Project Number: 901700

Project Start: Jan. 1, **2017**[1] **Project Duration (in years):** **3 years**

Please indicate if proposal includes requests for any of the following (mark all that apply).

X	X	X		
Ship Time	**ROV**	**AUV**	**Wave Glider**	**Mini ROV**

Please indicate what type of project is being proposed (mark only one).

		X		
Feasibility/Scoping [Less than 100 days effort]	**Development**[2]	**Research**	**Infrastructure**[2]	**Education**
	Time Series	**Institute Initiative**		

Project Manager[3]: Chad Waluk

Principal Investigator: Kelly Benoit-Bird

Lead Scientist: Kelly Benoit-Bird

Lead Engineer: Chad Waluk

Project Title: Acoustical Ocean Ecology

[1] This date and number should remain the same for the duration of the project. If your project start date for 2016 is not January 1, please indicate the start date in the first cell of the milestone chart. Format for duration example: “Year 2 of 5”.
[2] Development and infrastructure projects must complete the risk matrix (see item #5 at the end of the proposal form).
[3] Not all projects will require all four titles to be filled in. Please indicate individuals only for those titles that are appropriate for your project.

1) ABSTRACT (new projects only)

Patchiness, or the spatial variability in biomass at relatively small scales, is a key feature driving animal behavior, biogeochemical cycles, trophodynamics, and ecosystem structure. To address the role of heterogeneity in ecosystems, this research will focus on simultaneously addressing three challenges: 1) the development of methods and approaches for quantifying patterns in the biota and 2) identifying the processes underlying observed patterns, and 3) understanding the consequences of biotic patterns on ecosystem processes.

Spatial structure of midwater biota
There is a long-held view that the volume beyond the ocean's photic zone as largely homogenous, both physically and biologically, in the horizontal plane. Yet, visual observations, primarily from MBARI's ROV program, have revealed that mid-depth waters have an incredibly diverse array of animals and particles that are quite active and highly spatially structured at small scales and acoustic surveys from AUVs at depth have revealed significant variation in the distribution of animals at scales from hundreds of meters to tens of kilometers. We seek to take advantage of both of these approaches, leveraging MBARI's longstanding investments in technology and expertise in midwater. We propose to deploy a broadband echosounder with two transducers to cover frequencies extending from 50 to 150 kHz on Ventana in collaboration with the midwater ecology group. The acoustic system will be oriented forwards, paralleling a high-resolution camera to allow overlapping fields of view close to the ROV. These unprecedented in situ acoustical-optical measurements will greatly aid interpretation of other acoustic data, quantify the avoidance or attraction of animals relative to the survey platform, and provide a quantitative view of the spatial distribution of organisms in midwater to address at what scales animals are aggregated, if those aggregations are organized by taxonomy size or other features, and what role variation in the habitat plays in structuring the biota.

Forage species aggregation in Monterey Bay
Recent work has shown that the fine-scale spatial distribution of prey is critical to how predators perceive the suitability of their food supply and the mechanisms they use to exploit it. However, our understanding of the biological and physical drivers of the aggregation of forage species remains limited. Using vessel-based (Paragon and/or other small vessel) acoustic sampling, profiled cameras, underway CTD measurements, and remote sensing, we will begin to unravel how krill respond to topography and intra-seasonal variation in upwelling (Collaborators: Ryan and Figurski). Quantifying these driving forces is critical for predicting the state of the ecosystem, understanding predator-prey dynamics, and following the fate of carbon. This basic research will allow us to further our aims of further developing acoustic measurements and classification approaches and will provide an important base for future research with other platforms and directly ties to the larger scale studies being undertaken by Chavez and others

One key component of aggregation formation is the attraction of animals to others (e.g., schooling and swarming). The characteristics of the aggregations themselves have provided considerable information on the proximate and ultimate factors driving these social aggregations, particularly in laboratory studies. Making measurements of the shape, internal distribution, and movement of aggregations in situ is considerably more challenging. We seek to further the development of the Dorado mapping AUV for water column applications (Collaborators Caress and Thomas). We will deploy the AUV in areas

identified to have aggregations of forage species to measure their shape characteristics and internal organization and how these features change with environmental influences identified to be important from ship-based studies and when under attack from predators like seabirds and marine mammals. In addition to providing key new information on forage species behavior, this study is a good test case for biotic sampling with the mapping AUV which other researchers hope to exploit in more challenging arenas including the deep sea (Smith) and demersal habitats (Hobson).

