2004 Proposal Form – Internal-only Projects
Submission Deadlines: Phase I: 8:00 a.m. on August 4th, Phase II: TBD

Project Number: 200002

Project START: Jan 1, 2003 Project Duration (in years): 3

Project Manager/PI: Jim Barry

Project Title:

Benthic Biology and Ecology

2004 Proposal Form – Internal-only Projects
Submission Deadlines: Phase I: 8:00 a.m. on August 4th, Phase II: TBD

1) Abstract (new and continuing projects)

This is a continuation of project 200002. 2004 will be the second year of a 3-year project involving studies of 1) seafloor community dynamics & benthic-pelagic coupling, 2) the biological consequences of deep-sea CO2 disposal, and 3) cold seep biology.

Seafloor community dynamics and benthic-pelagic coupling

This subtheme focuses on the role of carbon cycling in the structure and dynamics of benthic faunal communities, with particular focus on Monterey Canyon. Benthic community structure is measured using video transects (megafauna), and sediment cores (infauna). Sediment community oxygen demand (SCOC), a proxy for the carbon demand of the sediment community, is measured using benthic respiration chambers (BRS). The availability of food and coupling with pelagic productivity is assessed using sediment traps, coupled with current measurements, backscatter sensors (suspended sediment) and fluorometers (suspended chl a). The role of Monterey Canyon in transporting organic carbon will be assessed from comparisons of carbon flux, community structure, and rate processes (e.g. SCOC) between sites within Monterey Canyon (1300m) and on Smooth Ridge (1300 m). Carbon flux studies from this project have been located as near as possible to S2, the site studied by Chavez' upper water column studies.

Status of the Project

During 2003, we have continued development of the upgraded benthic respiration system (project 900261), which has been delayed owing to rapid advances in optical sensor technology (especially CO2 optodes). We hope to finalize the sensor selection for the upgraded system during late 2003. We have also used our original respiration system (BRS1) to measure SCOC in Monterey Canyon. Benthic moorings including sediment traps, optical sensors, and current meters have been deployed near the bottom within the canyon and on Smooth Ridge to initiate measurements of carbon flux rates. These activities will continue through 2004.

Results to Date

Sediment Community oxygen consumption (SCOC) in Monterey Canyon, and results from mooring deployments have shown that oxygen availability appears to regulate aerobic carbon mineralization, at least in Monterey Canyon, and oxygen uptake is negatively correlated with the organic carbon content of the seafloor sediments. Figure 1 (left) shows a typical oxygen profile (green line), and the respiration rate measurement within Monterey Canyon. The right figure illustrates the linear inverse relationships of bottom water oxygen & organic carbon to SCOC. These results have been presented at meetings (ASLO) and seminars, and will be submitted for publication soon.

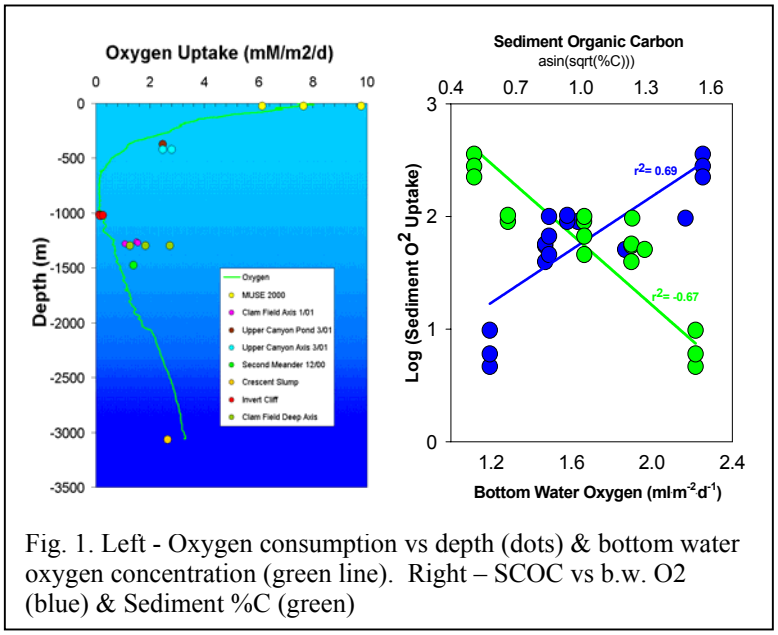

Fig. 1. Left - Oxygen consumption vs depth (dots) & bottom water oxygen concentration (green line). Right – SCOC vs b.w. O2 (blue) & Sediment %C (green)

