APPENDIX 1. WORKSHOP AGENDA

Attaining Operational Marine* Biodiversity Observations:

A Workshop to Determine the Status of Current Abilities and Scope Future Solutions

Consortium for Ocean Leadership

1201 New York Avenue NW, Fourth Floor, Washington, DC

May 24-27, 2010

Agenda

GOAL: Identifying the BEST OPTIONS for IMPLEMENTING a Local, National and Global Biodiversity Observing Network (BON)

Monday, 24 May

8:30-9:00 **Assemble/Breakfast**

9:00-9:20 **Opening Remarks - Welcome**

- *Ocean Leadership, Federal Sponsors*

I. INTRODUCTION

9:20-9:40 **Introduction** to the Overarching Goal Regarding Marine Biodiversity Monitoring

- *J. Stachowicz*

II. HABITATS

9:40-10:10 **Overview of Benthic Habitats: Shallow/Deep**

- *E. Duffy*

10:10-10:30 **Q&A**

10:30-10:45 *Break*

10:45-11:15 **Overview of Pelagic Habitats: Shallow/Deep**

- *T. Rynearson, H. Sosik*

11:15-11:45 **Q&A**

11:45-12:15 *Lunch*

12:15-1:15 **(No. 1) Breakout Groups to Discuss Major Challenges and Opportunities by Habitat**

- *Facilitated by SC members*

1:20-1:50 **Breakout Summaries (10 minutes per group)**

- *SC members*

III. TAXONOMY

1:50-2:20 **Overview of Taxonomy Issues: Microbes to Metazoa**

- *G. Paulay, L. Amaral-Zettler*

2:20-2:40 **Q & A**

2:40-2:55 *Break*

2:55-3:55 **(No. 2) Breakout Groups to Discuss Major Taxonomic Challenges and Opportunities**

- *Facilitated by SC members*

4:00-4:30 **Breakout Summaries (10 minutes per group)**

- *SC members*

4:30-5:00 **Day 1, Wrap-up Discussion / Review**

- *SC Chairs*

Tuesday, 25 May

8:00-8:30 **Breakfast**

IV. METHODS

8:30-9:00 **Overview of Existing and Anticipated Biodiversity Observing Methodologies**

- *T. Rynearson*

9:00-9:20 **Q&A**

9:20-10:20 **Breakout Groups to Identify Major Methodological Challenges and Opportunities**

- *Facilitated by SC members*

10:20-10:35 *Break*

10:35-11:20 Breakout Groups continued

- *Facilitated by SC members*

11:25-11:55 Breakout Group summaries

- *SC members*

11:55-12:25 Lunch

12:25-1:25 Small groups to Review Objectives of the BON, formulate 5 most-important questions a BON could address

- *Facilitated by SC members*

1:30-2:00 Plenary to discuss top 5 questions from each group

2:00-2:15 Break

2:20-4:20 Breakout Groups to Discuss Habitats, Taxa, Methods that would Best Address Objectives

- *Facilitated by SC members*

4:20-5:00 Breakout Summaries (10 minutes per group)

- *SC members*

5:05-5:30 Wrap-up Discussion / Review

- *Steering Committee Chairs*

Joint reception with the Revolution of Science through Scuba Symposium at the Smithsonian National Museum of Natural History Ocean Hall from 6:30 pm – 9 pm.

Wednesday, 26 May

8:30-9:00 Breakfast

VI. Synthesis

9:00-11:00 (No. 5) Breakout Groups Condense and Prioritize Taxa and Methods, Address BON Questions

- How often to sample as a function of habitat, taxa and methods?
- *Facilitated by SC members*

11:00-11:15 Break

11:15-12:15 Breakout Group Summaries/Plenary Review of BON Options

- *SC members*

12:15-12:45 *Lunch*

12:45-2:30 **Breakout Groups Discuss Linking Spatial, Temporal, and Taxonomic Scales**

- What might be transformative? Existing Programs-What makes them successful? Legacy data? OOI?
- *Facilitated by SC members*

2:30-3:00 *Break*

3:00-4:00 **Case Study Examples by Participants**

- *SC members, Participants*

4:00-4:30 **Identify Action Items (Online Forum for Comments) – Participants, Community, Federal**

- *SC members, Participants*

Thursday, 27 May

Steering Committee Wrap-Up

9:00-2:30 **Steering Committee Workshop Synthesis**

VII. TIMELINE

June-December	**Workshop Synthesis Posted to Online Forum for Public Comments, Moderated by the Steering Committee;** **Workshop Results Presented at Major Conferences**
January 2011	**Workshop Summary, and Online Forum Comments, Presented to Interagency Working Group on Ocean Partnerships Ad Hoc Group on Biodiversity**
February 2011	**Ad Hoc Group on Biodiversity to Consider BON Implementation Steps**

APPENDIX 2. STEERING COMMITTEE, PARTICIPANTS and SPONSORS

Steering Committee	
Amaral-Zettler, Linda	Marine Biological Laboratory
Duffy, J. Emmett	Virginia Institute of Marine Science
Fautin, Daphne	University of Kansas
Paulay, Gustav	University of Florida
Rynearson, Tatiana	University of Rhode Island
Sosik, Heidi	Woods Hole Oceanographic Institution
Stachowicz, John	University of California-Davis
Workshop Participants	
Best, Ben	Duke University
Bowen, Don	Fisheries and Oceans Canada
Caley, Julian	Australian Institute of Marine Sciences
Caron, David	University of Southern California
Clark, Chris	Cornell University
Costa, Dan	University of California-Santa Cruz
Diaz, Bob	Virginia Institute of Marine Science
Etter, Ron	University of Massachusetts-Boston
Fogarty, Mike	National Marine Fisheries Service
Frank, Ken	Dalhousie University
Galagan, James	Boston University
Geller, Jon	Moss Landing Marine Laboratory
Guild, Liane	National Aeronautics and Space Administration
Guinotte, John	Marine Conservation Biology Institute
Haddock, Steve	Monterey Bay Aquarium Research Institute
Jaffe, Jules	Scripps Institution of Oceanography
Lawson, Gareth	Woods Hole Oceanographic Institution
Levin, Lisa	Scripps Institution of Oceanography

Meyer, Chris	Smithsonian Institution
Ohman, Mark	Scripps Institution of Oceanography
Reid, Philip	University of Plymouth
Scholin, Chris	Monterey Bay Aquarium Research Institute
Short, Fred	University of New Hampshire
Vanderploeg, Hank	Great Lakes Environmental Research Laboratory
Vecchione, Mike	Smithsonian Institution / National Marine Fisheries Service
Ward, Bess	Princeton University
Watling, Les	University of Hawaii
Westberry, Toby	Oregon State University