2) PROPOSAL

a) New Projects

Statement of the problem, why it is important

Understanding the relative roles of the biological and physical factors that control populations and communities is the central challenge in ecology and a focus of many of the research programs undertaken by MBARI. While some researchers have argued that heterogeneity must be considered in assessing the relative roles of ecological forces, a widespread and fundamental ecosystem characteristic, patchiness, or the spatial variability in biomass at relatively small scales, has been difficult to incorporate in studies of these controls. Two reasons underlying this challenge in the ocean are 1) the difficulties in sampling at appropriate scales to quantify these patterns across a wide range of taxa and 2) the development of a mechanistic understanding of why and how these patterns occur. Yet, because patches of organisms, or 'hotspots', have ecosystem impacts disproportionate to the biomass of organisms within them, addressing this challenge is *critical* for understanding animal behavior, biogeochemical cycles, trophodynamics, and ecosystem structure.

How does it relate/contribute to MBARI's mission and strategic plan?

Marine ecosystems are complex, driven by processes that are patchy, dynamic, and ephemeral. Gaining insight into how our world works requires sampling tools capable of sampling at the appropriate scales across a wide range of taxa and, in many cases, radically different approaches to deployment in the sea, requirements that can best be met with MBARI's unique capabilities. The proposed research will address several themes of the MBARI strategic plan including exploring the deep sea as well as providing new ways to visualize the variability in the abundance, distribution, and activity of biota in the water column by leveraging and building upon existing MBARI investments in order to enhance understanding of the fluctuations and fate of forage species from the surface to the upper bathypelagic and the populations of larger marine animals for whom they are a primary food source.

How does it relate/contribute to the Packard Foundation's Ocean Visions Grantmaking policies?

(See http://mww.mbari.org/oed/OED_Documents.htm#Packard for documents.)

The basic research proposed is aimed at understanding the general rules that underlie how ocean ecosystems function, using the west coast as a testing ground for describing globally important phenomena. This directly matches one of the five Packard Foundation Ocean Vision strategies to focus on "basic research to understand the functioning of ocean ecosystems". One aspect of this work is specifically aimed at addressing how marine birds, a key focus of the Foundation's10-year plan, and other top predators are affected by ocean ecosystem structure which will allow appropriate mitigation pathways and conservation strategies to be identified, influencing a second strategy in the plan.

Does it relate to the Technology Roadmap? If so, please describe how.
(See http://mww.mbari.org/oed/TechnologyRoadmap.pdf.)
This research is aimed at understanding ecosystem processes, specifically aligning with the Technology Roadmap goal of enhancing "understanding of the fluctuations and fate of forage species" as well as the populations of larger animals for which they serve as food. The acoustic tools and approaches developed and advanced through this work allow new ways to visualize life in the ocean, fitting the Technology Roadmap focus to "relate water-column conditions and variability to the abundance, distribution, and activity of biota."