Our sediment trap and sensor data from Monterey Canyon show the dramatically higher carbon fluxes (~20 X – Figure 2 at left) in the canyon compared to non-canyon sites at the same depth (1300 m). Our Monterey Canyon mooring location at 1300 m also captured 2-3 turbidity flow events that swept down-canyon from the Canyon Dynamics site. Data from these events can be viewed at http://mww.mbari.org/rd/science/science.htm.

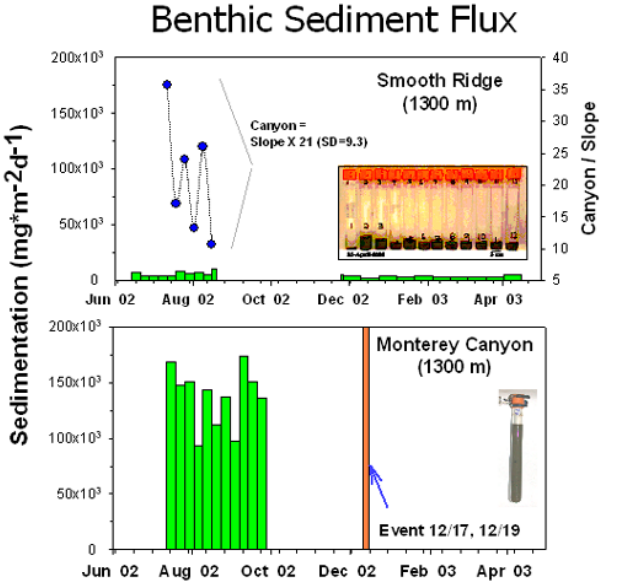

Figure 2. Sedimentation flux on Smooth Ridge (top) and Monterey Canyon (bottom). Green bars are fluxes. Blue dots are ratios between MC/ SR. Images of sediment trap tubes show typical sediment levels for non-canyon (many tubes & canyon (1 tube). The turbidity event that filled the sediment trap with sand is indicated by 'event'.

Publications, manuscripts, presentations

Barry et al., (ASLO abstract, ms in preparation Limnology & Oceanography, ASLO), Sediment community oxygen consumption in Monterey Canyon using a new in situ optrode-based respirometer

Paull, W. Ussler, III, H. G. Greene, R. Keaten, P. Mitts, and J. Barry (2003) Geo-Mar Lett, 22: 227-232. Caught in the Act: The December 20th, 2001 Gravity Flow Event in Monterey Canyon.

Plans for 2004

The objectives of the pelagic-benthic coupling studies for 2004 are to continue the time series of flux measurements and complete a comparison of SCOC in and out of Monterey Canyon. In addition, the ongoing carbon / sediment flux studies at 1300 m will be compared to results from similar studies in lower Monterey Canyon in Shepard Meander, if those studies are supported. Specific objectives include; 1) measuring the flux of organic debris that enters the benthic boundary layer, as sinking flux, 2) the flux of material near the seabed (i.e. 10 m above bottom), which includes the sinking flux, resuspended material, and lateral flux, 3) measure sediment community oxygen consumption (SCOC) to estimate carbon demand by the seafloor community. These activities are planned for Smooth Ridge and within Monterey Canyon. Comparison of these, coupled with measurements of organic material on the seabed (top cm) should help constrain the energetics of canyon and non-canyon benthos. In order to define the energy budgets of both locations, we require SCOC and the input flux of organic carbon. We are requesting funds to purchase an additional sediment trap and HS2 (backscatter / fluorometer) to allow flux measurements entering the benthic boundary and to provide spares to replace instruments that require repair or calibration.

