within 2½ years of the inception of venting activity, 12 vent-associated species were in the vicinity of newly-formed vents and, after one additional year, 29 species were documented within this same area. Based on these observations, we hypothesize that the above general sequence of biological successional changes will occur at deep-sea hydrothermal vents formed during eruptive events along the East Pacific Rise and contiguous ridge axes. Furthermore, we suspect that between 5 and 10 years after an eruption, mytilid and vesicomid bivalves gradually replace the vestimentiferans as the dominant megafauna and the abundance of suspension feeders decline while the abundance of carnivores increases.

Environmental Periodicities and Faunal Colonization Associated with Nascent Low-Temperature Hydrothermal Venting; Results of Time-Lapse Videography and Multi-Probe Temperature Measurements at 9° 49.8'N on the East Pacific Rise

T.M. SHANK¹, D. J. FORNARI², G. LEVAI¹, AND R. A. LUTZ¹

¹ Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ 08903 USA

² Dept. of Geol. and Geophys., Woods Hole Oceanographic Institution, Woods Hole, MA 02543 USA

Temporal and spatial variability in hydrothermal fluid temperature within an actively developing biological community have been successfully documented using time-lapse temperature probe arrays and time-lapse videography during a 10 month deployment at 9° 49.8'N on the East Pacific Rise crest. Using temperature as an indicator of cycles of venting activity, we have continuously measured (at various intervals) the frequency duration and relative strengths of hydrothermal cycles since December 1993 along a venting fissure at the Marker #141 site (2510m), a nascent hydrothermal vent area within the Biologic-Geologic Transect which was established in March 1992. This area has been extensively and increasingly colonized by vestimentiferan tube worms since April 1991 when the maximum fluid temperature was 29°C (ambient temp. 1.8°C). A Hi-8 video time-lapse system, and a linear array of 6 time-lapse temperature probes (arranged within the field of view of the video camera), each 9 cm long x 4 cm in diameter, spaced at intervals of ~10 cm, and capable of recording 1800 discrete temperature measurements (to within 0.5°C), were deployed in December 1993. Twenty seconds of video imagery were recorded once a day for the entire deployment, while discrete temperature measurements were obtained every 3.2 hours by the six temperature probes. Recovered temperature profiles from the 10 month deployment indicate marked short-term temporal variability (frequent 12°C increases between recording intervals) and spatial variability of temperature regimes (~14°C shifts within 10 cm between recording intervals). Spatial variation within the tube worm assemblage was demonstrated in August 1994 as one probe monitored temperature consistently between -3°C and -7°C and another probe 40 cm distant measured temperature increasing from -3°C to -22°C suggesting that transient and strong temperature gradients may develop with these microhabitats. Spectral analysis of individual temperature records supports the presence of a prominent ~12.5 hour tidal signature in the 9° 50'N area.

Video images illustrate dramatic short-term bursts of venting activity and a coincident increase in mobile megafauna, including brachyuran and galatheid crabs, zoarcid fish, and dense swarms of pardaliscid amphipods surrounding the vestimentiferan community. Recruitment was actively occurring and biomass was significantly increasing over time at this site. Vestimentiferan tube worms, *Tevnia jerichonana* (135 indiv.) with tube lengths up to 17 cm and *Riftia pachyptila* (30 indiv.) with tube lengths up to 25 cm, colonized the six-probe temperature array during the 10 month deployment. Other fauna attached to the recovered probes included lepidodrilid limpets (*Lepidodrilus elvatus* and alvinellid polychaetes (*Paralvinella grasslei*).

Poster

Effects of temperature on the development and survival of larval *Nanomia bijuga*

R.E. SHERLOCK, B.H. ROBISON, AND K.R. REISENBICHLER

Monterey Bay Aquarium Research Institute, PO Box 628, Moss Landing, CA 95039-0628; 408-775-1700

Nanomia bijuga inhabit a broad geographic and vertical range in the world ocean. Throughout this range these siphonophores encounter widely varying temperatures. Temperature is commonly thought to be a principle factor governing larval development rate and survivorship, although it has been suggested that temperature compensation by larvae may make other factors, *e.g.*, nutrition, more important (Clarke, 1990, 1992). Effects of temperature on development have been studied, largely in benthic organisms. For this experiment, gametes were collected from *Nanomia bijuga*, a meso-pelagic organism, and self-crossed. Immediately following fertilization, half of the eggs were placed in a 8° C treatment and the other half were kept at 12° C. Larvae were preserved at four different times during development for subsequent microscopic analysis (SEM). Size was determined by image analysis. Larval development slowed appreciably at colder temperatures. A simultaneous experiment compared larval survivorship. Eggs were collected from a second siphonophore and allowed to develop to planula larvae (~24 hours) after which time they were divided and placed in four temperature treatments. Survivorship of larvae was recorded on a daily basis. Larvae developed more rapidly at higher temperatures, but survivorship was greater at lower temperatures. After ten days at 4° C, larvae had not developed to the same degree they had at 18° C after one day. However, after ten days at 4° C 60% of larvae were alive where as only 3.3% of larvae from the 18° C treatment remained.

Rate and Process of deep-sea vestimentiferan tube Growth

B. SHILLITO¹, J. RAVAUX¹, F. MENARD¹, G. GOFFINET², J.J CHILDRESS³, E. THIEBAUT¹, J. DELACHAMBRE¹, F. GAILL¹

¹ INSU CNRS Roscoff, UPMC, 7 Quai Saint Bernard, 75252 Paris, France

² Institut de Zoologie, Universite de Liege, 22, Quai Van Beneden, B-4020 Liege, Belgium.

³ Department of Biological Sciences and Marine Science Institute, University of California, Santa Barbara, California, 93106, USA.

Tube growth rate and process were investigated in the case of the hydrothermal vent vestimentiferan *Riftia pachyptila*. Morphological aspects of worms and their tubes were studied. In parallel, tube production experiments were performed on live animals, in pressurized aquaria. Dry weights of the secretions, along with their chitin content (a major component of the tube) were used to quantify tube production. Our results show a variation of the gross morphology of the plume and the trunk of *R. pachyptila* during its growth and indicate that vestimentum length and tube diameter could be useful indices of individual and tube sizes of *R. pachyptila*. The presence of basal partitions of freshly secreted tube material at the base of the exoskeleton, as well as observation of branched (bifid) tubes, allow us to propose a model of tube growth at both extremities. In this model the tube growth would exhibit a moulting-like step. Bifid shapes may help in space displacement, and the modification of the positioning in height (by synthesis of basal partitions) may be used by an individual to modify its access to vent fluid.

Ultrastructural observations of the chitin secretion system of this animal, as well as fresh tube material deposits (experiments on live animals) confirm that tube growth occurs at both ends. The experiments performed on repressurized worms indicate that tube production may be extremely rapid, perhaps as an instantaneous response to stressful conditions. When compared to other marine ecosystems, it is obvious that chitin production of the vent communities, based on *Riftia pachyptila* alone, is the highest recorded and similar values were only reported from polluted freshwater environments.

Whale-Fall Communities on the Northwest Pacific Slope: Succession and Food-Web Structure

CRAIG R. SMITH AND AMY R. BACO

Department of Oceanography, University of Hawaii, 1000 Pope Road, Honolulu, HI, 96822, USA

Chemoautotrophic communities on lipid-rich whale skeletons are known from a total of 8 modern sites and 8 fossil sites (up to 30 million years old) in the deep Pacific Ocean. We are using natural and experimentally implanted whale skeletons to study community structure, succession, and vent-seep affinities of whale-fall communities in the northeast Pacific at water depths of 1000 - 2000 m. With ROV's and submersibles, we have thus far sampled whale carcasses of the following ages: 1 wk, 2 wk, 4.5 mo, 3.4 yr, > 4 yr, > 7 yr, and > 11 yr? since arrival at the seafloor. Because of the experimental difficulties of working with dead whales, these carcasses cover a broad range of sizes and occur in a variety of different habitats. Nonetheless, results are consistent with the following successional pattern. (1) An early stage dominated by large mobile scavengers, e.g., hagfish (*Epatretus deani*), macrourid fish, lithodid crabs and sleeper sharks (*Somniosus pacificus*?) during which soft tissue is stripped from the skeleton on time scales of months. (2) An intermediate stage lasting months to years(?) in which local sediments are organically enriched, and the infauna dominated by high densities of enrichment respondents such as dorvilleid polychaetes (up to 10,000 m⁻²) and/or large gastropods (e.g., *Bittium* sp., up to 100 m⁻²). (3) An advanced sulfophilic stage in which chemoautotrophic bacterial mats, mussels, vesicomysid clams and vestimentiferans utilize sulfide released by anaerobic decay of bone lipids. This advanced stage can persist for > 11 yr on large skeletons. Stable isotope analyses using C⁻¹³ and N⁻¹⁵ suggest that this last stage can harbor a broad based food web, including macrofaunal species living solely on chemoautotrophic production (vesicomysid clams), mixotrophs utilizing both endosymbiont-based chemoautotrophy and heterotrophy to obtain carbon (e.g., the mussel *Idas washingtonia*), bacterial mat grazers (two limpets, an isopod, and possibly a snail) and direct feeders on bone organic material (two limpets).