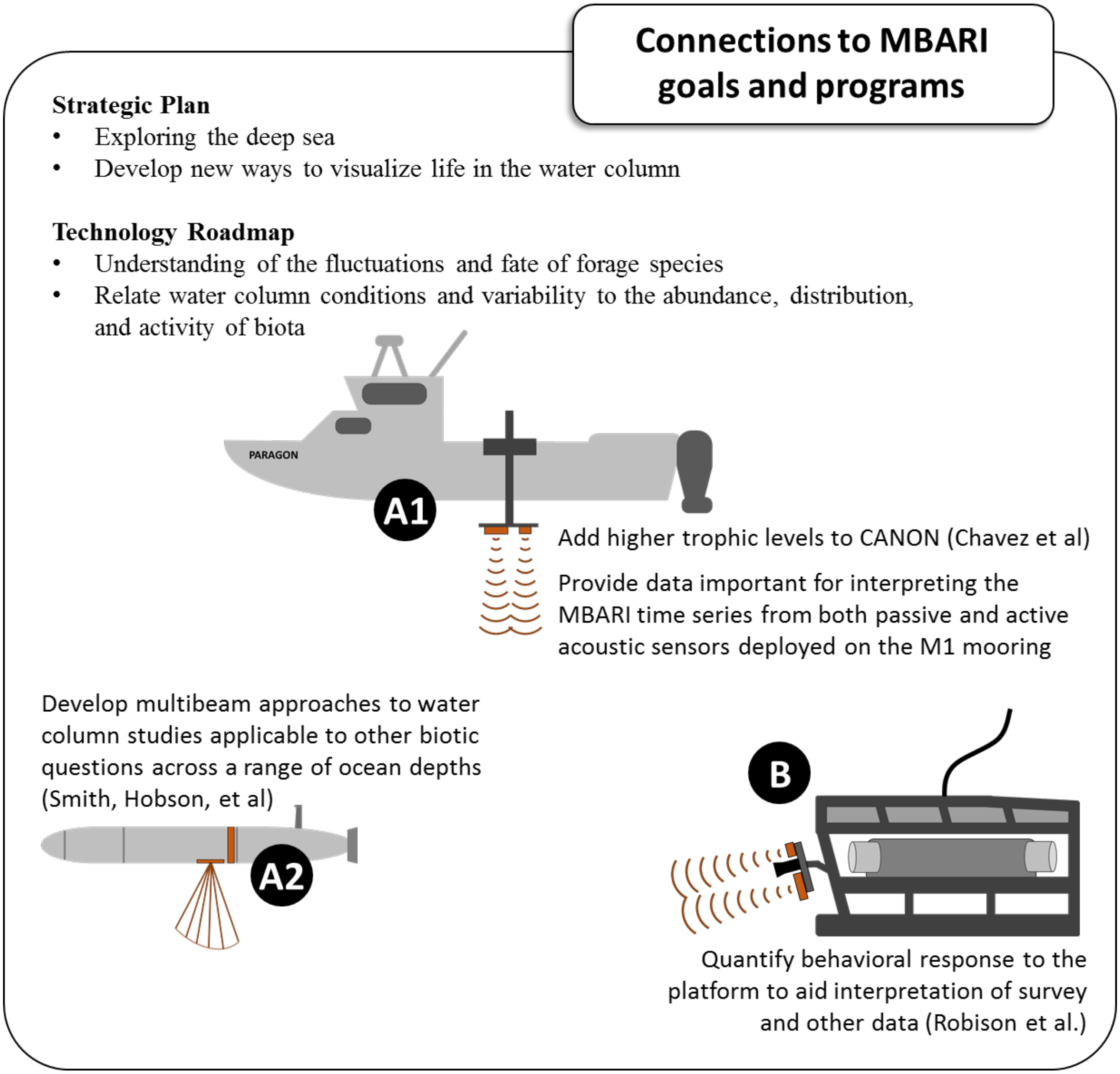


Figure 1. *Connections of the proposed Ocean Ecological Acoustics program to other activities at MBARI.*

Approach to the problem

To address the role of heterogeneity in ecosystems, this research will (A1) use ship-based sampling to address when and where animals form groups and how these groups affect the ecosystem. This sampling will be complemented by (A2) AUV based 3-dimensional mapping of the internal organization of animal groups to address why and how groups are formed. In order to understand how hotspots shape life in the ocean, we (B) seek to extend our growing understanding of the role of spatial variability to midwater using ROVs to provide an entirely new view on these understudied regions.