Workshop Sponsor Representatives	
Beach, Reginald	National Oceanic and Atmospheric Administration
Breuer, Eric	National Oceanic and Atmospheric Administration
Canonico, Gabrielle	National Oceanic and Atmospheric Administration
Eckman, Jim	Office of Naval Research
Garrison, Dave	National Science Foundation
Gisiner, Bob	Marine Mammal Commission
Lindstrom, Eric	National Aeronautics and Space Administration
Meyer, Chris	Smithsonian Institution
Snyder, Scott	National Science Foundation
Ticco, Paul	National Oceanic and Atmospheric Administration
Turner, Woody	National Aeronautics and Space Administration
Valdes, Sally	Minerals Management Service
Weise, Michael	Office of Naval Research

APPENDIX 3. ACRONYMS AND ABBREVIATIONS

ARMS	Autonomous Reef Monitoring System
AUV	Autonomous Underwater Vehicle
BOEMRE	Bureau of Ocean Energy Management, Regulation and Enforcement
BON	Biodiversity Observing Network
CalCOFI	California Cooperative Oceanic Fisheries Investigations
COI	Cytochrome c Oxidase I
CRIOBE	Centre de Recherches Insulaires et Observatoire de l'Environnement
DNA	Deoxyribonucleic Acid
ECOHAB	Ecology and Oceanography of Harmful Algal Blooms
ENSO	El Niño / La Niña Southern Oscillation
EPA	Environmental Protection Agency
GLOBEC	Global Ocean Ecosystem Dynamics
GLOS	Great Lakes Observing System
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
IWG	Interagency Working Group
IWG-OP	Interagency Working Group on Ocean Partnerships
JSOST	Joint Subcommittee on Ocean Science and Technology
LIDAR	Light Detection And Ranging
LMER	Land Margin Ecosystem Research
LTER	Long Term Ecological Research
LTMP	Long-Term Monitoring Project
MEA	Millennium Ecosystem Assessment
MMC	Marine Mammal Commission
MMS	Minerals Management Service
NASA	National Aeronautics and Space Administration
NBIC	National Ballast Information Clearinghouse

NEMESIS	National Exotic Marine and Estuarine Species Information System
NeMO	New Millennium Observatory
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NOPP	National Oceanographic Partnership Program
NSF	National Science Foundation
OBIS	Ocean Biogeographic Information System
ONR	Office of Naval Research
PacOOS	Pacific Coast Ocean Observing System
PDO	Pacific Decadal Oscillation
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
RAMP	Reef Assessment and Monitoring Program
RNA	Ribonucleic Acid
ROV	Remotely Operated Vehicle
R/V	Research Vessel
USGS	United States Geological Survey
WoRMS	World Register of Marine Species

Appendix 4. Preliminary list of approaches and methods considered potentially useful in monitoring marine biodiversity, as well as existing monitoring programs, providing a flavor for the feasability of biodiversity monitoring across a range of spatial and taxonomic scales using currently available technologies. The list was compiled with input from various sources and is not exhaustive. Comments from the community that will be useful in expanding and filling in the table are welcome.

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
1	**Colonization-trap methods**													
1.01	**Autonomous Reef Monitoring System (ARMS)**	Epifaunal macroinvertebrates: diversity and abundance of colonists	Benthic hard substrata, shallow (Coral Reefs)	Designed to systematically assess and compare indices of invertebrate biodiversity across gradients of biogeography, environmental conditions, and anthropogenic stress over time.	Morphological taxonomy; Barcode of Life DNA; Mass parallel sequencing (454) proposed for large-scale efforts.	Long-term devices designed to mimic the structural complexity of benthic habitats for collecting colonizing invertebrates (following Martin et al).	~$100 in materials, 3 hours labor.	Diver	Diver	Simplicity of design, low cost; Mass parallel sequencing: Quicker (minimal sorting of sample just grind up and sequence), Cost effective for large volume surveys.	Not representative of all species; Technology not yet optimized for sequencing most invertebrates yet. Genetic databases often not to species level yet.			
1.02	**Sediment trays**	Infaunal macroinvertebrates: diversity and abundance of colonists	Benthic soft substrata, deep sea	To quantify recruitment and the assembly of of soft-sediment communities under different flow regimes and sediment characteristics. Can be used at various temporal and spatial scales	Invertbrate diversity, Community structure and temporal dynamics	Trays are used to mimic specific sediment substrates and sample the natural communities.	$300 but can vary depending on size and style	ROV/Submersible	ROV/Submersible	Important for quantifying community development in remote settings	Usuallu isolated from surrounding sediments precluding colonization through sediments.			
1.03	**Granite blocks**	Epifaunal macroinvertebrates: diversity and abundance of colonists	Benthic hard substrata, shallow	Designed to mimic rock wall habitats to quantify community assembly and to experimentally manipulate bitoic and abiotic forces. Can be oriented vertically or horizontally	Invertbrate diversity, Community structure and temporal dynamics	Long-term blocks Designed to mimic rock wall habitats (Miller and Etter 2008)	$100	Diver	Diver	Good for setting up experiemntal manipulations (flow, cages, etc) on hard substrates. Can be placed in specific microhabitats and can be monitored	Can be labor intensive to install and some may be removed by storms.			
1.04	**Disc rack - Virtue Project**	Epifaunal macroinvertebrates: abundance and diversity of colonists	Marine Environment	Educational tool, standardized method to look at communities. Apparently widespread in the EU	Invertbrate diversity, Community structure and temporal dynamics	A simple rack hung or suspended with CDs separated from one another (thus providing upper and underside surfaces	Probably < $10/rack	Diver in shallow water, hang from pier? ROV or sub in deep water	Diver, ROV or SUB	Simple, useful educational tool, can engage school children, college students. Can be used globally due to ready materials	CD surfaces may only attract a subset of the hard substrate fauna. Isolation from natural substrate may create artifacts	uncertain. Probably 1-2 years	apparently wisespread in Scandinavia, Europe	
1.05	**Settlement plates**	Epifaunal macroinvertebrates: abundance and diversity of colonizing recruits	Benthic substrata, shallow	monitor recruitment	sessile fauna diversity and ecological interactions	Old-fashioned, "2D ARMS"	$5	manual	manual	simple, very widely used, cheap	ID of recruits challenging morphologically if fauna not well known		very widely used, especially in intertidal and harbors	
2	**Field survey methods**													
2.01	**Photoquadrats/rock walls**	Epifaunal macroinvertebrates: abundance and diversity	Benthic hard substrata, shallow	To monitor changes in community dynamics, biodiversity and the impacts of climate change and invasive species. Can be used on larger scales to explore regional and global biogeographic forces.	Community structure and temporal dynamics	Long-term quadrats on existing rock walls that are visited on a regular basis. Diversity and temporal dynamics can be easily quantified from photos.	$10 material, 1 hr labor	Diver	Diver	Fast, relatively easy and cheap. Can be easily replicated in space and time.	Some of the community might be obscurred in photos by luxuriant growth (macroalgae) or overgrowing epifauna			