Dr. Christian Levesque, a new MBARI postdoctoral fellow, will be joining this research effort in late 2003 and 2004. His research focus will concern comparisons of the energetics of Monterey Canyon and non-canyon benthic communities using lipid and stable isotope analyses. To allow some of the measurements Dr. Levesque is planning, we will request funds to modify our gas chromatograph to include an additional flame ionization detector for lipid analyses and modifications to our HPLC system to support pigment analyses.

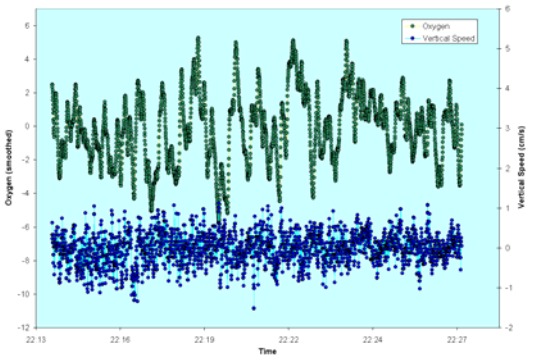

Figure 3 – Eddy Correlation flux measurement test data. Green dots = oxygen, blue dots = vertical velocity. Data are residuals from detrended mean.

Eddy Correlation Flux Measurements

Because studies of SCOC typically require repeated deployment and recovery of respiration systems or electrodes, we (with Ken Johnson) are now evaluating eddy correlation techniques to measure oxygen consumption by the sediment community. Briefly, this analytical technique relies on rapid (4-20 Hz) measurements of the concentration of oxygen (or any other parameter) as well as current speed measurements (in 3 dimensions). For parameters in which flux is occurring, a correlation should exist between the vertical flow velocity and the

parameter concentration. If possible using this technique, a mooring (e.g. MARS / MOOS) could collect repeated measurements of oxygen flux, providing higher resolution measurements than have been possible to date.

We collected an exploratory data set to assess the potential application of this technique to measurements of oxygen flux. These data indicate a small correlation between vertical flow and oxygen suggesting that the eddy correlation method may be a useful method to measure oxygen fluxes on the shelf and slope.

We will continue to investigate this method in collaboration with Ken Johnson.

Significant Changes from the 2002 project proposal
Other than delays in the upgraded benthic respiration system, we have not made any significant changes to our plans.

Biology of deep-sea CO2 disposal
The goals of this project are to evaluate the response of deep-sea organisms to environmental perturbations expected in association with large-scale deep-sea CO2 releases, under consideration as a method to reduce atmospheric levels of CO2. This subproject is coupled closely to Brewer's studies of CO2 chemistry and physics. Partial support for these studies is provided by DoE (705001, 705002), which have recently been renewed for an additional 3 years.

Status of the Project
We completed CO2 release experiments during 2001 & 2002 to examine the effects of CO2 exposure on deep-sea (3600 m) animals. A new release experiment, including collaboration with other DoE-funded investigators (Carman – LSU, Thistle – FSU) will occur in August and September of 2003. Most analyses from these experiments are completed and we are in the process of revising a publication for resubmission. We also have a fully functional laboratory-based respiration system to evaluate pH and CO2 effects on animals collected from the field. This facility will be in use for the next 2-3 years, based on MBARI and recently renewed DoE funding. Jeff Drazen, a DoE & MBARI postdoctoral fellow, has led the development of a deep -sea pressure trap / respirometer, which is presently being assembled and will be deployed in late 2003.

Results to Date
In the past year or two we have,

1. Published a significant workshop report (58 pages) entitled "Direct Ocean Sequestration Expert's Workshop", based upon a meeting held at MBARI in 2001. The report is available both in hard copy, and on the NETL web site.
2. Carried out three major, deep ocean, (3600m) cruises to examine the physical chemistry, and biological consequences, of multi-liter quantities of CO_2 released on the ocean floor.
3. Nearly completed the development of a deep-sea benthic respiration system capable of evaluating *in situ* the respiratory response of deep-sea animals to elevated CO_2 or altered pH.
3. Submitted the first major paper on biological impacts as determined from our field studies. This ms is under revision for resubmission.
5. Presented the results of our studies at several scientific meetings and invited seminars