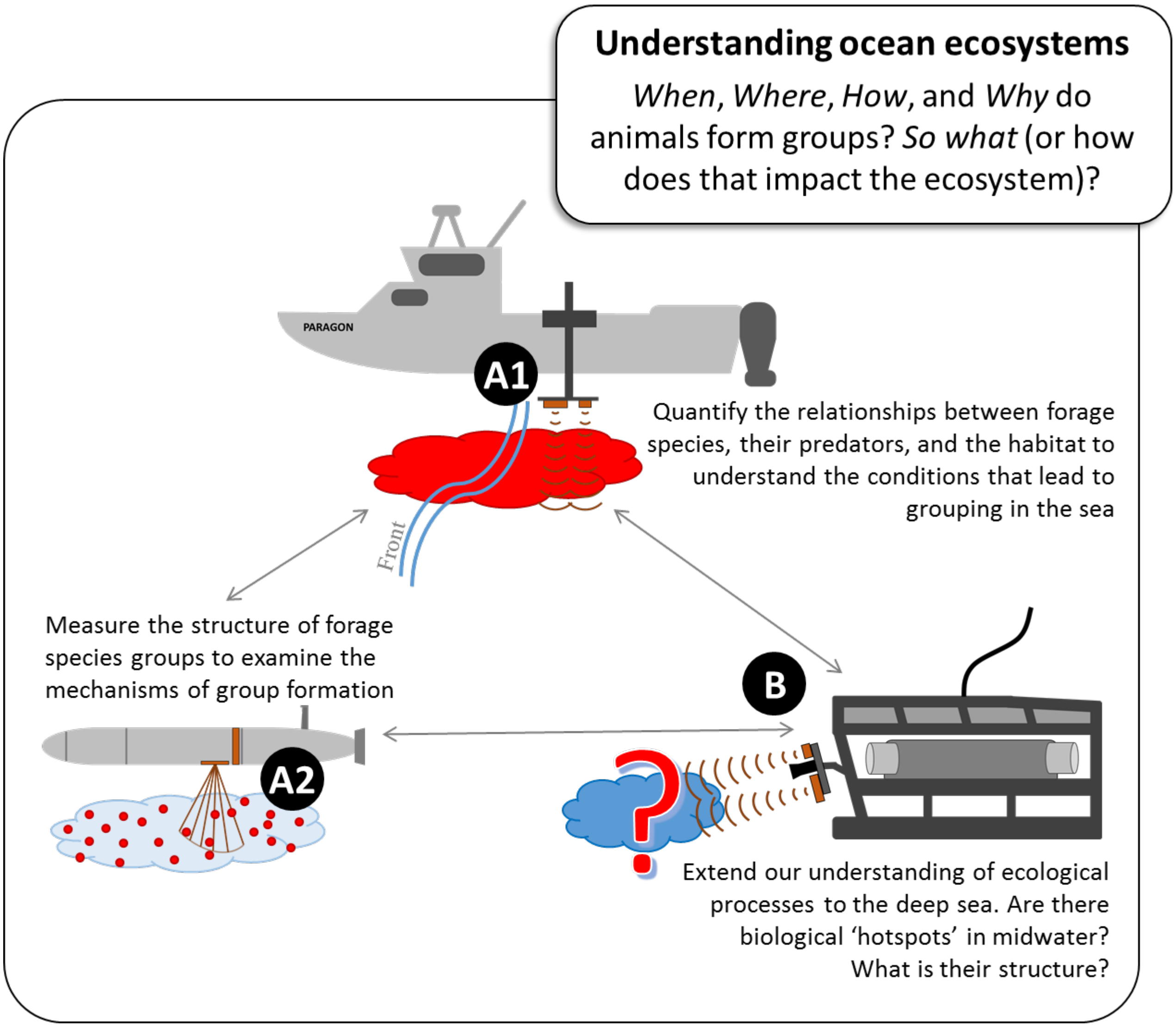


Figure 2. *A conceptual overview of the ecological questions posed in this work, foci shown in red, the general approach to addressing them using acoustics and other tools, and the inter-relationships of the questions and methods.*

This work will use a combination of traditional and novel platforms to carry cutting edge acoustic tools, pushing these tools to add new dimensions to our measurements of life in the water column including adding a third dimension with multibeam sonar, taxonomic specificity through integration of acoustics and imaging, and 'acoustic color' through broadband measurements.