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
2.02	**MARINe (Multi-agency Rocky Intertidal Network: www.marine.gov)**	Epifaunal macroinvertebrates and algae: abundance and diversity	Benthic hard substrata, shallow	Designed to assess population and community dynamics as well as size structure over time	Population and community metrics, Size structure analyses (all over	Marine Rocky reefs along west coast of NA (since 1992 in many sites)	Many different pieces of equipment	Field sampling by people	Field sampling by people	Very detailed and accurate assessments	Cost of personel, need for experts	NA	Along the whole Western coast of US	
2.03	**CBS (Coastal Biodiversity Surveys: http://cbsurveys.ucsc.edu/)**	Epifaunal macroinvertebrates and algae: abundance and diversity	Benthic hard substrata, shallow	Designed to provide spatially explicit maps of species distribution at sites across the intertidal gradient	Biogeographic analyses of biodiversity and community composition	Marine Rocky reefs along west coast of NA; Spatially explicit (X,Y,Z) assesment of biodiversity	Many pieces of equipment	Field sampling by people	Field sampling by people	Very detailed and accurate assessments	Cost of personel, need for experts		Along much of Western coast of North America	
2.04	**Long-Term Monitoring Program**	fishes and macrobenthic invertebrates: diversity, long-term temporal and spatial dynamics	coral reefs	long term monitoring of the GBR	standardized reporting, various scientific papers			diver	n/a	long term monitoring	much is not ampled	n/a	standardized for GBR and other AIMS monitoring	
2.05	**SeagrassNet**	Seagrasses: diversity and abundance. Environmental parameters	Benthic soft substrata, shallow (also some hard, and coral reef)	Designed to statistically sample seagrass habitats of all species with repeated measures to detect change over time and identify trajectories	Seagrass specied ID, percent cover, biomass, canopy height, density, change in seagrass bed size, plus temperature, light, salinity and sediment	Trained monitoring teams collecting date 4x/yr at fixed transects and reporting to a common database via the internet		Intertidal or diving		Standardized protocol, works for all species in the world, trains local scientists and managers, comparable date	Start up costs for site location and training required		114 sites worldwide	

3 Sample-based methods

3.01	**Continuous Plankton Recorder**	Phytoplankton, mesozooplankton, smaller organisms: diversity and abundance. Chlorophyll, physico/chemical parameters	Epipelagic	Quantitative sampling of mesozooplankton (including meroplankton), semi-quantitative for phytoplankton and smaller constituents and fish larvae, presence/absence for coelenterates and some other planktonn on a moving band of silk of 270um mesh. One sample on silk represents 10 nautical miles of tow and 3 m3 filtered water. Production of a visual estimate of chlorophyll into 4 categories (Phytoplankton Colour index). Has been intercalibrted with SeaWifs satellite measurments.	Morphological taxonomy, DNA anlyses, photography, biomass,. Long-term changes, interocean comparisons, SEM and EM. Used to measure biodiversity, non-natives species, biomass, phenology, growing season, HAB species. Used in studies of eutrophication, ecosystem stability, ocean acidification, conservation, carrying capacity, trophic mismatch, pelagic benthic coupling.	The Continuous Plankton Recorder is an approximately 900cm long machine that samples plankton on a moving band of 270um silk at a rate that is proportional to the speed of the tow ship. A cassette system is used; one cassette equals ~500 nautical miles of tow. The machines are towed by voluntary merchant ships (Ships of Opportunity, SOOP).Survey started in June 1931, stopped during the Second World War and has sampled using Merchant ships on their regular routes each month since January 1946 in the North Sea and North	1CPR + 1Cassette and 1 Ship requiring fitting with a davit. Cost for 1 CPR/Cassette $19,000, Davit construct and instal $11,000 (varies with ship, not needed on 30% of ships) . Cable and block $500 (varies with ship). Set up costs for new route - assume 500nm tow x 12 tows per annum,	CPRs sent to ships in a standard yellow box using a normal carrier. The machine is unloaded and deployed from the stern of the vessel by the ship's crew using the normal winch and equipment on the vessel or when necessary via a small davit or in one case from an articulated arm. A 100m cable is used, marked so 22m is between the surface and the CPR.	CPR recovered by the ship's crew, If the tow is longer than 500 nautical miles the cassette system is changed by them. When tow completed the CPR is loaded in the box and returned to the laboratory for sample analysis and machine servicing. Relatively inexpensive for detail obtained.	Extensive and well proven methodology. Used extensively, more than 200,000 samples processed. Large standardised computer database of historical data. Large archive of historical samples preserved in formalin from ~1998 that are available for further analysis. No cost for the ship platform. voluntary help by ship's officers and crew. Develops a centre of expertise in plankton taxonomy.	Only samples near surface. Shipping routes can change. Some regions of the world rarely traversed by merchant ships. Some species may be selectively sampled. Laour intensive use of parataxonmists. Some organisms not preserved in formalin and disintegrated.	Can be deployed on short coastal to trans-ocean routes. Operates remotely behind the ship for days. Samples are preserved in excellent condition for many decades.	Now extensively used througout the globe, but still only covering a small area of the global oceans.	Director SAHFO Prof Pe Burkill. Philip (Chris) Reid
3.02	**Multiple Opening and Closing Net and Environmental Sensing System (MOCNESS)**	Mesozooplankton, Micronekton, Nekton: diversity and abundance	Pelagic (Epi, Meso, Bathy, Abysso)	Quantitative sampling of target size class using various sized systems (1/4-m, 1-m, 10-m) and nets (100 um - 2mm)	Morphological taxonomy, DNA barcoding, live photography, biomass, silhouette photography, 454 pyrosequencing (proposed)	Stratified oblique tows with real-time environmental data (T/S/D, fluorescence, etc)	$50,000 - $100,000	Coastal to Ocean-Class Research Vessel	Coastal to Ocean-Class Research Vessel	Quantification and verification of valid sampling, high-volume sampling for rare species, recovery of living specimens	Deployment from research vessels	Tow length dependent on depth sampled: 2-3hrs for surface samples; 24+ hrs for deep tows (to 5000m); archived samples preserved in formalin (no end date), alcohol (2-5 years for DNA), liquid	MOCNESS or similar instrumented multi-net systems used world-wide	Erich Horgan (BESS) or Peter Wiebe (WHOI)