Whale carcasses reach floor about every
30-40 km

Study 2 whale fall that are natural
& 3 carcasses that are placed from carcasses
furnished by NOAA - dead animals on beach

at last stage, when sulfides produced
then autotrophic mussels settle on bone
& *Calyptra* clams in the mud next
to whale bone

Detrital Aggregates on IRE Sea Floor: Chemical Composition and Aerobic Decomposition Rates at a Time Series Station in the Abyssal NE Pacific

K.L. SMITH, JR., R.J. BALDWIN, R.C. GLATTS AND R.S. KAUFMANN

Marine Biology Research :Division 0202, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093-0202

Seasonal pulses of phytoplankton-derived particulate matter reach the deep-sea floor as phytodetritus in many temperate and equatorial regions of the World Ocean. Shipboard observations of phytodetrital aggregates collected at bathyal and abyssal depths strongly suggest their importance as food inputs to the benthic community. As part of a 7-year time-series study of the bend bounds layer at an abyssal site in the NE Pacific, we examined detrital aggregates to test the hypothesis that detrital aggregates create localized areas of intense biological activity. We predicted that aggregates should create "hot spots" of elevated sediment community oxygen consumption (SCOC) over the course of their decomposition.

Detrital aggregates were collected and incubations conducted on the sea floor using the submersible *Alvin* at an abyssal site located at a depth of 4100 m on the Monterey Deep-Sea Fan. At this location, detrital aggregates typically are visible in photographs of the sea floor from July through December. We collected samples and measured SCOC at this site twice when aggregates were present on the sea floor (August and September 1994) and once when aggregates were absent (April 1995). A total of 55 aggregates were collected in August and 88 in September. Undisturbed sites occupied by aggregates during August were relocated with an acoustic positioning system and sampled in September and April.

Aggregates were generally smaller and more diffuse in August than in September. Aggregate chemical composition was highly variable within and between sampling periods. The C:N ratio of aggregates was significantly lower in September than in August, but chlorophyll content was higher in August. Aggregate chemical composition was similar to that of synoptically-collected sinking particulate matter and significantly different from the composition of surface sediments. Oxygen consumption in cores containing aggregates was significantly higher in September than in August and significantly higher in cores containing aggregates than in those without aggregates during both sampling periods. Oxygen consumption of aggregates was correlated strongly with organic carbon, total nitrogen and ATP content. The contribution of detrital aggregates to the chemical composition of the underlying sediments and benthic community activity will be discussed in the context of the 7-year time-series study at this site.

Systematics and phylogeny of the hot vent family Lepetodrilidae McLean, 1988 (Gastropoda: Lepetodriloidea) - a cladistic analysis

KATHRIN SOBJINSKI

Philipps-Universität, Dept. of Biology/Zoology, 35032 Marburg/L., Germany; e-mail: sobjinsk@mail.uni-marburg.de

The systematical relationship of the Lepetodrilidae is revised in this study based on results of a cladistic analysis that incorporated 15 taxa (species and subspecies) of the genus *Lepetodrilus* and, as an outgroup, the genus *Gorgolectis*. A cladogram was compiled from the data obtained from the examination of shell, radular, and soft part characters (light microscopy, SEM). The analysis shows a distinctive division of plesiomorphic species inhabiting the western Pacific and species with apomorphic character states that predominantly occur at the East Pacific Rise. An as yet unnamed species from the Mid Atlantic Ridge is considered to be closely related to species from the Guaymas basin and the East Pacific Rise. According to the results of the analysis, *Rhynchopelta?* nux Okutani, Fujikura & Sasaki, 1993 is transferred to the genus *Lepetodrilus*.

Evidence presented in this poster suggests that the Lepetodrilidae originated at the East Pacific Rise during the late Paleozoic or early Mesozoic.

Poster

Activity and biomass of the small benthic biota under permanent ice-coverage in the central Arctic Ocean

THOMAS SOLTWEDEL

Alfred-Wegener Institut, Bremerhaven, Germany

Sediment samples collected during expedition "Arctic Ocean '96" with the Swedish ice-breaker *ODEN* were investigated to estimate for the first time heterotrophic activity and total microbial biomass (size range from bacteria to small metazoans) from the perennial ice-covered, central Arctic Ocean. Benthic activities and biomasses were evaluated analyzing a series of biogenic sediment compounds (i.e. bacterial exo-enzymes, total adenylates, DNA, phospho-lipids, particulate proteins). In contrast to the very time consuming sorting, enumeration and weight determination, analyses of biochemical sediment parameters represent a useful method to obtain rapid information on the ecological situation in a given benthic systems.

Bacterial cell numbers and biomasses were estimated for comparison with biochemically determined biomass data, to evaluate the contribution of the bacterial biomass to the total microbial biomass. It appeared that bacterial biomass made up only 8 to 31% (average of all stations = 20%) of the total microbial biomass suggesting a large fraction of other small infaunal organisms with the sediment samples (most probably fungi, yeasts, protozoans like flagellates, ciliates or amocbac as well as a fraction of small metazoans).

In contrast to other oceanic regions, benthic activities and biomass values determined within this study generally were extremely low, characterizing the seafloor of the Central Arctic Ocean as a real 'benthic desert'. Nevertheless clear tendencies in the data could be found within the sediment columns, with increasing, water depth of sampling stations, as well as between different Arctic deep-sea regions.

Through a Porthole Darkly: Observations of Behavior Changes Associated with Aggregative Mating of Tanner crab, *Chionoecetes bairdi*: a five-year retrospective

BRADLEY G. STEVENS

National Marine Fisheries Service, P.O. Box 1638, Kodiak AK 1 99615. Fax (907 487-5961;
email:bstevens@atsc.nosagov

Each spring from 1991 through 1995 we have observed aggregative mating of Tanner crabs in Chiniak Bay, Kodiak Alaska, using a combination of submersible and ROV. Over that period we have observed crabs before, during, and after the aggregation event, and can now piece together the sequence of events leading to aggregation. Female crabs winter in about 150 m depth at a traditional site which has been used continuously from 1991 through 1997. During the day, they remain buried in the mud at densities of up to 3/m², emerging to forage at night. A few weeks prior to spawning, females cease feeding, and males start migrating to the aggregation site. Over a 2-day period in 1995, females emerged from the mud and formed mounds containing hundreds of crabs, with densities >50/m². Female crabs in the mounds were release hatching larvae. In 1991, approximately 200 such mounds were observed, involving an estimated 100,000 crabs. Sex ratios ranged from 10 to 100 females per male. Before or after releasing larvae, females mate with male: around and between (but not in) the mounds. After hatching, females leave the mound, extrude new clutches, and resume their diurnal cycle of burial and emergence, and males disperse (although some also die). Female behavior (emergence, mound forming, and hatching) is a rapid phenomenon, and probably occurs the response to some environmental variable, but neither bottom water temperature or surface water clarity (a proxy for phytoplankton abundance) change as suddenly as, or in sequence with, female density. The function of crab mounds is still unclear; they may help to attract males, although their association with hatching suggests that mounds are a mechanism for launching, larvae clear of the sediment boundary layer.

Seasonal dispersal and allopatric settlement and growth of the bathyal brittle star *Ophiocten gracilis*

P.Y.G. SUMIDA¹, P.A. TYLER¹, R.S. LAMPITT² AND J.D. GAGE³

¹Dept. of Oceanography, University of Southampton, SOC, Southampton SO14 2ZH UK

²George Deacon Division, SOC, Southampton SO14 3ZH UK

³Scottish Association for Marine Sciences, PO Box 3, Oban Argyll PA34 4AD

Ophiocten gracilis is a small brittle star found throughout the north Atlantic with its centre of distribution at ~1000m depth. This species is known to reproduce and recruit seasonally (February to September) and has a larval form identified as *Ophiopluteus ramosus*. From data from benthic samples and from sediment traps deployed in the NE Atlantic we observe that the postlarvae of *Ophiocten gracilis* has a far wider distribution than that known for the adults. From post-larvae caught in sediment traps we have been able to determine minimal horizontal and vertical dispersion of this species, with some individuals being collected at 4500m depth over the Porcupine Abyssal Plain. In addition, we have calculated the settling rate of the postlarvae which suggests they sink more rapidly than phytodetrital material. From post larvae in sediment traps we have been able to determine the early growth rates of postlarvae and juveniles of *Ophiocten gracilis*. The data show that this species grows fast, increasing ~2.5 times in disk diameter in less than three months. The reproductive biology shows that the gonads of this species start developing at 1 to 2 mm disk diameter, suggesting that with the growth data, that individuals could be ready to reproduce the year after settlement. In this paper we discuss why this species has such widespread and allopatric settlement of its larvae whilst the reproducing adult population has a relatively restricted vertical distribution.

Distribution of larvae of mesopelagic fishes in the western south Pacific

ANDREI SUNTSOV

Virginia Institute of Marine Science, School of Marine Science, PO Box 1346 Gloucester Point VA 23062; (office) 804-684-7338 (home) 804-642-4923; E-mail: asuntsov@vims.edu

The large scale distributional patterns of larvae of mesopelagic fishes based on samples taken during the 34th cruise of Russian R/V "Dmitrii Mendeleev" (January -March 1986) in the central and western sub-antarctic region of the Pacific, are described and related to major hydrological phenomena. Quantitative data on ichthyoplankton composition were analyzed by combination of classification (TWINSPAN) and both direct (Canonical Correspondence Analysis - CCA) and indirect (Detrended Correspondence Analysis - DCA) ordination methods. Temperature, salinity and DO, as well as latitude and longitude were used in ordination analysis to reveal correlations between both observed species and sample groups. Major larval fish assemblages were revealed by classification and ordination techniques to be associated with 1) Antarctic - Antarctic Polar Front, 2) Subantarctic Zone, 3) Subtropical Convergence and 4) Subtropical Zone, and thus are consistent with known hydrological zonation of the region and distinct latitudinal gradation. Ordination analysis showed the importance of temperature and salinity as well as latitude, as major factors ruling the observed zonation patterns. The larval fish assemblages revealed by multivariate techniques are discussed and compared to previous zoogeographical divisions of the region.