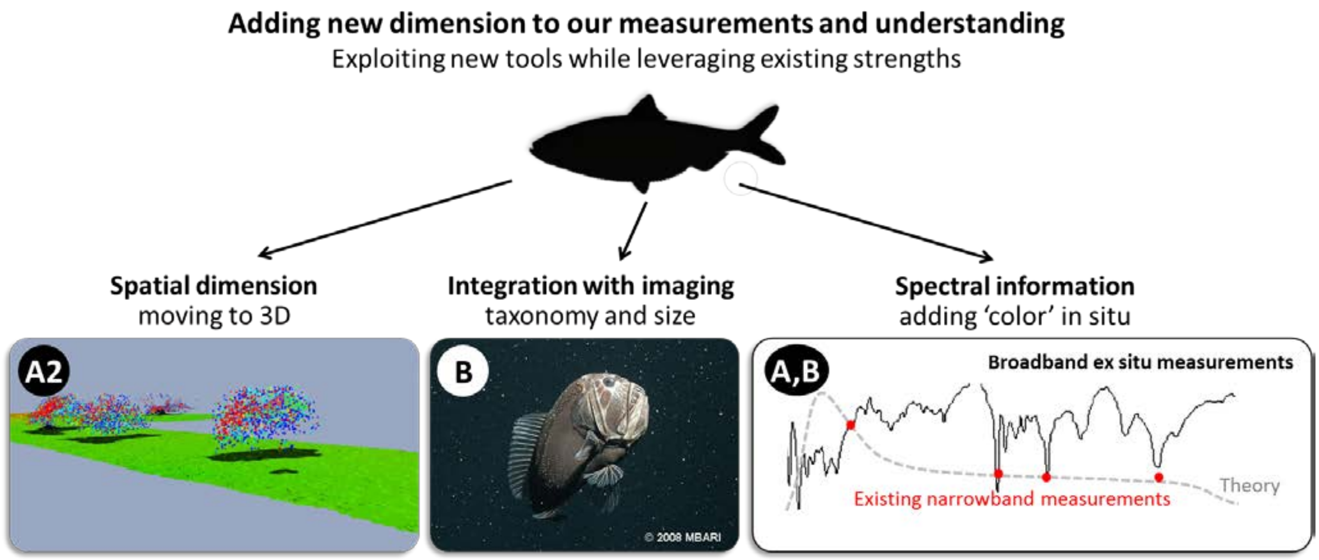


Figure 3. *To increase our ecological understanding, we propose to add new dimensions to acoustic measurements including (A2) spatial dimensions, (B) taxonomic information, and (A and B) 'color'.* The right hand panel shows available data in red, modeled data in grey, and the first broadband data in black. The opportunity to collect these data in situ with accompanying imaging will address a number of longstanding questions in acoustics and provide new opportunities in data analysis.

The new measurements just beginning to be provided by broadband sonars and multibeam systems are shedding light on long standing problems of acoustic models of life. These models, based on simplistic physical analogs, do not capture the complexities present in biological targets, either as individuals or as groups.