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3.03	**Ship-board DNA sequencing**	All taxa: diversity	Pelagic	Accurate DNA-based species identification; species diversity (presence / absence)	DNA barcodes from Identified specimens: PCR and DNA sequencing of target gene	ABI Automated DNA Sequencer (4-capillary GeneScan)	$75,000	Coastal to Ocean-Class Research Vessel	Coastal to Ocean-Class Research Vessel	Rapid at-sea confirmation of species identification	Currently done on individual specimens (labor intensive; expensive)	Appropriate for cruises lasting weeks to months; DNA data permanent record	Not usual yet	Ann Bucklin (UConn
3.04	**Classical biological oceanographic sampling**	Phytoplankton, zooplankton: abundance (and diversity?). Chlorophyll, physico-chemical parameters	Pelagic (epi)	time series	microscopy for cell counts and spp id	tranditional time series program	combination of moorings and ships	CTD casts/ship	CTD casts/ships	well defined methods, long running sereis	limited coverage		common	Francis Chavez
3.05	**Lake Michigan Pelagic and Benthic Monitoring Program**	Phytoplankton, zooplankton, benthos, fishes: diversity and abundance. Nutrients, physical parameters	Pelagic and benthic soft substrata	Designed to describe seasonal dynamics of plankton and benthos in nearshore and offshore waters and to serve as foundation for process studies to understand the causes of changes in the ecology of the lake	Morphological taxonomy	Standard plankton and benthos monitoring using nets and benthic grab samples (ponar)	N/A	Shipboard	Shipboard	The methods are standard and seasonal sampling (if samples are processed immediately) will allow identification of invading species.	Season sampling at inshore and offshore sites is expensive. Phytoplankton taxonomy is difficult and time consuming.	Zooplankton and benthos samples have indefinite shelf life. Phytoplankton samples last only a year or two unless slides are made.	Standard. Zooplankton and benthos taxonomy is simple. Phytoplankton and microzooplankton taxonomy is difficult.	
3.06	**Predator diet sampling**	Fishes and their prey: diversity and abundance	Pelagic, demersal on continental shelf	interannual and seasonal	morphological taxonomy, fatty acid signature analysis	seasonal sampling of predator diets	$120/sample	live-capture	live-capture	relatively inexpensive, consistent temporal sampling, may sample some species better than research	may not reflect changes in prey field; subject ot bias by changing foraging distribution of predator	~20 yr	broadly	
3.07	**Groundfish trawl survey**	Fishes: diversity and abundance	Demersal on continental shelf	spatial and temporal indices	community analyses	stratified random trawl surveys		ship	ship	large area of consistent temporal and	low sampling intensity	~40 yr	continental shelves	
3.08	**Research Vessel (RV) Bottom Trawl Survey**	Fishes, benthic macroinvertebrates, (recently added: zooplankton): diversity and abundance. Bottom-water temperature, (recently added: oxygen, chlorophyll)	Demersal on continental shelf	Designed to provide annual, fishery-independent indices of abundance of commercially exploited species over large spatial scales. All species are assessed, including non-commercial providing useful information on species diversity, dominance and changing compositional patterns over time.	All species are identified and measured (lengths and weights). For a sub-set of species, aging information is obtained.	For the Scotian Shelf, the RV survey was intiated in 1970 and continued un-interrupted to present. Bottom waters of the Northwest Atlantic Ocean at depths ranging from 50 to 200-300 m	A large, science-dedicated vessel deploying a bottom trawl in pre-detemined geographic areas, lasting one month each year during July. The annual cost of the program is $1M CDN.	Ship	Ship	Data on fish stock status and diversity obtained independently from fishery. Standardized sampling in existence since 1970 and cover large spatial scales.	Some species not adequately sampled. High cost.		Similar surveys of exploited fish species are conducted throughout the United States, Canada and the European Seas.	
3.09	**HPLC pigment analysis**	phytoplankton: abundance and higher-taxon diversity	Pelagic (epi)	phytoplankton biomass and pigment types	decomposition into class-specific pigments through optimization (e.g. Chemtax)	discrete water samples, filtered, extracted in organic solvent and analyzed with high pressure liquid chromatography		ship, boat, pier, etc.	ship, boat, pier, etc.	Wide taxonomic range, in common use and limited taxonomic expertise required	Subject to uncertainty due to species-specific and physiological variability in pigment ratios; no in situ or automated application to date, requires immediate sample handling	indefinite storage in liquid nitrogen	in wide use in biological oceanography	