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Poster

Trophic ecology of the deep-sea fish *Malacosteus niger* Ayres: Planktivory by a top mesopelagic predator?

TRACEY T. SUTTON, AND THOMAS L. HOPKINS

Department of Marine Science; University of South Florida; 140 7th Avenue South; St. Petersburg, FL, 33701, USA; (813) 893-9187; FAX (813) 893-9189; E-MAIL: sutton@jaws.marine.usf.edu

A fundamental precept of ecology is that functional morphology reflects the lifestyle and resource usage of an organism. With regard to fishes, prey type has been shown to correlate closely with feeding morphology (e.g. gape, dentition, gill rakers, etc.). Planktivores characteristically have small teeth, numerous fine gill rakers, and small to large gapes, while piscivores tend to have fewer, larger teeth, no gill rakers, and large to enormous gapes. The mesopelagic fish *Malacosteus niger* (Stomiiformes: Stomiidae: Malacosteinae) has a huge gape (dentary 24-28% of SL) bearing large, barbed fangs, and lacks gill rakers and an ethmoid membrane. It has been reported that *M. niger* is a large-item predator, like most other barbelled stomiiformes, but analysis of specimens from around the world indicates that large calanoid copepods are the most frequent prey items (86 of 119 prey items [72%], 92 specimens), with fish, decapods, and euphausiids comprising the remainder. The prey capture method of *M. niger* is unknown, but a theory presented here is that *M. niger* may scan a small illuminated volume using its red bioluminescence/vision system and must therefore sustain itself by snacking on red copepods in between rare encounters with large prey.

Poster

The Chemical Ecology of Deep-Sea Scavengers

MARIO N. TAMBURRI AND JAMES P. BARRY

Monterey Bay Aquarium Research Institute, P.O. Box 628, Moss Landing, CA 95039

Although it is believed that there are no obligate scavengers in marine systems, many benthic animals derive much of their nutrition through the consumption of spatially and temporally unpredictable food falls. The exploitation of carrion may therefore play an important role in structuring deep-sea communities where facultative scavenging is common. Organisms that rely on rare food falls for part or all of their nutrition are typically able to survive extensive periods without eating and respond quickly when food is available. However, the behavioral and physiological traits that allow most deep sea scavengers to utilize food falls are poorly understood.

Chemoreception evolved very early in nearly all phyla and is the key sensory system regulating the feeding behavior of most animals, especially in the deep sea where vision is limited. We investigated how the Pacific hagfish *Eptatretus stouti* (demersal yet highly mobile), the snails *Neptunea amianta* (slow benthic crawlers), and the amphipod *Orchomene obtusus* (small but also highly mobile) use waterborne chemical cues to identify and locate carrion. Because these organisms appear to depend on scarce food falls for much of their nutrition, we also determined their ability to respond to odors of other scavengers (a potential indication of carrion) and to defend food from competitors.

Environmental Risks of Large-scale Deep-sea Impact studies

HJELMAR THIEL AND GERD SCHRIEVER

Alfred Wegener Institute for Polar and Marine Research, 27568 Bremerhaven, Germany

During preceding years it became environmental policy to consider those impacts which research might have on animal species, populations, communities, or on ecosystems. In this context the General Directorate XII for Science, Research and Development of the European Union issued a call for proposals. "The sole objective and topic covered by this call is the assesment of any possible risk likely to affect the marine environment in association with research, monitoring and surveying in marine sciences and technologies". One of the proposals approved is the project "Environmental risk from large-scale ecological research in the deep sea. A desk study a, acronymed RISKER. It is based on new approaches in oceanographic investigations which are collectively termed "large-scale experiments.

Most oceanographic research activities impact the ocean and the organisms to some extent, but these influences remain neglectable and acceptable. However, new approaches to environmental research were verified after industry began its explorative research in the deep sea on metalliferous resources, and after I realizing that normal-scale oceanographic methods did not lead to results extrapolatable to full-scale industrial uses of the ocean.

RISKER is concerned with mining (polymetallic nodules and crusts, metalliferous muds, massive sulfides, phosphorites) and with dumping (radioactive material, carbon dioxide, sewage sludge, dredge spoil, munition, large structures). For each of these potential uses of the deep sea RISKER describes the material, the mining and dumping technologies, respectively, and the potential impacts. Yet the focus will be placed on the two central questions:

- What type of research has to be executed to evaluate full-scale uses of the deep sea?
- Will the impacts of these research activities, most probably large-scale disturbance experiments, be acceptable under environmental considerations?

General results from this desk study will be presented.

Megabenthic Recolonization within the DISCOL Area (Abyssal Peru Basin) Results from the environmental research programs DISCOL and ECOBENT

HARTMUT BLUHM¹, GERD SCHRIEVER² AND HJALMAR THIEL¹

¹Alfred Wegener Institute for Polar and Marine Research, D-27568 Bremerhaven, Germany

²Biolab Research Institute, Kieler Strabe 51, 24594 Hohenwestedt, Germany

Megabenthic organisms are defined as species large enough to be identified on photographs. Due to their low density, the megabenthos is difficult to catch by usual sampling methods. However, megabenthic organisms are widely distributed in manganese nodule areas and are suitable as indicator organisms for monitoring environmental changes. The poster presents the recolonization of the megabenthos after the mechanical impact created within the DISCO / ECOBENT project (ref. poster Thiel et al.).

For monitoring the megabenthos a photo-/videosystem (OFOS) was used, which was equipped with a low-level black and white video camera and a 35mm still camera with photo-on-command capabilities. The system was towed by the German Research Vessel Sonne at a distance of approx. 3m above the seafloor. In the laboratory the image material was carefully examined and all observations transferred into video and photograph databases. Diversity and density calculations were made with a specially created abase IV program, based on the video recordings. Photographic information was used to correct the density values to more realistic levels.

Although the sharp edges of the experimentally created disturbance tracks were smoothed due to the influence of bottom currents, the plow-harrow tracks are still visible in the image material seven years after their creation. The depopulated plow-harrow tracks were recolonized by highly motile animals such as the hermit crab *Probeebei mirabilis*, Ophiuroidea and Holothuroidea, especially between the second and third post-impact study (half a year and three years after plowing). Total density reached baseline values. After seven years hemisessile organisms (e.g. Lophenteropneusta, Anthozoa) were also observed in the impacted area. Although only few data sets of the fourth post impact study have been analyzed yet, megafaunal density in the plow tracks had again declined seven years after plowing.

In the areas not directly impacted by the plow-harrow device, densities exceeded the baseline values three years after plowing due to possible external effects, but declined again to baseline levels during the fourth post-impact study. Although the megafauna studies demonstrated the re-establishment of the fauna in the disturbed area seven years later, the impact was still to be recognized.

Poster

Harpacticoid copepod diversity at two physically reworked sites in the deep sea

DAVID THISTLE

Department of Oceanography, Florida State University, Tallahassee, FL 32306-3048, U.S.A.

Patches on the millimeter-to-meter scale are thought to be crucial to the maintenance of the high diversity of macrofauna and meiofauna in the deep sea. Disturbances larger than this scale should obliterate the small-scale patchiness. Sites disturbed so frequently that the patchiness is eliminated should have lower diversity than sites where there is time between disturbances for this type of heterogeneity to build up and be exploited. To test this expectation, I compared the diversities of two sites that were exposed to large-scale disturbance at different frequencies. The sites were on the summit of Fieberling Guyot. White Sand Swale (= WSS), 32° 27.581' N, 127° 47.839' W, and Sea Pen Rim (= SPR), 32° 27.631' N, 127° 49.489' W. White Sand Swale experienced large-scale disturbances daily; SPR experienced large-scale disturbances a few times annually. Contrary to expectation, the diversity of harpacticoid copepods was significantly greater at WSS than at SPR. Although the reason for this result was not clear, I will discuss the possibility that the large-scale disturbance at WSS creates heterogeneity on a smaller spatial scale that promotes harpacticoid diversity.

Aggregation Processes in the Benthic Boundary Layer at the Celtic Sea Continental Margin

LAURENZ THOMSEN¹ AND I. NICK MCCAIVE²

¹GEOMAR, Wischhofstr. 1-3, 24148 Kiel, FRG

²Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ, UK

Abstract Aggregation rates in the benthic boundary layer (BBL) are calculated for the interaction between measured large particles and assumed fine particle number distributions at three stations (667, 1400, 3500 m) forming a transect across the Celtic Sea continental margin. Aggregation due to turbulent shear was calculated using the "equal or larger than Kolmogorov Kij encounter rate". The Kij calculation incorporates the effect of particle size larger than 0.1 of the Kolmogorov microscale on their inability to follow high frequency fluid motions. It is shown that aggregate formation in the BBL at the transect leads to either settling and disaggregation or sediment accumulation. Aggregation rates were in the order of 3.8×10^{-6} to $2.7 \times 10^{-1} \text{ cm}^{-3} \text{ s}^{-1}$. Under continental margin and deep sea conditions aggregation is a major process controlling particle accumulation. Under low flow conditions aggregation due to differential settling is dominant whereas turbulent shear is the dominant process for aggregation under higher flow conditions. Scavenging of fine particles via suspension feeding is expected to dominate over physical aggregation at the upper slope.