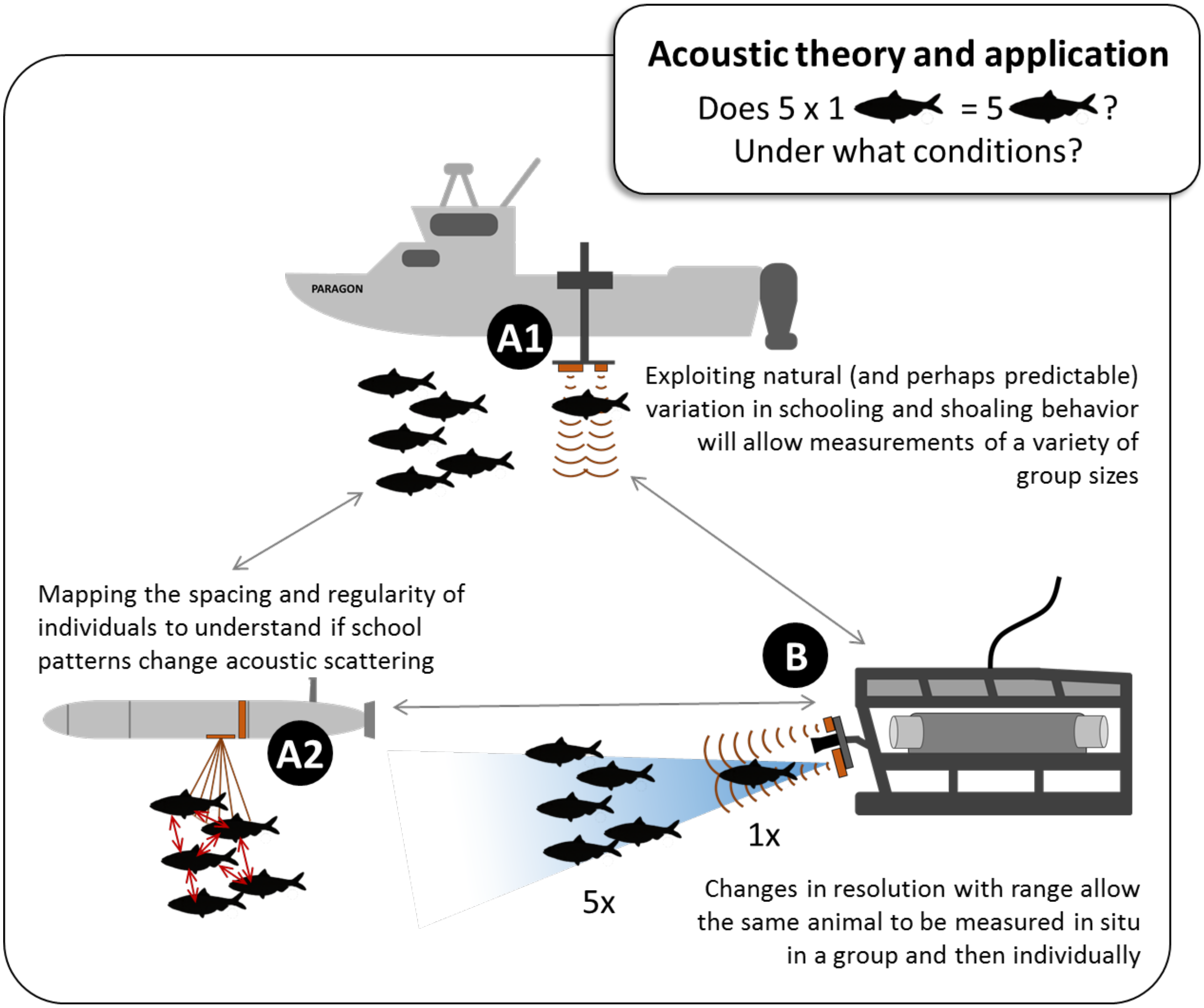


Figure 4. *One significant aspect of acoustic theory that remains unaddressed is the relationship between individual and multiple scattering. This idea is critical to our interpretation of biomass and we have considerable data that challenges the current assumptions, yet the linearity theorem (where 5 × X = 5X) has remained largely untested. The integrated approach proposed here will provide the data necessary to fully explore the limits of linearity and explore the opportunities provided by the data for biological understanding.*

We seek to address these problems in ways only possible at MBARI, using a range of platforms to observe animals in situ from a variety of perspectives. These will be amongst the first in situ measurements of untethered animals, providing an incredible opportunity to reconcile what we think we know about the physics and how it is applied with the measurements obtained from individual animals and groups. This will also expand our ability to understand ecological processes as we learn to apply acoustic tools in increasingly sophisticated ways, improving our classification algorithms for ascribing acoustic data to groups (taxonomic or otherwise) of interest, our ability to separate individual targets for measurements of acoustic length, and the description of group characteristics that may also contribute to identification. Of course, this kind of progress does not come without risk. Our research approach manages that risk through the careful choice of sensors that can be compared directly across platforms and a field research program that utilizes operations on small boats as an opportunity for technology testing of these new generation instruments where risk and costs are relatively low and human observation can facilitate deeper understanding of the instrument performance and the resulting data.