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
3.10	**454-Pyrotag sequencing**	Microorganisms, micrometazoans: diversity, some components of abundance	All environments, in principle	Provides both taxonomic and relative abundance data for Bacteria and Archaea and presence/absence data for Eukarya	rRNA gene hypervariable regions for bacteria, archaea and eukaryotes	Taxonomic resolution to genus or species possible but depends on extent of annotations in database; captures diversity information for both abundant and rare community members; ability to extend this to longer reads and barcoding applications.	~30K/per run yielding ~ 1 million sequences			captures diversity information for both abundant and rare community members; ability to extend this to longer reads and barcoding applications.	Currently restricted to labs with available facilities; expensive up-front costs but different platforms promise cost reductions; not available for in situ platforms but resulting data could be adapted for use with in situ instrumentation such as ESP via phylochips, microarrays etc.		ICoMM International Census of Marine Microbes project: (http://icomm.mbl.edu); data are downloadable at the VAMPS website (http://vamps.mbl.edu). Project descriptions, DNA extraction methodology, proposals and associated metadata are found the MICROBIS pages: http://icomm.mbl.edu/microbis/project_pages/pp_by_name/ The MIRADA-LTERS project	Amaral-Zettler
3.11	**PhyloChip: Universal 16S rRNA Gene Microarray**	Microorganisms, micrometazoans: diversity (and abundance?)	All environments, in principle	The Phylochip is a microarray that uses genetic probes on the chip to match gene sequences in a water, air, or soil sample.	Microarray uses genetic probes (rRNA gene fragments) on chip to match gene sequences in water or sediment sample	The GeneChip Phylochip Manufactured by Affymetrix Corporation ® can detect up to 32,000 unique versions of the bacterieal 16S RNA gene.	<$1000 a chip			Taxonomic resolution to genus or species possible. T Another advantage is that it can be used with RNA to determine the most	Targets known diversity and will not capture unknown or novel diversity.			
3.12	**Lab-on-a-chip**	Microorganisms, micrometazoans: diversity and abundance	Pelagic		Lab-on-a-chip (LOC) probes for any gene fragment on single chip mm to a few cm square. Can be applied to real-time qPCR to detect					Requires minimal reagents, fast, high-though-put, cost-effective	Still in development, detection issues, etc.			
3.13	**Hand-held Nucleic Acid Sequence Based Amplification (NASBA) sensor**	Microorganisms, micrometazoans: diversity (and abundance?)	Pelagic			prototype hand –held reverse-transcription Nucleic Acid Sequence Based Amplification sensor.				Isothermal amplification does not require thermocycling during the procedure. Has a high sensitivity. Can be used to detect viruses (has been tested with Noroviruses) and other microbes. NASBA assay has also been developed for the detection of rbcL mRNA from the red tide dinoflagellate Karenia brevis by	No capacity for sample archival.			
3.14	**Autonomous Microbial Genosensor**	Microorganisms: diversity (and abundance?)	Pelagic			in situ sensor for marine microbe detection. Based on					No capacity for sample archival.			

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
3.15	**Environmental Sampling Platform**	Microorganisms, micrometazoans: diversity (and abundance?). Proteins and biotoxins	Pelagic	Can archive and detect in situ, can be coupled with other equipment to obtain environmental data associated with sampling event. Real-time. Expandable to other techniques.	HABS, and biotoxins DNA and protein array analyses via filtered samples		~$190K	Shipboard	Shipboard	real-time monitoring in situ	$$$, coastal deployment challenges, as with all in situ instrumentation – the possibility of vandalism; biofouling			Chris Scholin
3.16	**All Taxon Biodiversity Inventories (ATBI)**	All taxa (potentially)	All environments (potentially)	document "total" biodiversity of area	Taxonomic, genetic	Team of taxonomists and collectors document biodiversity by "saturation" sampling	reasonable efforts start at $100K	varied	varied	most taxonomically thorough; sets background taxonomic knowledge; creates	mostly qualitative; relies on taxonomic experts; utility increased over long-term as samples get		examples: CReefs, Biocode, BIOTAS, Bouchet inventories	

4 Mixed sample/video/acoustic methods

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
4.01	**ROV transects: mid-water time series**	Nekton, gelatinous zooplankton: diversity and abundance	Pelagic: mid-water	time series/discovery	Video, various molecular analyses	ROV transcets	very expensive	ship	ship	robust and long running	expensive/limited range	generally hrs - day/DNA can be archived for extended periods	not widely used	Bruce Robisor Steve Haddoc
4.02	**ROV transects: benthic biology**	Macroinvertebrates and fishes: diversity and abundance	Benthic soft and hard substrata, deep sea	ecology/discovery	video/discrete sampling	ROV								Jim Bar
4.03	**Bio-Optical Multi-frequency and Environmental Recorder (BIOMAPER-II)**	Mesozooplankton: diversity and abundance. Temperature, salinity, transmittance, fluorescence	Pelagic	Sample zooplankton diversity, abundance, size		Multi-sensor system including multi-frequency echosounder, VPR, and environmental sensing system (temperature, salinity, transmittance,	~$1M	Towed from vessel		Combination of instruments allows cross-comparison, especially the use of video samples to assist in the interpretation of	Large (1 tonne), requires a large vessel and handling system			

5 Remote sensing (optical / spectral methods)

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
5.01	**Airborne Visible Infrared Imaging Spectrometer (AVIRIS)**	Habitat-forming plants and macroinvertebrates: areal coverage and higher-taxon diversity	Benthic hard and soft substrata, shallow	Designed to support NASA's research programs with airborne measurements of upwelling spectral radiance in 224 contiguous spectral channels from 400 to 2500 nm.	Spectral analysis of shallow water benthic type and coastal vegetation type	Spectral radiance information for terrestrial and shallow water marine ecosystems; Image classification of benthic types, HAB, and coastal terrestrial cover types		Aircraft	Aircraft		Cost			NASA JPL
5.02	**Customized Headwall Imaging Spectrometer**	Phytoplankton, habitat-forming plants and macroinvertebrates: areal coverage and higher-taxon diversity	Pelagic (epi); benthic hard and soft substrata, shallow	Designed to support NASA's ocean color and marine research airborne missions with measurements of upwelling spectral radiance in 120 contiguous spectral channels from 400 to 1000 nm.	Spectral analysis of shallow water benthic type and coastal vegetation type	Image classification of benthic types, HABs; Spectral radiance information for ocean color and shallow water marine ecosystems		Aircraft	Aircraft	Portable	Cost			NASA Ames Airborne Sensor Facility
5.03	**Spectroradiometer (GER1500, SpectraVista Corp) and underwater housing**	Habitat-forming plants and macroinvertebrates: areal coverage and higher-taxon diversity	Benthic hard and soft substrata, shallow	Designed to collect field spectroscopy data of terrestrial and marine ecosystem features	Spectral analysis of shallow water benthic type and coastal vegetation type	Spectral radiance curves (spectral library) for terrestrial and shallow water marine ecosystems		Diver	Diver	Portable	Time in the field			NASA Ames, Guild, F

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
5.04	**Ocean Color Satellites (SeaWiFS, MODIS)**	Phytoplankton: abundance and higher-taxon diversity	Pelagic (deep, shallow) and both Hard and Soft Bottom environments (shallow) - CORRECT?	Remote assessment of algal pigment stocks; rates of production; coarse taxonomy	Detect "color" differences in surface ocean via fluorescence signature of pigment, processesd via bio-optical	Polar-orbitting satellites designed to maximize global coverage and repeat	several hundred million dollars per satellite	Rocket	None	Global coverage; long term deployment	low spectral resolution; requires ground-truthing	N/A	Relatively common due to centralized processing and distribution	