Poster

Spatial and temporal variability of particulate matter in the benthic boundary layer at the North East Atlantic Continental Margin

LAURENZ THOMSEN¹, ELS FLACH² AND TJEERD V. WEERING²

¹GEOMAR, Wischhofstr. 1-3, 24148 Kiel, FRG

²NIOZ, P.O.Box 59, 1790 AB Den Burg, Texel, NL

³N.I.O.O., Vierstraat 28, 4401 EA Yerseke, the Netherlands

Near bottom water samples and sediments were taken during five cruises to 6 stations forming a transect across the Celtic Sea continental margin. Flow velocity spot measurements in the benthic boundary layer [BBL] always increased from the shelf to the upper slope [1400 m] from 5 to 9 cm s⁻¹ in spring/summer and from 15 to 37 cm s⁻¹ in autumn/winter. Decreasing values were detected at the lower slope [2000 m] and lowest values of ~2 cm s⁻¹ at the continental rise at 4500 m water depth. Long term measurements with a benthic lander at 1400 m depict that currents have a tidal component and reach maximum velocities up to 20 cm s⁻¹, sufficiently high to periodically resuspend, transport and prevent fine particles from settling. During these long term observations, currents were always weaker in spring/summer than in autumn/winter. Critical shear velocities of sediments increased with depth from 0.5 to 1.7 cm s⁻¹ and major resuspension events and INLs should formate around 1000 m. Chloroplastic pigment equivalents [CPE] ranged from 0.0 to 0.21 µg dm⁻³, particulate organic carbon [POC] from 12 to 141 µg dm⁻³ and total particulate matter [TPM] from 0.2 to 10.0 mg dm⁻³. Aggregates in the BBL occurred with a median diameter of 152 to 468 µm. Close to the sea bed downslope transport may dominate. Under flow conditions high enough to resuspend fresh phythodetritus from sediments at the productive shelfedge, it could be transported to 2000 m depth within 10 days.

Experiments on Biodeposition were carried out to estimate carbon storage rates by macrofauna. Even under supercritical flow conditions with sediment) as reported for mid slope areas, the reduction of phytodetritus and POC from the benthic boundary layer was 50 % and 60 % higher in sediments with macrofauna than in control sediments of similar bottom roughness without macrofauna.

Effects of starvation on the enzymatic activities of the deep sea crab *Geryon longipes* (Decapoda, Geryonidae) from the western Mediterranean Sea

J.B. COMPANY¹, ERIC V. THUESEN¹, G. ROTLLANT², JAMES J. CHILDRESS¹

¹Institut de Ciències del Mar (CSIC), Passeig Joan de Borbo sin. 08039 Barcelona, Spain

²Marine Science Institute, University of California at Santa Barbara, Santa Barbara, CA93106, USA

Geryon longipes is the most abundant deep-sea crab species on the middle and lower slope of the western Mediterranean Sea and has a bathymetric range between 450 and 1950 meters of depth. We collected 43 specimens of *G. longipes* from depths of 550-1600 meters in October, 1996. Six individuals were frozen in liquid N immediately after capture, and the other individuals were maintained in the laboratory under starved and fed conditions (n = 19 and 18, respectively). After 9, 20, 27, and 34 days under laboratory conditions these individuals were frozen, and leg muscle and hepatopancreas tissue were later analyzed for citrate synthase and lactate dehydrogenase activities and total protein contents. Citrate synthase activities in the hepatopancreas of *G. longipes* was found to be much lower in starved crabs compared to fed crabs after 20 days of starvation. No lactate dehydrogenase activity was detected in hepatopancreas tissue, and no starvation effects were observed for either lactate dehydrogenase or citrate synthase activities in leg muscle tissue. Enzyme activities of fed and starved specimens maintained in the laboratory encompassed the natural range of variation measured in freshly caught crabs. These results indicate that *G. longipes* exists under various levels of fed conditions in their deepsea environment and that citrate synthase may serve as a useful indicator of nutritional condition in deep-sea crustaceans.

Benthopelagic zooplankton biomass in the western North Pacific

T. TODA, M. TERAZAKI, J. HASHIMOTO AND T. KIKUCHI.

*Department of Bioengineering, Faculty of Engineering, Soka University, 1-236, Hachioji-shi, Tokyo 192 Japan;
Phone : +81-426-91-9455, Fax : +81-426-91-4086, e-mail : toda@t.soka.ac.jp*

The environment just above the sea floor is the boundary layer where the two marine ecological divisions of the pelagic and benthic contact each other. The benthopelagic fauna quantitatively as well as qualitatively differs from the pelagic deep-sea plankton. We designed some new sampling gears to collect benthopelagic organisms, using the Deep Tow system of JAMSTEC. The Deep Tow system is equipped with a deep-sea stereo camera and video camera to observe the deep-sea floor, and thus we were able to operate the sampling gear watching a monitor on board the research vessel. The new multiple plankton sampler (DT-MPS) attached to the Deep Tow system is an opening/closing sampler (70 cm x 42 cm in the outside dimensions of the mouth opening) with four plankton nets. Plankton collections were made southeast of Hatsushima Island in Sagami Bay during 21-23 February 1992.

Benthopelagic biomass including megaplankton ranged from 4.0 to 43.3 g/1000 m³ and excluding them, biomass ranged from 4.0 to 22.6 g/1000 m³. The biomass of Copepoda ranged from 1.5 to 14.3 g/1000 m³ and other animals, 2 to 11 g/1000 m³. If we excluded megaplankton, Copepoda comprised half of the total biomass in the benthopelagic region. The percentage of benthopelagic biomass to surface biomass varied from about 5 to 30%, with an average of 15%.

Can clam shells reveal the nature and history of fluid discharge at a vent site?

MARTA E. TORRES¹ AND JAMES P. BARRY²

¹COAS, Oregon State University, Corvallis, OR 97331; 541-737-2415; email:mtorres@oce.orst.edu

²MBARI, 7700 Sandholdt Rd. Moss Landing, CA 95039; 408-775-1726; email:barry@mbari.org

High-resolution profiles of a group of minor and trace elements in shells of bivalves have been obtained by Laser Ablation Inductively coupled mass spectrometry to evaluate their potential as monitors of chemical variations in fluid composition at sites of active fluid discharge. Our current focus is on the chemistry of Ba, Sr, Mn, Pb and U. We hypothesize that although the *concentration* of these elements in the shell may be complicated by a variety of factors, the ratios between various elements to calcium can be related to the compositional differences in the venting fluids.

The bivalve shells analyzed represent specimens from *Calyptogena pacifica* and *Calyptogena kilmeri* collected from the "Clam Field" cold seep site in Monterey Canyon at 904 m. This site is located near outcrops in the hydrocarbon-bearing Monterey Formation. Variations in the chemical profiles document that these specimens grew in contact with fluids of significantly different chemical compositions. The *Calyptogena kilmeri* specimen records much higher levels of Ba, Pb, Mn and U than the *Calyptogena pacifica* shell. This is consistent with the observation that *Calyptogena kilmeri* dominates the vesicomyid population at seeps with high sulfide content, whereas, *Calyptogena pacifica* is the major species present at seeps with low sulfide levels. Variations within a specimen suggest changes in the composition of the fluids through time, which are consistent with variations in the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ data obtained from subsamples of shell material.

Comparison between these specimens with samples recovered from seeps in Cascadia margin and from a Galapagos hydrothermal site show changes in the chemistry and isotope profiles which represent changes in the compositional characteristics of the discharging fluids. The present study indicates that shells of living clams may be used to reconstruct geochemical history of fluid discharge at vents and seeps on the seafloor.

Site-Specific and Ontogenetic Variations in Mussel Carbon and Nitrogen Stable Isotope Compositions at Lucky Strike

JENNIFER TRASK AND CINDY LEE VAN DOVER

Institute of Marine Science, University of Alaska, Fairbanks, AK 99775; email (Trask): jtrask@ims.alaska.edu

Mussels that dominate hydrothermal vent sibs at Lucky Strike support two metabolically distinct prokaryotic symbionts (thiotrophic and methanotrophic; Fiala-Medioni, pers. comm.). Dual symbiosis is an unusual condition in metazoans and has obvious advantage to the host mussel in allowing it to adapt to spatially and temporally unpredictable or changing chemical environment. The site-specific relative abundance of the different symbionts is likely to reflect the environmental availability of sulfide vs methane. Because thiotrophic and methanotrophic carbon fixation typically result in organic material with distinctive $\delta^{13}\text{C}$ values, isotopic composition of individuals may also reflect site-specific differences in sulfide and methane availability.

Len et al., juvenile and a range of adult mussel (*Bathymodiolus* sp.) sizes were collected from two Lucky Strike mussel bells, allowing us to address issues of spatial variation in isotope composition and dietary changes as mussels pass through metamorphosis and maturation. Juvenile and adult mussels were collected from Sintra and Eiffel Tower (1700 m). These sites are separated by 500 m. To our knowledge, the mussel populations at both sites belong to a single species, but this remains to be confirmed by detailed morphological and genetic studies. Chemical data indicate the two sites are fed by separate hydrothermal systems (von Damm, pers. comm.) Larvae were sorted from mussel washings, preserved in formalin and stored in alcohol prior to isotope analysis. The preservation effect on larval isotope composition was determined by comparison of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ compositions of formalin/alcohol-preserved and frozen clam (*Mya arenaria*) larvae.