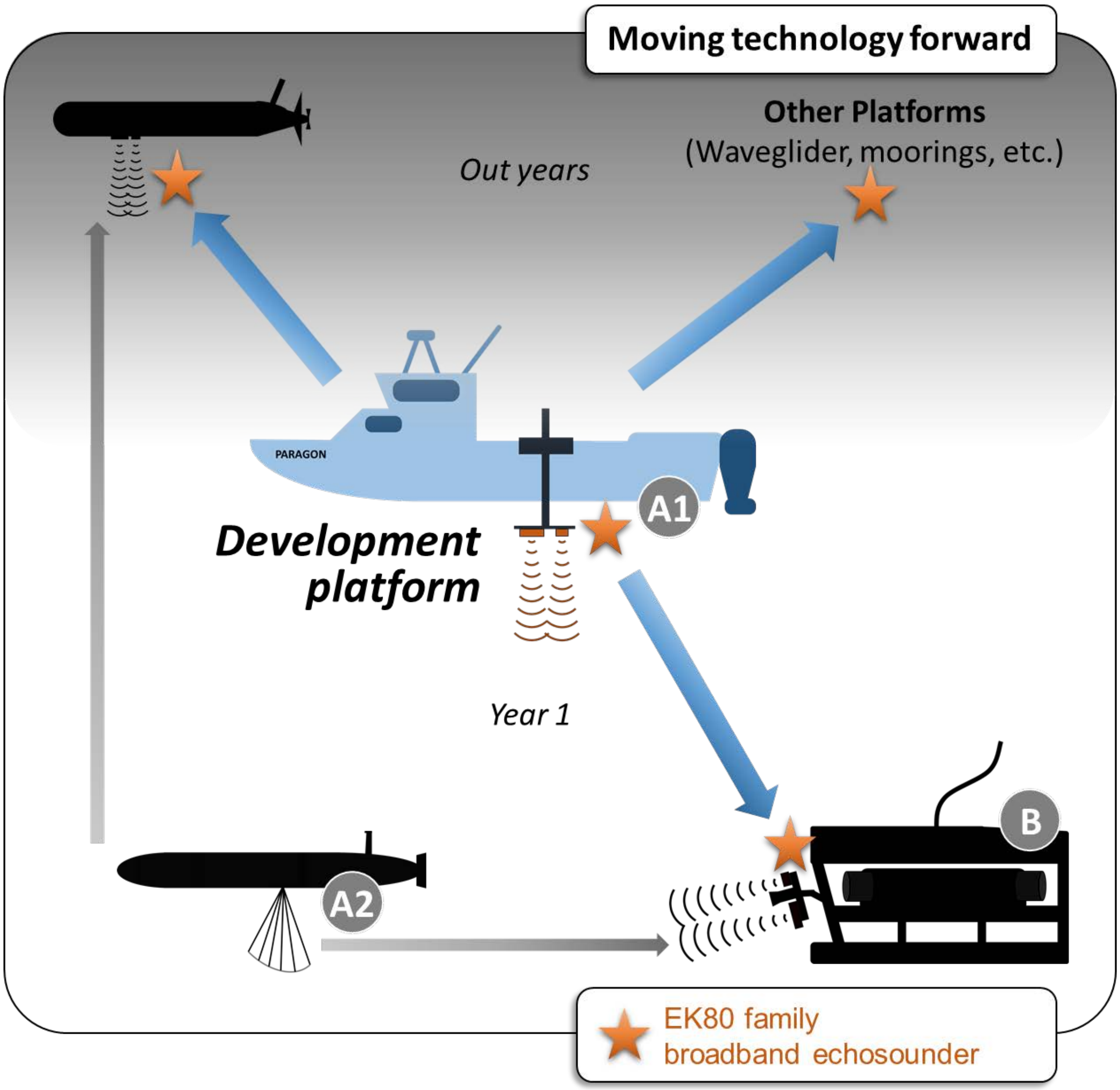


Figure 5. *The research plan proposed for the next 3 years takes a calculated approach to the application of new acoustic technologies while laying the groundwork for future endeavors integrating with other science and engineering groups MBARI. All instruments identified by orange stars can be directly compared, facilitating both careful development and later, a fully integrated field program. The mapping AUV provides the opportunity to develop 3D water column acoustics that will later be ported to the ROV for other programs and a testbed for using AUVs as acoustic platforms*

A. Forage species aggregation in Monterey Bay

A1. Where, when, and why do animals school and swarm?

Recent work has shown that the fine-scale spatial distribution of prey is critical to how predators perceive the suitability of their food supply and the mechanisms they use to exploit it. For many krill predators, for example, the energetic costs of foraging exceed their gains unless the krill are swarming. However, our understanding of the biological and physical drivers of the aggregation of forage species remains limited. In collaboration with John Ryan and Jared Figurski, we will quantify where and when krill swarms and fish schools in Monterey Bay are found. Using vessel-based (Paragon and/or other small vessel) acoustic sampling (bioacoustics and an ADCP), profiled cameras, underway CTD measurements, and remote sensing, we will begin to unravel how krill respond to topography and intra-seasonal variation in upwelling. Quantifying these driving forces is critical for predicting the state of the ecosystem, understanding predator-prey dynamics, and following the fate of carbon. This basic research will allow us to further our aims of further developing acoustic measurements and classification approaches and will provide an important base for future research with other platforms (e.g., the LRAUV and mapping AUV). It directly ties to the larger scale studies being undertaken by Chavez and others in the epipelagic and will provide data important for interpreting the MBARI time series from both passive and active acoustic sensors deployed on the M1 mooring.

A2. How are swarms organized?

One key component of aggregation formation is the attraction of animals to others (e.g., schooling and swarming). The characteristics of the aggregations themselves have provided considerable information on the proximate and ultimate factors driving these social aggregations, particularly in laboratory studies. Making measurements of the shape, internal distribution, and movement of aggregations in situ is considerably more challenging. Multibeam sonar systems, applied to 'mapping' the water column, are increasingly being used with great success to address questions about animal groups in the ocean. In collaboration with Caress and Thomas, we seek to further the development of the Dorado mapping AUV for water column applications. We will deploy the AUV in areas identified to have aggregations of forage species to measure their shape characteristics and internal organization and how these features change with environmental influences identified to be important from ship-based studies and when under attack from predators like seabirds and marine mammals. In addition to providing key new information on forage species behavior, this study is a good test case for biotic sampling with the mapping AUV which other researchers hope to exploit in more challenging arenas including the deep sea (Smith) and demersal habitats (Hobson).