Barry, J., Seibel, B., Drazen, J., Tamburri, M., Lovera, C., Brewer, P. 2002. Field experiments on direct ocean CO2 sequestration: the response of deep-sea faunal assemblages to CO2 injection at 3200 m off Central California. Eos Trans. AGU, 83, Spring Meet. Suppl., Abstract OS51F-02

Caldeira, K., Wickett, M.E., Duffy, P.B., Barry, J.P. Anthropogenic carbon and ocean pH. Eos Trans. AGU, 82(47), Fall Meet. Suppl., Abstract OS11C-0385, 2001

Barry, J.P., Seibel, B., Lovera, C. Deep-sea field studies on the biological consequences of direct ocean CO2 sequestration. Eos Trans. AGU, 82(47), Fall Meet. Suppl., Abstract U32B-09, 2001

Invited seminars

2003 Field studies of CO2 sequestration – Kyoto University
2003 Biological consequences of CO2 sequestration. – Hopkins Marine Station.
2002 Biological consequences of CO2 sequestration. – Tiburon Marine Laboratories.
2001 Biological Studies of Ocean Carbon Sequestration, DOE Center for Carbon Sequestration Research Workshop, Oakland, CA

2001 Biological Studies of Ocean Carbon Sequestration, MBARI / DOE Direct Ocean Injection Experts Workshop
2002 Deep-sea field studies on the biological impacts of direct ocean CO2 sequestration, Scripps Inst. Oceanography
2002 Deep-sea studies of the biological impacts of CO2 sequestration, Moss Landing Marine Laboratories
2001 Ocean Carbon sequestration, MBARI Open House, 2001 seminar

Plans for 2004
We will continue studies of faunal tolerance to CO2 / pH plumes and physiological studies of pH compensation and metabolic depression for deep-sea organisms. This will include at least one cruises to deploy and tend field experiments w/ Peter Brewer and short cruises to collect animals. Collaborations are planned with Doug Nelson at UC Davis concerning changes in microbial rate processes under CO2 exposure (partially funded by DoE), and Kevin Carmen (LSU) on studies of meiofaunal responses to CO2 exposure (DoE funding), and Jim Kennett (UCSB) & Joan Bernhard (USC) for studies of responses of foraminifera to CO2 exposure (DoE funding). Laboratory studies will become a larger focus for 2004, using the existing respiration system to measure metabolic responses of deep & shallow water animals to elevated CO2 levels. In addition, the deep-sea hyperbaric fish trap will be functional and will be deployed several times during 2004 (Jeff Drazen).

If possible, we hope to collaborate with Dan Golomb, a chemist at U. Mass who has developed a novel technique of binding CO2 to carbonate minerals to create a stable, negatively CaCO3/CO2/H2O emulsion. We would like to collaborate with Dr. Golumb to perform a small experiment to release a slurry of this emulsion onto a corral on the seafloor to evaluate it stability over time.

Significant Changes from the 2001 project proposal
We have increased the number of external collaborations on this project, but have not increased its scope significantly.

Cold Seep Biology

Cold seep studies have examined the distribution of seep fauna (especially vesicomyid clams) in relation to the pore fluid chemistry (particularly sulfide) of seep habitats. We have shown that strong links exist between the blood physiology of clams and their distribution among seep habitats. Experiments are now in progress to evaluate the role of physiology in mediating competition for space among species inhabiting the same seeps, and should complete these studies in 2003.

We hypothesize that the evolution of shell shape in vesicomyid clams is related both to the distribution of sulfide in the sediment and to the spatial distribution of seeps and clam mobility. We have initiated experiments using time-lapse video to measure the mobility of different species of vesicomyids. One species has been measured and other species will be studied as dive-time becomes available as the schedule for higher priority activities (benthic-pelagic coupling, CO2 studies) allows. Studies of mat-forming, sulfide-oxidizing bacteria from seep habitats, an ongoing collaboration with Doug Nelson (UC Davis) will continue in 2004.