No ontogenetic shift in diet between juveniles and adults (20-81 mm) is indicated by carbon or nitrogen stable isotope data for either Sintra or Eiffel Tower mussel populations. Larval isotope compositions most closely match those of adult mussels from Sintra, regardless of where the larvae were collected. A very significant between-site difference in both carbon (~ 9‰) and nitrogen (~ 6‰) isotope composition was found ($p < 0.001$). If mussels at Eiffel Tower and Sintra are indeed a single species, the isotope data provides compelling evidence for use of different nutritional resources between sites. The $\delta^{13}\text{C}$ values at Eiffel Tower are $-30.6 \pm 1.1\text{‰}$, typical for thiotrophic bivalves. Sintra $\delta^{13}\text{C}$ values for mussel tissue ($-21.4 \pm 2.1\text{‰}$) are consistent with a nutritional contribution from a vent source of methane [$\delta^{13}\text{C}$ vent methane (East Pacific Rise) = -15.0 to -17.6‰ ; Welban and Craig 1983]. Samples to be collected during 1997 dives will be preserved for additional isotope analyses and corresponding microscopic determinations of the relative abundance of methanotrophs and thiotrophs within gill bacteriocytes. These data will be used to test the hypothesis that at Sintra, methanotrophs are more abundant in gill bacteriocytes than thiotrophs.

Comparative Biodiversity: Hydrothermal Vent and Intertidal Mussel Communities

JENNIFER TRASK¹, CINDY LEE VAN DOVER¹, DANIEL FORNARI² AND SUSAN HUMPHRIS²

¹*Institute of Marine Science, University of Alaska, Fairbanks, AK 99775; (Trask email): jtrask@ims.alaska.edu*

²*Woods Hole Oceanographic Institution, Woods Hole, MA 02543*

Extensive mussel beds are characteristic of Lucky Strike hydrothermal vents. Similar hard-substrate mussel beds are found in a variety of locations worldwide, including Atlantic and Pacific hydrothermal vents, cold seeps, and most shallow-water environments. Rich faunal communities are known to be associated with shallow-water mussel beds and characterization of these communities provides a database for study of global biodiversity patterns. Because of the wide distribution of vent mussel communities, we chose to use quantitative samples of their associated macrofauna as an indicator of biological diversity.

During the *Lustre '96* cruise to Lucky Strike, we collected five two-liter mussel clumps from each of two sites using the ROV JASON. Samples were washed through a 63 μ m sieve to collect organisms living among the mussels. These organisms were sorted according to species and counted. Comparable replicates were collected from two intertidal mussel beds on the south-central Alaskan coast. These samples will be used for a comparison of diversity between deep-sea hydrothermal vents and shallow-water environments.

More than 20,000 invertebrates from Lucky Strike were collected and preserved for taxonomic analysis. Ostracods, amphipods, and copepods numerically dominated the hydrothermal vent faunal assemblage, whereas interstitial communities associated with intertidal mussels were dominated by nematodes, copepods, and limpets. Three major phyla—Annelida, Mollusca, and Arthropods—represented at each community, although relative abundance differed between sites.

This is the first in a series of studies that will place biodiversity of hard-substrate vent communities within the context of global marine biodiversity.

Seasonal variability in POM flux in the oligotrophic Cretan Sea (NE Mediterranean)

A. TSELEPIDES¹, S. STAVRAKAKIS², R. DANOVARO³, P. WASSMANN⁴, S. HEUSSNER⁵, G. DUINEVELD⁶, AND G. CHRONIS²

¹ Institute of Marine Biology of Crete, PO Box 2214, 71003 Iraklio, Crete, Greece

² National Centre for Marine Research, Aghios Kosmas-Elliniko 16604 Athens, Greece

³ Istituto Scienze Ambientali Marine, Univ. of Genova, 16038 S. Margherita L., Genova, Italy

⁴ Norwegian College of Fishery Science, University of Tromsø N-9037 Tromsø, Norway

⁵ Lab. of Sedimentology and Marine Geochemistry, Univ. of Perpignan, 66860 Perpignan, France

⁶ Netherlands Institute for Sea Research, Texel, Netherlands

As part of the project CINCS (Pelagic-benthic Coupling IN the Oligotrophic Cretan Sea, an EU funded MAST II Mediterranean Targeted Project), one sediment trap array was deployed in the Cretan basin (at 1550m water depth) consisting of two Technicap PPS3/3 sediment traps attached at 200 and 1470m depth from the surface. Fluxes of total particulate organic matter, organic carbon, nitrogen and labile organic carbon (carbohydrates, lipids and proteins) were recorded from November 1994 to November 1995. In both traps the observed seasonal changes reflected the fluctuations in primary production. Mean annual mass fluxes were -50 and $209 \text{ mg m}^{-2} \text{ d}^{-1}$ for the upper and deeper trap respectively. Total organic matter (TOM), POC and PON flux, as well as the associated C/N ratio, displayed marked depth related and seasonal differences between the two traps. The mean annual percentage for TOM was 12.9% and 4.8% at 200 and 1470 m respectively. POC, at 200 m was 5.55% while at 1470 m it dropped to 2.36%. For PON the respective values were 0.82% and 0.23%, while the mean C/N ratio was 8.2 and 11.7. Particulate carbohydrates were the major component of the flux of labile compounds (65.8 and 67.5% at 200 and 1470 m respectively) followed by lipids (20 and 21.1%) and proteins (14.2 and 11.4%). The labile organic carbon flux (i.e. biopolymeric carbon: the sum of lipid, protein and carbohydrate carbon) was very low (annual average of 0.9 and $1.2 \text{ gC m}^{-2} \text{ y}^{-1}$ at 200 and 1470 m depth, respectively). The qualitative composition of the organic flux, revealed a protein depletion with depth, while the food index (% of labile organic compounds of the total mass flux) strongly decreased in the deeper sediment trap (20.3% at 200m and 5.6 % at 1470 m depth) and did not show significant seasonal changes. The above values are equivalent to those recorded from other oceanic basins and much lower than those recorded in the western Mediterranean.

The microscopical analysis of the material collected from November 1994 to November 1995 revealed that the bulk of the sedimenting organic matter consisted of faecal pellets and unidentified detrital material. The faecal pellet flux was low compared to the POC-flux, and comprised 2.2-18.1% and 3.7-15.9% of the total mass flux at 200 m and 1470 m depth, respectively. Faecal pellets $< 250 \mu\text{m}$ made up the majority of the total pellet flux to the deeper waters. A temporal separation of the faecal flux was not detected within this size class. However, among the larger size classes ($> 250 \mu\text{m}$) seasonal differences were observed in both traps. The dominance of *Emiliana huxleyi* coccoliths within faecal pellets further supports the contention that this species plays an important trophical role in the eastern Mediterranean Sea. Among the planktonic protozoa, phaeodarians (Radiolaria) and small (possible juveniles) foraminiferans displayed the greatest seasonal variability.

The carbon flux calculations indicate that only about 2.8-4.8 % of primary production accounted for the POC-flux, while only 0.2-0.4% of the primary production accounted for the carbon-flux in faecal pellets. These results confirm the oligotrophic and regenerative nature of the Cretan Sea. The low levels of particulate organic matter are lower than expected based on the observed primary production, indicating that the DOC component could be of greater importance than the POC/faecal pellet-component for carbon export to deeper waters.

Taxonomic descriptions of bathyal and abyssal gastropods, *Solarisida*, *Bathybembix*, and *Lischkeia* (Trochidae) from off the Pacific coast of Japan

EIJI TSUCHIDA

Eiji Tsuchida tsuchida@ori.u-tokyo.ac.jp

Six species of deep-water trochid gastropods are known from Japanese and adjacent waters. Among them *Solarisida infundibulum* Watson inhabits depths of 1600-2000m and the other species are found at depths shallower than 1000m. A total of about 350 *S. infundibulum* was collected by means of beam trawl in the Kumano Basin of Kii Peninsula, the Pacific coast of Japan, on five occasions during 1986-96. The detailed examination of their internal and external characters revealed the morphological differences of the neck lobe between sexes, and of the mentum, proboscis and cephalic tentacle among the type species of closely allied genera, *Lischkeia* and *Bathybembix* (=Ginebis). From these results, the taxonomic position of *S. infundibulum* is discussed. This taxonomic consideration also makes clear that *S. infundibulum* is widely distributed in the South and West Pacific and Indian Oceans along with Japanese waters. The geographical and bathyal distributions of this species together with four closely related species which have not yet been recorded in Japan, are also reported.

Potential for deep-sea invasion through isothermal water columns II. The north Atlantic

P.A. TYLER¹ AND C.M. YOUNG²

¹Dept. of Oceanography, University of Southampton, SOC, Southampton SO14 2H UK

²Harbor Branch Oceanographic Institution, 5600 US 1 North, Ft. Pierce FL 34946, USA

Of all the genera of megabenthos in the north Atlantic the echinoid genus *Echinus* is the most speciose. Species of this genus have a distribution from intertidal to >2500m depth and a number of the species occur sympatrically. All the specimens of the individual species examined have a reproductive pattern indicative of seasonal reproduction and the production of a planktotrophic larva. We have examined the effect of temperature and pressure on the early embryonic development of three species of *Echinus*, viz *E. esculentus* from shallow subtidal, *E. acutus* from sub-littoral and from upper bathyal depths and *E. Affinis* from lower bathyal depths, and on the intertidal, closely related species *Psammechinus miliaris*. Embryos from species in shallow water were able to tolerate pressures down to equivalent of 1500m some 1400m below their known adult depth range. The embryos of *E. acutus* from upper bathyal depths were more tolerant of pressure than those from adults collected sub-littorally and the embryos of *E. affinis* from 2200m depth were truly barophilic, not developing at pressures less than an equivalent of 1000m depth. We interpret these data in light of circulation patterns in the north Atlantic since the last glaciation and propose mechanisms by which *Echinus* may have invaded the deep sea.