6 In situ optical methods

6.01	**Video Plankton Recorder (VPR)**	Meso- and macrozooplankton: diversity and abundance	Pelagic	Sample zooplankton diversity, abundance, size	Taxonomy	Image-forming optical system sampling a field of view of 7x7mm to 42x42mm	$75k	Profiled or towed from vessel, mounted on AUVs (eg REMUS), moored		High vertical resolution; processing can be done in real-time	Small sample volumes; sampling efficiency affected by density of organisms and avoidance behavior			
6.02	**In situ zooplankton imaging systems (VPR, SIPPER, LOPC, ISIIS, Ocean DIVA, UVP, ZOOVIS, etc; plus some holographic systems: Holocamera, eHolocam, Digital Holosub, etc.)**	Meso- and macrozooplankton: diversity and abundance	Pelagic	Sample zooplankton diversity, abundance, size	Taxonomy	video imaging or holographic imaging	$100K	ship, AUV, mooring		taxonomic resolution to genus or species possible; rapid and quantitative abundance estimates; enables unprecedented space / time resolution and range; automated in situ application possible	Routine operation with taxonomic resolution requires complex data analysis systems (e.g., supervised machine learning algorithms) and manual development of training sets, cost	days to months		
6.03	**Flow cytometry (many lab systems, plus in situ systems: Imaging FlowCytobot, FlowCAM, Cytobuoy/Cytosub)**	Phytoplankton, some microzooplankton: diversity and abundance	Pelagic	abundance, cell size, and taxonomic groups	optical signature analysis, image analysis in appropriate cases	scattering/fluorescence and/or video imaging of single cells in flow	$100K	ship, mooring, large AUV	ship, mooring, large AUV	taxonomic resolution to genus or species possible with imaging systems; rapid and quantitative abundance estimates; enables unprecedented space / time resolution and range; automated in situ applications exist	Routine operation with taxonomic resolution requires complex data analysis systems (e.g., supervised machine learning algorithms) and manual development of training sets, cost	months for in situ instruments, sample storage indefinite in liquid nitrogen for lab analysis	prototype in situ applications in coastal systems, ship-board analysis common for picoplankton	
6.04	**Absorption spectra (ac-9, ac-s, Optical Plankton Discriminator)**	Phytoplankton: abundance (and higher-taxon diversity?). Other absorbing constituents	Pelagic	Assessment of light absorbing constitutents, potential phytoplankton pigment types	spectral decomposition, derivative analysis	submersible "shiny tube" or liquid waveguide spectrophotometry	$20K	ship, AUV, mooring, etc.		Wide taxonomic range within phytoplankton, rapid and relatively inexpensive, no reagents, limited taxonomic expertise required; in situ application	low taxonomic resolution (maybe class level); subject to uncertainty due to species-specific and physiological variability in spectra; confounding signals from non-phytoplankton constituents, bio-fouling	weeks to months	relatively common in marine optics community	

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
6.05	**Fluorescence spectra (FluoroProbe, etc.)**	Phytoplankton: abundance and higher-taxon diversity (pigment types)	Pelagic	assess spectral fluorescence characteristics indicative of group-specific pigments	spectral decomposition, derivative analysis	spectral fluorometer	$20K	ship, AUV, mooring, etc.		Wide taxonomic range, rapid and relatively inexpensive, no reagents, limited taxonomic expertise required; in situ applications exist	Subject to uncertainty due to species-specific and physiological variability in spectra; confounding signals from non-phytoplankton constituents, biofouling	weeks to months	small user set to date	
6.06	**Bathysnap camera system**	Macroinvertebrates and fishes: diversity and abundance	Benthic hard and soft substrata: deep sea	to monitor long term changes in benthic communities	Changes in animals, sediment-water interface (e.g., color indications of timing and duration of settlement of phytoplankton to bottom)		$100K	ship with precise positioning by submersible	ship after acoustic release	gives very good look at long term variation in bottom community	areal coverage quite small	months to year	used rarely	
7	**Animal-carried sampling (tags)**													
7.01	**Position-only/ presence-absence**	Large vertebrates: position and movements.	All environments	track migrations, habitat use, find ecosystem hotspots	Position, movements of tagged animal: track migrations, habitat use, find ecosystem hotspots	could be anything from a microchip sized acoustic fish tag to a cigarette pack sized long term seal or large fish satellite tag (ARGOS)	$10-800	surface or surgically implanted	FM radio, acoustic, satellite, recapture and download	cheap, deployable in large numbers, provides data on migratory routes, habitat usage patterns, ecosystem	doesn't tell you why the animal is there or what the immediate environment is like - coarse movements only, usually	weeks to years	wide	Costa
7.02	**Environmental sampling**	Large vertebrates: position and movements. Temperature, pressure (depth), salinity (conductivity), color (fluorimetry)	All environments	determine physical and biochemical parameters correlated with animal presence, habitat selection	use correlative models to determine physical and biochemical parameters correlated with animal presence, habitat selection: GAM, GLM, EcoSim etc	generally about the size of a cigarette pack or small computer speaker. Potted in material for depth tolerance to 2000+ meters	$1200-4000	attached to pelage or with suction cops (short term) or barbed attachments (long term)	satellite telemetry, recovery	cheap, deployable in large numbers, can provide as many CTD casts when placed on 10 or more animals as could be obtained in 100 years of ship-based transects. Transport is free.	some sensors, like conductivity, can be sensitive to animal's electric field and must be carefully calibrated. Not programmable: animals go where they want to go. Fortunately they usually go to interesting parts of the ocean	weeks to years	wide	Costa
7.03	**Diving and behavior**	Large vertebrates: position and movements (depth, 3-D accelerometry), feeding biology	All environments	determine how animals sample the water column in 3-D, partitioning of feeding, resting, travelling, energy budgets, more	high resolution 3-D spatial modeling, statistical analyses	as above	$800 - 5000	as above	as above	can provide surprisingly detailed data about energy budgets, foraging success, behavior and habitat use	confirmatory sampling of prey fields or other data still requires ship-based sampling. Lab studies often needed to verify caloric costs/benefits	weeks to years	wide	costa