Status of the Project
Cold seeps studies during 2003 were de-emphasized owing to higher priority activities, but focused on 1) clam competition experiments, 2) continued analyses of infaunal samples, and 3) one time-lapse study of clam mobility.

Results to Date
Goffredi, S.K. and Barry, J.P. (2002) Energy acquisition in vesicomyid symbioses. Cah. Biol. Mar, 43: 345-350

Goffredi, S.K., **Barry, J.P**., and Buck, K.R. (2001), Invertebrate-bacterial symbioses from Pacific cold seeps; a microscopic survey, *Biological Bulletin* (revised ms resubmitted).

Torres, M.E., **Barry, J.P.**, & Suess, E. (2001) Reconstructing the history of fluid flow at cold seep sites from Ba/Ca in shells of vesicomyid clams. *Limnology & Oceanography* (accepted w/ revision).

Orange, D.L., Yun, J., Maher, N., **Barry, J**., Greene, G. (2001) Tracking California Seafloor seeps with bathymetry, backscatter and ROVs . *Continental Shelf Research* (in press)

Barry, J.P., Buck, K.R., Kochevar, R.K., Nelson, D.C., Fujiwara, Y., Goffredi, S.K., & J. Hashimoto (2002) Methane-based symbiosis in a mussel, *Bathymodiolus platifrons*, from cold seeps in Sagami Bay, Japan. *Invertebrate Biology,* 121(1): 47-54

Goffredi, S.K. & **Barry, J.P.** (2002) Species-specific variation in sulfide physiology between closely related vesicomyid clams. *Marine Ecology Progress Series*, 225: 227-238.

Bernhard, J.M., Buck, K.M., **Barry, J.P**. 2001. Monterey Bay cold-seep biota: Assemblages, abundance, and ultrastructure of living foraminifera, *Deep-Sea Research I,* 48: 2233-2249.

Invited seminars

2001 Cold seep biology and ecology, Hopkins Marine Station
2002 Cold seep biology and ecology, Moss Landing Marine Labs
2002 Cold seep biology and ecology, Romberg Tiburon Marine Lab

Plans for 2004

During 2004, we will continue a low-level effort in cold seep studies. We hope to; 1) continue clam mobility studies, 2) complete clam competition experiments, 3) continue deep-sea exploration for seeps with collection and physiological / environmental studies of new clam species (low level of effort in collaboration w/ Vrijenhoek, Paull), 4) collaborate with Doug Nelson (UCD) on bacterial mat processes, and 4) completion of infaunal sample analyses from cold seeps.

Significant Changes from the 2003 project proposal – NONE

Non-Vent Lava-Flow Ecosystem Studies

We would like to collaborate with Dave Clague on his studies of a series of subsea eruptions on the Juan de Fuca and Gorda Ridges. Dave intends to survey 6 submarine lava flows comprising a range of ages from 3.5 to 35 years, and an additional flow with an estimated age of 300 y. Dave's planned volcanic studies of these flows provides a unique collaborative opportunity to survey faunal communities on these flows and infer rates and patterns of successional development for deep-sea communities inhabiting hard substrata. These flows are all in the northeastern Pacific and all at comparable depths. Most studies of deep-sea faunal communities have focused on hydrothermal vents, cold seeps, sediment-dominated habitats, or to a lesser degree, seamount faunas. Information concerning patterns of development for deep-sea communities, in general, is very sparse, in part owing to the difficulty in aging developing communities. This project promises the opportunity to identify the time scales and patterns of deep-sea community development by comparing the faunal assemblages on flows of different ages.

Cruises planned by Dave Clague to these lava flows offer an excellent unique opportunity to collect video observations and samples of animals for age determination (as possible), and construct a history of community development. This sort of study is generally impossible for most deep-sea habitats.

We will request 6 dive days and 1 transit day on the Western Flyer to support studies of these lava flows in collaboration with Dave Clague.