Life cycles and reproduction of the deep-sea shrimps inhabiting hot vents: facts and hypotheses

A.L. VERESHCHAKA

Russian Academy of Sciences, Moscow, 117851

Deep-sea hydrothermal shrimps demonstrate different, sometimes very impressive morphological and physiological adaptations to their unusual habitats. Among several puzzles intriguing researchers, the almost complete absence of eggs in few dominant species is a most remarkable. Species of the genera *Alvinocaris*, *Chorocaris*, and *Mirocaris* are usually characterized by several ovigerous females per hundred examined specimens, whereas the most dominant species of the genera *Rimicaris* and *Iorania* demonstrate lacking ovigerous females in thousands of observed individuals. Detailed benthic and planktonic studies above the Broken Spur hydrothermal vent (Mid-Atlantic Ridge) in 1996 allowed to catch one ovigerous female of *Rimicaris* bearing very loosely attached eggs which appeared identical to those sampled by net in the water column above the field. Eggs of *Rimicaris* at various stages of development (one included perfect larva) were abundant and dominant in the total plankton blames above the field. There are arguments that the eggs of *Rimicaris* and *Iorania* are not born, get lost soon after spawning and develop within the water column. Hatched juveniles rapidly settle near the black smokers and grow until become mature. On the contrast, females of the genera *Alvinocaris*, *Chorocaris*, and *Mirocaris* bear eggs attached to the abdomen until hatching. Visual observations and slurp-gun samples show that juveniles of these genera develop in the water at various distances from the sea floor (from tens of meter in *Chorocaris* to hundreds of meter in *Alvinocaris*). Isotope analyses ($\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) showed that larvae of the two groups (*Rimicaris-Iorania* and *Alvinocaris-Chorocaris-Mirocaris*) have different sources of feeding: the former living mainly on the chemosynthesized organic, the latter using mixed feeding of both photo- and chemosynthetic origin. Thus, the progressed adaptations to the extreme habitats may be traced within the chain *Alvinocaris-Mirocaris-Chorocaris-Iorania-Rimicaris* not only morphologically, but also at the life cycle and reproduction level. Evidences of similar adaptations may also be found in other groups of hydrothermal crustaceans: copepods and amphipods.

Assessing the endemism of vent predators and resultant implications for the evolution of hydrothermal vent fauna

JANET R. VOIGHT

*Department of Zoology, Field Museum of Natural History, Roosevelt, Rd at Lake Shore Dr., Chicago, IL 60605.
voight@fmnh.org*

Large mobile predators are members of all abyssal hydrothermal vents species assemblages that have been studied to date. Whether these taxa are restricted to vent habitats is difficult to assess, as a taxon can be considered as habitat-endemic only after it has been demonstrated to be absent from other habitats. Given our meager knowledge of abyssal non-vent taxa, current assessments of vent specificity are suspect. Biological criteria were defined to estimate the extent to which members of predatory taxa are restricted to vents. These criteria include the comparative distribution of a taxon between vent and non-vent habitats, its distribution within vent fields, whether animals of all sizes occur at vents, evidence of successful reproduction at vents, and how the predators exploit vent fauna. These criteria are designed to reflect habitat use in post-settlement individuals and their degree of reliance on vent habitats. Collections and observations made at hydrothermal vent fields on Juan de Fuca Ridge in the North Pacific using the ROV ROPOS. Within-taxon evaluations based on these criteria suggest that the galatheid crab, *Munidopsis alvisca*, is potentially restricted to vents or other chemosynthetic habitats. Other predators documented at vents, including the octopodid *Graneledone pacifica*, the zoarcid fish, *Pachycara gymninium* and the spider crab, *Macroregonia machrochira* are likely to be opportunistic in exploiting the vent habitats. Although opportunistic predators are common at North Pacific hydrothermal vents, apparent vent-endemic predators dominate East Pacific Rise vents. As specialist predators are predicted to be rare in ephemeral habitats such as hydrothermal vents, the contrast suggests that the vent systems differ fundamentally. Individual vents on Juan de Fuca Ridge are larger and perhaps more temporally stable than are those at the East Pacific Rise; these large habitats would be predicted to be more likely to sustain lineages of vent specialist predators. The smaller and more open disturbed vents on the East Pacific Rise, however, are more dense. Large, vagile predators may move among these small, transient but relatively close vents to experience the habitat as a mosaic. Because North Pacific vents are more isolated, predators in these areas may perceive the vents as individual islands. The low habitat predictability in this area may preclude the evolution and/or maintenance of vent specialist predatory lineages.

Does physical disturbance cause a persistent change in the structure of an abyssal meiobenthic community? Results from the environmental research programmes DISCOL and ECOBENT

KAY VOPEL¹, AHMED AHNERT², GERD SCHRIEVER² AND HJALMAR THIEL¹

¹ Alfred Wegener Institute for Polar and Marine Research, Columbusstrasse, D-27568 Bremerhaven, Germany

² Biolab Research Institute, Kieler Strasse 51, 24594 Hohenwestedt, Germany

Abyssal meiobenthos is characterized by high species diversity, low population densities and a usually strong small scale spatial heterogeneity, which results in highly variable faunal data obtained from replicate samples. Limited knowledge on the life cycles of deep sea meiobenthic organisms and long term variation of faunal densities and species composition renders the interpretation of such data even more difficult. Meiofauna was collected in the DISCOL experimental area seven years after a disturbance experiment (ref. poster Thiel et al.). Replicate cores (multiple core samples, animal size > 63 μ m) were taken from "plough-harrow" tracks, the adjacent area which was subject to resedimentation of the suspended fine material, and from a reference site located 6 km south of the experimental area. Furthermore, sediment samples from pre-impact and earlier post-impact studies were used for comparison. The poster describes the state of the meiobenthic community seven years after the disturbance experiment based on counts of major taxonomic groups of metazoans and more detailed taxonomic analyses of nematodes and harpacticoid copepods. These two taxonomic groups represented at least 80 % of the metazoan meiofauna. Harpacticoid copepods from 15 families were found, the numerically most important being the Ectinosomatidae, Tisbidae, Ameiridae, Neobryidae and Diosaccidae. Nematodes accounted for 78 - 90 % of all metazoans. They were represented by about 250 - 350 species, 137 of which have been described previously by Bussau (1993). Furthermore, small scale horizontal and vertical distribution patterns of dominant taxa were analyzed. The results of the study are discussed in view of the possible long-term effects of an anthropogenic physical disturbance on the abyssal meiobenthic community, thus contributing to an assessment of the environmental impact of ocean mining activities.

Poster

Development of multibank rod retinae in deep-sea fishes

HANS-JOACHIM WAGNER AND ELEONORE FRÖHLICH

Anatomisches Institut der Universität Tübingen, Österbergstr. 3, D-72074 Tübingen, Germany

We studied the development of multibank rod retinae by monitoring the size-related addition of new layers of rod inner and outer segments in four species of deep-sea fishes. In contrast to the continual addition of layers of rod inner and outer segments, previously shown in *Chauliodus sloani*, there are three other species (*Antimora rostrata*, *Coryphaenoides guentheri* and *Nematonurus armatus*), where the addition of new banks ceases when the fish have reached between about 20 and 40 % of their maximal size. This finding indicates that retinae are mature and fully functional only when the full complement of rod banks is present. In a reconstruction of serially sectioned outer retina we could show that all rod inner and outer segments are connected to perikarya in the outer nuclear layer, and to synaptic terminals in the outer plexiform layer. The absence of isolated rod inner and outer segments in the photoreceptor layer suggests that all banks are functionally equivalent, at least in these three species. When comparing the rod densities in the most vitread and most sclerad banks we found that, in most species, both figures did not differ by more than 10% and remained fairly constant throughout the growth of the retina. Taken together with earlier data on rod proliferation patterns in deep-sea fish we argue that the continual mitotic activity as observed in species with rod precursor cells forming an uninterrupted layer inside the external limiting membrane serves to maintain a constant rod density in all layers of rapidly growing multibank retinae as in *Antimora* and *Coryphaenoides*. The more slowly growing *Chauliodus*, by contrast, has a disseminated arrangement of rod precursor cells throughout the outer nuclear layer, and decreasing mitotic activity.

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Signal economics of coelenterate bioluminescence displays

E.A. WIDDER¹ AND P.J. HERRING²

¹Harbor Branch Oceanographic Institution, 5600 U.S. 1 N, Fort Pierce, Fla 34946, USA

²Southampton Oceanography Centre, Empress Dock, Southampton SO14 3ZH, UK

There is, as yet, no direct evidence for what role bioluminescence displays serve in coelenterates. However, display characteristics may provide insight into the perceptual abilities and possible intentions of the receivers. *In situ* observations, recordings and collections made from midwater submersibles over the past decade have revealed a remarkable degree of signal complexity among the coelenterates. Some of these signal characteristics will be illustrated with a video recording and analyzed in terms of signal economics.