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
7.04	**Multi-sensor tags with acoustics or video**	Large vertebrates: position, movements, feeding biology	All environments	observe foraging ecology, identify prey species, prey capture behavior. Detect responses to human, conspecifics, predators	Very large data sets (Gb to Tb). Analytic methods are intensive and time consuming, even with automated processing algorithms	devices are generally 1 kg or larger, and therefore usually only attached for hours or a couple days (lg coffee cup to thermos sized)	$10k-$30K	usually harnessed, attached to skin/pelage by adhesive or suction cup. Can use skin-penetrating tether (barbs) in some cases.	device must usually be recovered due to the volume and bandwidth of data	combines environmental and biological sensors with broadband stereo acoustics or hi-res video. Usually programmable sampling to prevent memory limits to useful lifespan of tag (memory gets better, smaller, cheaper all the	still too large to put on small animals (<50 kg or so). Great sophistication means more things that can go wrong, greater cost, and greater operator expertise required.	usually deployed for days or hours. Data are digital and last indefinitely.	relatively few users (tens)	Costa
7.05	**Multi-sensor animal tags**	Large vertebrates: position, movements, physiology. Environmental parameters and acoustics	All environments	sample throughout ocean	position, depth, temperature, oxygen, movement, sound	penetration or suction animal tags	$10k	small boats to ships	small boats to ships	small-scale and large-scale sampling to integrate animal activity with ocean ecology and habitat	recovery risk	days to many months	limited	Oregon UCSC, WHOI, private etc

8 Acoustic methods

8.01	**Autonomous Acoustic Habitat Monitoring**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	All environments	Sample acoustic habitats to quantify spatio-temporal-spectral variability and detect occurrence and distribution of acoustically active marine animals	Noise statistics; spatio-temporal maps; animations tuned to species or groups, location, tracking	Acoustic recorders: ambient noise, species specific acoustic signals	$8000/ unit	Surface vessel or diver; attach to trees, bury in ground	Surface vessel or diver	one person can deploy and retreive, lots of data	too expensive, deployment too short, data processing intensive	duration - 100+ days10+ years	all oceans, ca. 120years of data collected per year	C.W. Clark
8.02	**Passive Acoustic Recievers**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	Pelagic and benthic: continental shelf	temporal indices	community analyses	deploymentof fixed station receivers		ship	ship	longer-term continuous monitoring	species must vocalize	??	continental shelves, basins	
8.03	**Mutli-frequency echosounder**	Mesozooplankton, micronekton, fishes: abundance (and diversity?)	Pelagic	Sample zooplankton/micronekton/fish diversity, abundance, size	Acoustic inversions of abundance in size/taxonomic categories	Measures acoustic backscattering	$200k	Profiled or towed from vessel, mounted on AUVs (eg REMUS), moored		High temporal sampling frequency, high range resolution to large range	Provides only indirect measurements of zooplankton/fish, discriminating among species/groups present based on acoustic data along is challenging			
8.04	**Passive Acoustic Monitoring - autonomous**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	All environments	Sample acoustic habitats to quantify spatio-temporal-spectral variability and detect occurrence and distribution of acoustically active marine animals	Noise statistics; species detection, spatio-temporal maps; animations tuned to species or groups, location, tracking	Autonomous seafloor recorders: ambient noise, species-specific acoustic signals	$1000-8000/ unit	Surface vessel or diver; attach to trees, bury in ground	Surface vessel or diver	one person can deploy and retreive, lots of data	too expensive, deployment too short, data processing intensive, species must produce sound	duration - 100+ days10+ years	becoming much more common, all oceans, ca. 120years of data collected per year	C.W. Clark
8.05	**Passive Acoustic Monitoring - towed**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	All environments	Detect occurrence and distribution, and estimate relative abundance of acoustically active marine animals	Beamforming, auro-detection, tracking	Towed hydrophone array	$400/sensor plus ancillaries	ship	ship	augments other survey methods, provides archived record for post-processing	requiresexperienced analyst, back-deck logistics	duration of cruise, 10+ yrs usage, long-term archive	very limited	C.W. Clark

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
8.06	**Passive Acoustic Monitoring - cabled**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	All environments	Sample acoustic habitats to quantify spatio-temporal-spectral variability and detect occurrence and distribution of acoustically active marine animals	Noise statistics; species detection, spatio-temporal maps; animations tuned to species or groups, location, tracking	Seafloor, cabled hydrophone arrays	>$100K	ship	not	Real-time data, beamforming	expensive maintenance and repair, fixed location	decades	very limited	C.W. Clark
8.07	**Passive Acoustic Monitoring - moored with surface expression**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	Pelagic and benthic substrata, coastal	Reduce ship strikes and quantify acoustic impacts	Noise statistics, species detection	Moored with satellite links	>$100K	ship	ship	Near-real-time data for monitoring and mitigation, dual comms for reprogramming	expensive maintenance and repair, fixed location	years	very limited	C.W. Clark
8.08	**Autonomous glider**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	All environments	sample throughout ocean	oceanogrphic productivity variables and acoustics	passive glider that samples acoustics	>$25k	ship	ship	spatial sampling coupled with acoustics	glide, not active propulsion	many months	becoming more common	WHOI, SIO, UV Duke, Industry military
9	**Potential Future Technologies**													
9.01	**Portable Remote Imaging Spectrometer**	Phytoplankton, habitat-forming plants and macroinvertebrates: areal coverage and higher-taxon diversity	Benthic hard and soft substrata, shallow	Small imaging spectrometer intended to fly on a variety of airborne platforms. Optimized for coastal ocean science	Spectral analysis of shallow water benthic type and coastal vegetation type			Aircraft	Aircraft	Portable				NASA Ames Airborn Sensor Facility
9.02	**Next Generation Airborne Visible Infrared Imaging Spectrometer (AVIRISng)**	Habitat-forming plants and macroinvertebrates: areal coverage and higher-taxon diversity	Benthic hard and soft substrata, shallow	Designed to support NASA's research programs with measurements of upwelling spectral radiance in 224 contiguous spectral channels from 400 to 2500 nm.	Spectral analysis of shallow water benthic type and coastal vegetation type			Aircraft	Aircraft					NASA JPL
9.03	**Autonomous Acoustic Habitat Monitoring**	Sound-producing mammals, fishes, and other animals: diversity (and abundance?)	All environments	Sample acoustic habitats to quantify spatio-temporal-spectral variability and detect occurrence and distribution of acoustically active marine animals	Noise statistics, spatio-temporal maps and animations tuned to species or groups	Acoustic recorders w on-board auto-recognition, underwater comms to AUVs and surface buoys	$300-400/unit	Surface vessel or diver; attach to trees, bury in ground	Surface vessel or diver; detach, unbury					
9.04	**imaging AUVs for water column and benthos**													
9.05	**sample collection AUVs for microbial communities (sample return)**													
9.06	**ecogenomic sensors (real-time analyses + sample return)**													
9.07	**OOI/IOOS sustained observatories (e.g., ENDURANCE,NEPTUNE,MARS, VENUS)**	Hydrographic data, currents, DO, sound, Chlorophyll, seismic activity, nitrate, pH, pCO2	shelf, slope, vents, seeps	long term monitoring and research, ecosystem response to climate variability	video and still time series, experiments, acoustics all possible	NE Pacific Margin with nodes at 80 m, 150 m, 500 m, 3000 m; Juan de Fuca Plate	MEGABUCKS… 210M? (approved)	Permanent Nodes, attach instrumentation	ROV, Submersible	Infrastruture will be in place, with a host of continuous environmental variables measured.	High cost of placement and retrieval. Fouling possible	Unknown,	Limited regional access	
9.08	**DNA probes for invasive species (already used for Asian carp)**	All taxa	All environments											