2004 Proposal Form – Internal-only Projects
Submission Deadlines: Phase I: 8:00 a.m. on August 4th, Phase II: TBD

2) Proposal

a) The problem addressed (for new projects only)

- Statement of the problem
- Why it is important
- Present state of art/understanding
- How it relates/contributes to MBARI's mission and strategic plan

b) Approach to the problem (new and continuing projects)

- Engineering/technology development

Seafloor community dynamics and benthic-pelagic coupling

The only tech development planned is further exploration of the eddy correlation technique for measuring SCOC.

Biology of deep-sea CO2 disposal

CO2 sensitivity studies:

Little tech development is planned for CO2 studies. We hope to utilize the upgraded benthic respirometer (900261) for CO2 studies, once complete.

CO2-carbonate slurry experiment (collaboration w/ Dr. Golumb –U. Mass).

We will also request a 2 machine shop days and 2 days of MOT time for adaptation of Dr. Golumb's CO2-carbonate slurry apparatus to the Pt. Lobos so that we can perform an experiment evaluating the stability of the slurry on the seabed.

Cold Seep Biology

No engineering / tech development planned

- Field programs

Seafloor community dynamics and benthic-pelagic coupling

Benthic Respiration Rate / carbon flux measurements

We will continue measurements of benthic respiration (SCOC) and carbon flux in / out of Monterey Canyon @1300 m depth. Zephyr cruises are used for small mooring deployments (10 d/y). Pt. Lobos cruises will be used for respirometer deployments (6-10 d/y).

Non-Vent Lava Flow Community Studies

We will also request 6 days of WF time for collaboration w/ Dave Clague's cruise to Juan de Fuca & Gorda Ridges

Biology of deep-sea CO2 disposal

Deep-sea animal collections

Deep-sea animals for laboratory assays of CO2 sensitivity will be collected during Pt. Lobos cruises for other primary purposes, and 1-2 days of WF/ Tiburon time.

Deep-sea CO2 release experiment

In addition, we plan to collaborate with Peter Brewer on 1-2 larger deep-sea CO2 release experiments. This will require 5-10 days shared dive time per experiment.

CO2-Carbonate Slurry Experiment

Evaluation of the stability of CO2-carbonate slurries, a collaboration with Dr. Dan Golomb of U. Mass, will be examined during a short (2 Pt. Lobos days) experiment in which we release a slurry into small corrals on the seafloor at 500-1000 m depth. We will reexamine the stability of the slurry after a few months, in association with other dive priorities.

Cold Seep Biology

Clam Mobility Studies

Field deployments of a time-lapse camera to measure clam mobility will be done as a low-level effort if dive time is available associated with other dive priorities.

Lava Flow Studies w/ Dave Clague

Lava Flow Cruise

We plan to accompany Dave Clague to the Juan de Fuca & Gorda Ridges to measure differences in benthic community development on lava flows of different ages (~3.5- 300 y). We are requesting 7 WF days (6 dive 1 transit) to support this collaboration. During these dives we will annotate the abundances of benthic animals and collect specimens for size (and potentially age) determination.

- Data reduction and analysis
  The project team generally performs data reduction and analyses.

- Proposed duration of project and approximate plan of action
  This is the second year of a 3-year project.

c) Specific deliverables (new and continuing projects)

- Products from research and development (instruments, tools, documentation, publications, presentations, etc.)
  Products for the benthic biology project are principally the publication of research results in peer-review journals, and presentation of results at scientific meetings and workshops

- How success will be measured
  The project will be successful if we advance our understanding in these areas of research and disseminate results of these studies to the scientific community.

d) Project team (new and continuing projects)

Jim Barry – lead investigator, responsible for project management, direction of research, publication of results.
Kurt Buck – microscopy, benthic respirometer, sediment trap, and sensor maintenance, meiofaunal analyses
Chris Lovera – moorings, video analyses, sediment analyses
Patrick Whaling – logistics, seagoing support, moorings, seep studies
Linda Kuhnz – CO2 studies.
Jeff Drazen – MBARI Postdoctoral Fellow studying the effects of CO2 on deep-sea fishes
Christian Levesque – MBARI Postdoctoral Fellow studying the carbon cycling in Monterey Canyon.

e) Project Lab Space (new and continuing projects)

We request use of the benthic biology lab & left side of the seawater lab, as well as continued use of space in Building B expansion presently used for development of the benthic respiration system upgrade. This space continues to be used for calibration of sensors for the existing respirometer and will also be used for completion of the BRS 2 system.