All bioluminescent signals have a cost; they require energy and they may attract predators. Therefore, an analysis of signal economics, i.e. the relative detectability of the signal in terms of the total photon flux, as well as the temporal and spatial properties of the display, may provide some insight into the purpose of these signals. For the signals we have recorded, we propose three possible receivers: 1) non-predators where the display serves to minimize accidental contact, 2) primary predators where the display serves to distract or blind the receiver, and 3) secondary predators where the display acts as a burglar alarm which may draw attacks on the primary predator, thereby affording the victim an opportunity for escape. Examples of displays which would be optimally suited to each of these receivers will be presented. In addition we will show cases where more than one display type occurs in a single species in what appears to be a hierarchy of defensive adaptations, or lines of defense, which

DIVERSITY AND EVOLUTION OF DEEP-SEA PENNATULACEAN OCTOCORALS

GARY C. WILLIAMS

*Department of Invertebrate Zoology & Geology, California Academy of Sciences,
Golden Gate Park, San Francisco, California 94118 U.S.A.*

The extant pennatulaceans, or sea pens, are a morphologically diverse, highly specialized, and monophyletic group of octocorals. Thirty-two genera are recognized, and 436 species have been described, at least half of which are currently considered valid. Many taxa have long been recognized as characteristic members of deep-sea biotic communities. Sea pens are benthic sessile animals adapted exclusively for living partly imbedded in fine or medium to relatively coarse sediments such as mud, sand, or abyssal ooze deposits, by means of a fleshy proximal portion - the peduncle. Because of this, many deep-sea taxa have near cosmopolitan or extremely widespread distributions. As a group, the sea pens are encountered throughout the world's oceans and at virtually all depths - from intertidal areas to over 6100 meters.

A nineteenth century view held that the deep-sea pennatulaceans are primitive forms and probable relicts of an ancient extinct fauna. This view was countered by the end of that century, as a striking variety of deep-sea forms was recognized. A modern view holds that the sea pens first differentiated in tropical shallow water and subsequently dispersed and diversified in temperate and polar regions, and to all ocean depths, as well as the shallow water tropics. This view is supported by recent cladistic analysis. Overall, sea pens exhibit certain morphological changes as evolutionary events within different lineages, including bilateral symmetry, localization and concentration of polyps, the development of lateral processes as polyp leaves or ridges, and reduction in size and number of sclerites. In addition, deep-sea taxa such as *Amphiacme*, *Chunella*, *Kophobelemnion*, and *Umbellula*, also exhibit changes towards an increase in polyp size along with a decrease in number of polyps. This view is also supported by recent cladistic analysis.

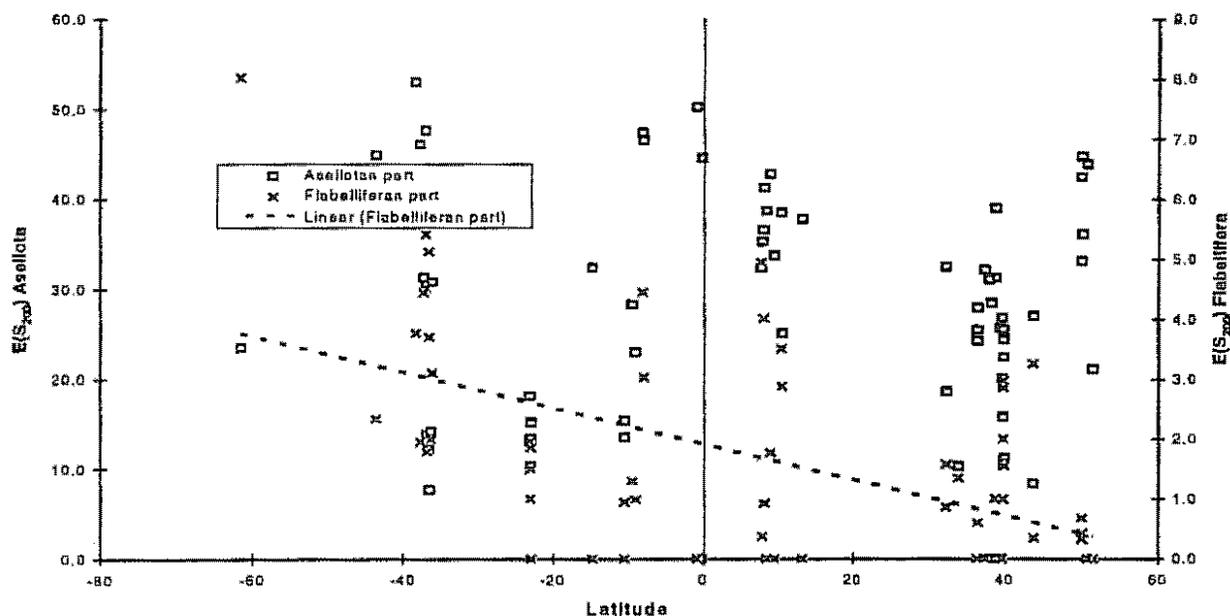
Of the 32 living genera, 19 (6056) are recorded from depths exceeding 500 meters, while 15 (48%) are known to occur at depths greater than 1000 meter. Several genera are apparently restricted to depths exceeding 500 meters, including *Amphiacme*, *Chunella*, *Distichoptilum*, *Gyrophyllum*, and *Scleroptilum*. At least 20 species in 5 genera - *Distichoptilum*, *Kophobelemnion*, *Protoptilum*, *Scleroptilum*, and *Umbellula* - inhabit depths in excess of 4000 meters. Several sea pen genera, such as *Virgo* and *Pteroeides* - are in need of major taxonomic revision.

Historical Influences On Deep-Sea Isopod Diversity In The Atlantic Ocean

GEORGE D.F. WILSON

Centre for Evolutionary Research, Australian Museum, Sydney

Most isopod crustaceans in the North Atlantic deep sea belong to the suborder Asellota. In contrast, South Atlantic isopod faunas have a significant component of flabelliferan isopods, a phylogenetic clade that contains suborders derived evolutionarily later than the Asellota. The flabelliferans decrease in diversity from shallow water to deep water and on a south-to-north latitudinal gradient. Although many asellote families are endemic to the deep sea, none of the flabelliferan families appear to have evolved in the abyss. Recent colonisations of the deep sea, which may have been limited to the southern hemisphere by oceanographic conditions, have significant consequences for observed regional diversities of some taxa. Instability in oceanographic conditions owing to glaciation and benthic storms may have further limited benthic species richness in the North Atlantic deep-sea benthos.



Relationship between latitude and diversity partitions $E(S_{200})$ Asellota (left axis) and $E(S_{200})$ Flabellifera sensu lato (right axis).

Mesozooplankton Biomass in the Upper 1000 m in the Arabian Sea: Overall seasonal and geographic patterns, and relationship to oxygen gradients

KAREN F. WISHNER¹, MARCIA M. GOWING², AND CELIA GELFMAN³

¹University of Rhode Island, Narragansett RI 02882 USA

²University of California, Santa Cruz, CA 95064 USA

³University of Rhode Island, Narragansett, RI 02882 USA

Mesozooplankton biomass distributions in the upper 1000 m of the Arabian Sea were studied as part of the U.S. JGOFS project. Samples were collected in vertically-stratified MOCNESS tows during 4 seasons in 1995 at 6 - 8 stations spanning the Arabian Sea. This talk describes results from the size-fractionated dry weight and wet weight biomass profiles and their relationship to the seasonal monsoon cycle and the pronounced oxygen minimum zone (OMZ). The total mesozooplankton biomass and most size fractions exhibited a significant onshore / offshore biomass gradient during most seasons and at most depths. The gradient was strongest in August during the southwest monsoon and weakest in March during the intermonsoon, when maxima of some size fractions occurred offshore. There was little seasonal signal in zooplankton biomass, although the southwest monsoon was the time of higher biomasses for near shore stations, while the intermonsoon was the time of higher biomasses for offshore stations. Most of the zooplankton occurred in the upper 200 m, but there was substantial diel vertical migration, especially of the large size class, down to 300 - 400 m, well within the OMZ. A subsurface biomass peak occurred near the depth of the oxygen inflection point (about 500 - 600 m) in the OMZ. The enhanced zooplankton biomass, several indicators of bacterial activity, and possible short food chains suggested active biological modification of the sinking flux in this depth zone. Biomass profiles showed close relationships to oxygen profiles. The shapes of the zooplankton biomass and oxygen profiles varied with geographic location across the Arabian Sea but were remarkably consistent over the year at each station. Geographic differences in the shapes of the profiles may correspond to broad regional differences in the processing of the export flux in midwater, but the consistency of the shapes over time implies long-term stability in the structure and function of the midwater ecosystem at each location.

Scavenging communities in the deep Arabian Sea: observations by baited camera

URSULA WITTE AND OLAF PFANNKUCHE

GEOMAR Research Center, Wischhofstr. 1-3, 24148 Kiel, Germany

During cruise no. 118 with R.V. "Sonne" to the Arabian Sea (31.3.97 - 10.05.97), two large food fall experiments were carried out in order to study the composition of the scavenging fauna of the deep Arabian Sea and to investigate how fast large food falls are consumed. The experiments were carried out at our 2 westernmost stations, WAST-deep (16:12,0 N; 60: 16,0 E; 4040 m) and WAST-Kuppe (16:10,0 N; 59: 45 E; 1900m). Both are situated in the western Arabian Sea where the water circulation during SW-monsoon leads to upwelling along the coast of Oman and to upward Ekman transport in offshore areas. Annual maxima of primary productivity in the Arabian Sea thus occur here during SW-monsoon and benthic activity is several times higher than found for other deep-sea regions (Witte unpubl.).

At Wast-deep, a shark of 1.6 m length and 29 kg weight was deployed for 11 days, monitored by a still camera taking pictures at 20 min - intervalls. At WAST-Kuppe, a smaller shark of 1 m length was deployed for 5 days and photographed in 10 min - intervalls. The skin of both sharks was shed at the back to facilitate access for scavenging organisms.