	System/Program Name	Taxa Monitored	Environment	Purpose	Analyses	Description	Construction Cost	Deployment Method	Recovery Method	Pros	Cons	Employment Duration / Shelf Life of Materials Collected	Distribution of the Technique (How Widely Used?)	POC
9.09	**Autonomous Robot Swarms**	Macroinvertebrates and fishes: diversity and abundance. Environmenta parameters	Benthic soft and hard substrata, deep sea	To quantify long (or short)-term changes in deep-sea communities, abiotic environment, and ecosystem processes.	Spatial and temporal dynamics	An autonomous multiple robot system that can recharge while at sea and continue sampling and transmitting data to shore. Will allow us to sample at temporal and spatial scales that would provide novel insights into the functioning of deep-		Any ship transiting an area	Any ship transiting an area	Much less expensive than using existing technology (e.g. mounting repeated expeditions). Can be designed for a variety of different tasks. Can work at sea for extended	Still under development, actual costs and capabilities unknown.			
9.10	**Broadband acoustic scattering systems (up and coming)**	Mesozooplankton, micronekton, fishes: abundance (and diversity?)	Pelagic	Sample zooplankton/fish diversity, abundance, size		Active acoustic scattering systems capable of greater species discrimination than traditional narrowband multi-frequency systems	$150k	Towed from vessel, deployed autonomously (AUV, drifters, moorings)		High temporal sampling frequency, high range resolution to large range, improved species classification relative to	Provides only indirect measurements of zooplankton/fish			
9.11	**Stand-off optical systems (missing?)**	Mesozooplankton, micronekton, fishes: abundance (and diversity?)	Pelagic	Sample zooplankton/fish diversity, abundance, size		Image-forming optical system sampling at a distance far enough away from the instrument to minimize avoidance issues associated with current optical systems that	??	Towed from vessel, deployed autonomously (AUV, drifters, moorings)		Ability to sample larger animals currently not well sampled by most gears, especially micronekton				
9.12	**Next Generation Ocean Color satellites (ACE, HySPIRI, HICO, GEO-CAPE)**	Phytoplankton: abundance and higher-taxon diversity	Pelagic (deep, shallow), benthic hard and soft substrata (shallow)	Remote assessment of algal pigment stocks; rates of production; improved taxonomy	Bio-optical models	Satellites in appropriate orbit for monitoring coastal ocean or maximizing coverage of global	several hundred million dollars per satellite	Rocket	None	Greater spectral and spatial resolution allows for improved species ID and	Timeline uncertain, subject to funding	N/A	N/A	
9.13	**Wormcam**	Infaunal macroinvertebrates: diversity, abundance, activity	benthic soft substrata (shallow), possibly adaptable to other habitats	Designed to assess rates of bioturbation and other faunal activity.	Analysis of collected images.	Ethernet camera in an underwater housing in the shape of a sediment profile prism (Rhoads and Cande 1971) with water quality sensors. Connected to solar powered surface buoy that telemeters images	Housing ~$1,000. Plus off the shelf camera, electronics, buoy ~$7,000. Electronic tech labor ~$2,000	Surface vessel or diver	Surface vessel or diver	Near real-time insitu imaging of faunal responses to day to day variation in habitat and water quality. Relative low cost and off the shelf components.	Needs frequent maintenance in high fouling areas/seasons. Species identification limited to large fauna.	Days to months	Emerging techniques developed with NSF funding.	Robert Diaz, gc to and click on Wormca m: http://wv w.vims.(u/peopl(diaz_ri/i
9.14	**Ship board continuous flow cytometry**	Phytoplankton: higher-taxon diversity and abundance	Pelagic (epi)	Assess abundance and higher-taxon composition	analysis of optical data	Flow cytometer analyses organisms using the flow-through seawater system on-board a ship so spatial data is recovered.		ship	ship	Rela-time in situ analysis of phytoplankton composition	This method can't be used to detect species but can be used to detect classes of phytoplankton (e.g. dinos vs diatoms)	N/A	N/A	Ginger Armbrus
9.15	**In-situ microscope**	Microorganisms, including phyto- and microzooplankton: diversity and abundance	All environments	to determine size spectra of microbes, to assign phytoplankton to taxa	standard imaging processing methods	on chip microscopes are just starting to emerge. One for in-situ studies that could be put on a mobile platform that would accomplish in-situ studies w/o requiring	initial: $100k, in large batches, $1-5k	any underwater platform	vehicle recovery	potential high resolution spatial and temporal sampling with multiple systems	extensive digital processing			
9.16	**Underwater bathymetric lidar imaging systems**	Habitat-forming plants and macroinvertebrates: areal coverage	Benthic substrata, shallow	to obtain high resolution (~cm) of the sea floor incl topography (~10 cm res)	image and signal processing techniques	bathymetric lidars can be used to construct high res optical images of regions that containt both reflectance and depth data	$1M-$2M	towed, AUV, ROV	either ship based or land based (AUV from shore)	high resolution optical images have great utility for identifying many benthic features. The addition of sea floor topography lends a quantitative element to placing	expensive, lots of data			

APPENDIX 5. MAJOR HABITAT AND TAXA DIVISIONS TO BE OBSERVED

Benthic (Biogenic, Hard Bottom and Soft Bottom)

- Sessile Macrobiota
- Demersal Fauna
- Epibiota
- Cryptobiota
- Infauna
- Meiofauna
- Microbes (Bacteria, Archea, Protista, and Viruses)

Pelagic

- Microbes (Bacteria, Archea, Protista, and Viruses)
- Phytoplankton
- Protozoa
- Macrozooplankton
- Mesoplankton
- Gelatinous Zooplankton
- Marine Fish
- Marine Birds
- Marine Mammals
- Marine Turtles
- Squid