3) Budget Justification (new and continuing projects)

1. Capital Equipment

a. Rotating sphere sediment trap (1 ea = $17K). This sediment trap will be used principally as a spare. We prefer to purchase a spare so that the likelihood of an interruption in the time series at our 2 stations (Monterey Canyon and Smooth Ridge) is minimized.
b. Hydroscat-2 optical backscatter and fluorometer system (1 ea. = $16K). This will function as a spare for instruments presently on our moorings. Purchase of this unit will allow less interruption of our time series due to failure & calibration.
c. Shimadzu fluorescence detector (RF551) for existing HPLC $10,500. This will allow us to analyze plant pigments in sediment samples on the HPLC in the Barry lab. Barry and Levesque are both planning to use this instrument.

2. Travel and Conference Fees ($8400)
   a. Conferences - Barry is requesting support for 2 conferences. One conference each for Drazen, Levesque, Buck & Lovera = 6 @1300 = $7,800.
   b. Travel to Oregon for Juan de Fuca cruise (3 @ $1,000 = $3,000).
3. Outside Services
   a. Sediment Analyses, Stanford ($5K). This will support 200 CHN, Stable carbon and nitrogen analyses of sediments – Christian Levesque will require these analyses.
   b. Electron Microscopy (UCSC - $7000) This supports electron microscopy by Kurt Buck
   c. Taxonomy identification ($5K). We rely on professional taxonomists for some infaunal sample analyses. These funds will be used principally for identification of polychaete worms.
4. Supplies
   a. Equipment <$5000
      i. Homer Pro navigation beacons (8 X $3500= $28K). We are requesting purchase of 8 beacons to support our research. Because the new Homer Pro policy requires dedicated beacons for projects >3 mo., we will require purchase of the beacons for respiration systems, moorings, and location markers.
      ii. Flame Ionization Detector & parts (injector, w/ flow controller, misc.) for existing gas chromatograph - $5,800. This detector will be used to refit the existing GC in the Barry lab for use by Christian Levesque, a new MBARI postdoctoral fellow, for lipid analyses, in conjunction with the benthic biology program.
      iii. Shimadzu A/D board (SS420X) for HPLC fluorescence detector. See Shimadzu HPLC equipment above
   b. General Supplies
      General ($10K) + Science ($12K). This includes chemical, glassware, containers, gases, fittings, valves, and other equipment for all of our studies, and will support research by 2 postocs (Drazen, Levesque), in addition to other Barry lab activities.
   c. Outside Services
5. Labor –
   a. Machine shop – We request 5 days of machine shop time for unanticipated modifications or repairs to existing equipment, and 1 day of machine shop time to help adapt a CO2-carbonate slurry system from Dr. Dan Golomb (U. Mass) to the ROV.
   b. ITD – We request 55 days of support for analyses of benthic video transects. Linda Kuhnz is an ideal candidate for this.
   c. Kurt Buck & Chris Lovera will spend ~75-80% of their time on this project – see project team.
   d. Barry will spend 75% of his time on this project.
   e. Drazen and Levesque are both MBARI postdocs, who will spend 100% of their time on this project.

4) Milestones (new and continuing projects)

	Milestone 1	Milestone 2	Milestone 3	Milestone 4	Milestone 5	**Total Resources** [1] for each resource category for all milestones listed here
Milestone date	Each 3 month period	6/1/2004	7/15/04	12/1/04		
Milestone description	Complete Benthic mooring deployment / recovery	Complete test of eddy correlation method of flux measurements	Complete CO2 release experiment w/ Brewer & collaborators.	Complete CO2-carbonate slurry experiment w/ Dr. Golumb.		
EE	0	0	0	0		0
SE	0	0	0	0		0
ME	0	0	0	0		0
IAG	0	0	0	0		0
Machine Shop	0	0	0	1		6

[1] This number should be same as the number you entered on the resource requests for this particular resource