At WAST-deep, zoarcid fish dominated during the whole deployment period, accompanied by decapod shrimp. First decapods had reached the carrion after 20 min and during the period monitored 1 - 4 decapods regularly occurred on or near the carcass. Single zoarcids were first observed after 5 h, their number rising constantly during the initial 48 h up to 50-60, then remaining constantly at this level. At 1900 m, however, three individually identifiable deep-sea stone crabs were alternately feeding on the shark carcass for most of the observation period. Fish only appeared rarely and never stayed at the carcass for longer periods. Most strikingly, giant scavenging amphipods were absent at 1900 m and macrourids were absent at 4000 m, and not more than 20 % of the carrion was consumed.

Poster

Patterns of benthic activity and standing stock in the deep Arabian Sea: do bulk parameters tell the whole story ?

URSULA WITTE AND OLAF PFANNKUCHE

GEOMAR Research Center, Wischhofstr. 1-4, 24248 Kiel, Germany

Within the framework of the interdisciplinary research programme "Biogeochemical transport of energy and matter in the deep-sea (BIGSET)", in-situ remineralisation rates were measured and macrofaunal and megafaunal abundance determined at five stations during two cruises to the Arabian Sea in 1995 and 1997. As expected from long-term sediment-trap deployments (Haake et al. 1993), in-situ remineralisation rates were highest in the western Arabian Sea (WAST) and lowest at our southernmost station (SAST). At WAST they reached $4.7 \text{ mmol C m}^{-2} \text{ d}^{-1}$ in October '95 and $5.5 \text{ mmol C m}^{-2} \text{ d}^{-1}$ in March '97 and were thus considerably higher than usually measured in the deep-sea and five times higher than at SAST.

A ranking of 4 stations according to sediment oxygen demand and oxygen penetration depth results in WAST > NAST > CAST > SAST. This is in good agreement with vertical flux into the deep sea (Haake et al 93) and is also confirmed by CPE- and protein- content of the sediment. Macrofaunal and megafaunal abundance, however, indicate a structural difference between WAST and the other stations possibly connected to the fact that WAST is situated beneath an upwelling region.

Potential for deep-sea invasion through isothermal water columns

I. The Mediterranean

C.M. YOUNG¹ AND P.A. TYLER²

¹Harbor Branch Oceanographic Institution, 5600 US 1 North, Ft. Pierce FL 34946, USA

²Dept. of Oceanography, University of Southampton, SOC, Southampton SO14 2ZH UK

Hypotheses about the origin of the deep sea fauna often assume that the deep sea was colonized by cold-water animals migrating through isothermal water columns in polar seas. Deep water in the Mediterranean Sea has much warmer temperatures than comparable depths in the larger ocean basins. Moreover, the entire water column may be virtually isothermal during the winter months, making oceanographic conditions in the Mediterranean analogous to those prevailing throughout most of the world ocean during the Mesozoic and Cenozoic. We investigated the physiological potential for deep-sea invasion through a warm water column by studying the pressure and temperature tolerances of embryos and larvae of three species of shallow-water Mediterranean echinoids, *Paracentrotus lividus*, *Arbacia lixula*, and *Sphaerechinus granularis*. Early life-history stages of all three species tolerated pressures (to 150 atm) much higher than those experienced in the adult environment. Cold temperatures (<10°C) exacerbated the adverse effects of pressure; larvae were more likely to survive at deep-sea pressures and warm temperatures than at cold temperatures and shallow-water pressures. Tolerances to high pressures and low temperatures increased with ontogeny and varied with species. In the Mediterranean, high pressures should be a more important limiting factor than low temperatures. Nevertheless, some species have physiological tolerances that should allow them to colonize bathyal depths. Absence of these shallow-water species from such depths must be attributed to factors other than pressure and temperature. Pressure tolerances of warm-water echinoid larvae from the Mediterranean will be compared with those of bathyal and littoral species from the tropical Atlantic and Pacific Oceans.

Unexpected feeding strategies of ascidians from the deep Arabian Sea

CRAIG M. YOUNG¹ AND ELSA VAZQUEZ²

¹Department of Larval Ecology, Harbor Branch Oceanographic Institution, Ft. Pierce, Florida 34946, U.S.A.

²Departamento de Ecología e Biología Animal, Facultade de Ciencias do Mar, Universidade de Vigo, 36200 Vigo, Spain

Many deep-sea ascidians have reduced branchial ciliation and morphological modifications (e.g., long stalks; oriented siphons) that permit them to exploit the velocity gradient in the benthic boundary layer. Two new species of ascidians found in the deep Arabian Sea off Oman have unusual morphological features for the deep sea. *Agnezia monnioti* n.sp. from the abyssal plain at 3162m depth has strong branchial ciliation and a siphonal arrangement that appears completely inappropriate for utilizing ambient water currents for filtration. Although its upward-facing incurrent siphon could collect falling particles passively, comparison between carbon flux and estimated oxygen consumption suggests that only a small portion of the metabolic needs could be met by passive filtration. *Styela gagetyleri* n.sp. is found at a depth of 368m, which is in the middle of a persistent oxygen minimum zone. Surprisingly, the branchial sac of this species has a reduced number of folds and therefore fewer cilia for food collection and less surface area for oxygen exchange than shallow-water congeners living in well oxygenated habitats. We hypothesize that the unexpected morphologies of both species are made possible by the unusually high, monsoon-driven flux of organic material to the sea floor in this region. *Agnezia monnioti* is apparently able to use a feeding strategy typical of shallow-water ascidians because food is sufficiently abundant to offset the energy expended in ciliary pumping. Likewise, *Styela gagetyleri* requires fewer cilia to collect sufficient food for its needs. The observed reduction in branchial surface area in a persistent hypoxic zone suggests that branchial complexity in ascidians is more important for feeding efficiency than for gas exchange. Phylogenetic relationship between Annelida, Vestimentifera and Pogonophora revealed by the α -nino acid sequence of globin chains.

Poster

Phylogenetic relationship between Annelida, Vestimentifera and Pogonophora revealed by the amino acid sequence of globin chains

F. ZAL^{1,3}, T. SUZUKI², Y. KAWASAKI², J.J. CHILDRESS³, F. H. LALLIER¹, A. TOULMOND¹

¹*Equipe Ecophysiologie, UPMC - CNRS - INSU, Station Biologique, BP 74, 29682 Roscoff ceder, France*

²*Department of Biology, Faculty of Science, Kochi University, Kochi 780, Japan*

³*Department of Biological Sciences and Marine Science, Institute, University of California, Santa Barbara, CA 93106, USA*

It is now well established that phylogenetic trees built using Hb sequences exhibit a good correlation with common taxonomy. In the present paper we report the complete amino acid sequence of the monomeric, globin-like chain *b*, common to all *Riftia* Hbs. Alignment and phylogenetic analysis using the unweighted pair-group method were derived from 18 complete sequences from other vestimentiferans, pogonophorans and annelids globins. The sequence of *Riftia* chain *b* has between 30% and 80% of homology with those of annelid, pogonophoran and vestimentiferan globins. Moreover, vestimentiferans as well as pogonophorans are perfectly included in the phylogenetic tree built, indicating a close relationship with annelids. Consequently, following Suzuki and co-workers, *Riftia*, together with other vestimentiferans and pogonophorans, should be placed in a new class of the phylum Annelida, tentatively called Opisthochaeta. All "worm" globin-like chains analyzed here contained two cysteins involved in an intra disulfide-bridge. Some of the globin-like chains constituting these Hbs form disulfide-bonded dimers or trimers and, therefore, possess extra cysteine residues forming inter-chain bridges. However, two free cysteins, only found for pogonophoran and vestimentiferan globins, are unusual and located between the two histidines playing an important role in heme and ligand binding. Blocking selectively the free Cys residues by Nethylmaleimide and electrospray mass spectrometry experiments, we showed that the free Cys residue present of the chain *b* is involved in sulfide-binding ability by *Riftia*'s Hbs.

Identification of the sulfide-binding sites on the hemoglobin from the hydrothermal vent tube worm *Riftia pachyptila*

FRANCK ZAL^{1,3}, EMMANUELLE LEIZE², ALAIN VAN DORSSELAER², JIM J. CHILDRESS³

¹Equipe Ecophysiologie, UPMC - CNRS - INSU Station Biologique, BP 74, 29682 Roscoff cedex, France

²Laboratoire de Spectrométrie de Masse Bio-organique, ULP - URA 31, Institut de Chimie, 1 Rue Blaise Pascal, 67008 Strasbourg cedex

³Department of Biological Sciences and Marine Science Institute, University of California, Santa Barbara, CA 93106, USA

The deep-sea tube worm *Riftia pachyptila* Jones possesses a multi-hemoglobin system with three different extracellular Hbs: two dissolved in the vascular blood, V1 and V2, and one in the coelomic fluid, C1. V1 consists of four heme-containing chains and four linker chains. V2 and C1 are exclusively built from globin chains common to V1 except for one of them. One of the most remarkable properties of these Hbs is their ability to bind oxygen and sulfide simultaneously and reversibly at two different sites. However, no data were available on the accurate identification of sulfide-binding site(s). Each globin chain *b* and *e* found of these three *Riftia*'s Hbs possesses one free cysteine residue and at least one of them, the b-Cys⁷⁵ is conserved among vestimentifera (*Lamellibrachia* sp.) and pogonophora (*Oligobrachia mashikoi*). Blocking selectively the free Cys residues by *N*-ethylmaleimide and electrospray mass spectrometry experiments, we show that free Cys residues is involved in sulfide-binding by *Riftia*'s Hbs. Moreover, using the 335 absorbance related to the production of persulfide groups as a result of the cleavage of protein containing disulfide bridge by sulfide, we showed that this mechanism is as well implicated for V1 explaining well the higher sulfide-binding capacity evidenced previously.

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