B. Spatial structure of midwater biota

The challenges of studying the immense, dark, and traditionally inaccessible midwater zone mean many relevant aspects of its biology largely unexplored.There is a long-held view that the volume beyond the ocean's photic zone as largely homogenous, both physically and biologically, in the horizontal plane. Yet, visual observations, primarily from MBARI's ROV program, have revealed that mid-depth waters have an incredibly diverse array of animals and particles that are quite active and highly spatially structured at small scales and our acoustic surveys from AUVs at depth have revealed significant variation in the distribution of animals at scales from hundreds of meters to tens of kilometers. We seek to take advantage of both of these approaches, leveraging MBARI's longstanding investments in technology and expertise in midwater. We propose to deploy a broadband echosounder with two transducers to cover frequencies extending from 50 to 150 kHz on Ventana in collaboration with the midwater ecology group. The acoustic system will be oriented forwards, paralleling a high-resolution camera. The camera and the acoustic system will have overlapping fields of view close to the ROV, providing the opportunity to identify individual organisms and their orientation relative to the sonar beam, resulting in unprecedented in situ acoustical-optical measurements which will greatly aid interpretation of other acoustic data. The acoustic data, however, will have much greater range than the imaging systems on the ROV, providing the distribution of organisms out to a range of hundreds of meters. When deployed as part of the regular, ongoing midwater time series surveys, this information will make it possible to quantify the avoidance or attraction of animals relative to the survey platform. Most importantly, these data will provide a quantitative view of the spatial distribution of organisms in midwater to address at what scales animals are aggregated, if those aggregations are organized by taxonomy size or other features, and what role variation in the habitat plays in structuring the biota.

C. Scaling up and moving forward

Scaling up from the focused, process based studies proposed in the first years of this project will require a persistent presence. We propose to integrate with the time series programs currently undertaken by Chavez and Robison to understand the seasonal and interannual variation in both the biomass and distribution of forage species (including those in midwater) and their predators in order to make predictions about the fate of life in a changing ocean. Two key platforms for this effort will be the Long Range AUV and the Waveglider which, from an acoustic perspective, provide very different strengths and opportunities. Continuing from our first year work, we seek to develop an acoustic payload that could be adapted to either platform. It will be based on an EK80 family, 4-channel broadband echosounder. These four channels allow up to four frequency bands to be employed simultaneously or for a multi-channel system that allows target tracking. Integration of an acoustic system capable of applications ranging from copepods to fish to marine mammals will facilitate a range of applications. For example, exploiting the buoyancy engine in the LRAUV coupled with high-frequency acoustic sensors will permit tracking of the evolution and fate of zooplankton patches at close range as they respond to upwelling and are mixed or migrate out of the photic zone. Utilizing lower frequency transducers on the Waveglider would allow us to survey schools of sardines and anchovies and examine the behavioral responses to the environment that can determine the success of the local fishery and the drivers of the fluctuations of their biomass with climate. The ability for the Waveglider to carry large, low frequency transducers would also make it an excellent tool for observing the variation in midwater layers for processes ranging from diel migration to changes in biomass due to climatic variability, a critical process that has not been possible to quantify with existing approaches.

In year 3 of the project, integration of the acoustic payload is planned with the Waveglider along with test deployments. Ongoing developments in communication and power within the towbody will facilitate the integration of acoustics, allowing a very stable platform for the transducers within the towbody. In year 2 of the project, we propose to begin the development of an acoustic payload and test integration with existing LRAUVs. Test deployments of the LRAUV in year 3, alongside ongoing field efforts for proposal goals A&B, will precede consistent deployments of a specialized LRAUV which would be completed by the end of 2019. The acoustic LRAUV would provide the opportunity for further connection of the time series of Robison (which will begin to integrate acoustics in 2017) and Chavez. As a platform for process studies, we will collaborate with Hobson and Zhang to exploit the new capabilities of the LRAUV backseat driver to develop autonomous tracking of biological targets and autonomous decision making based on the input from the acoustic payload and other sensors.

Alternative AUV platforms have been considered (e.g. Remus 100) but the cost (~$700k for the base configuration) and long delivery timetable (currently >2 years for science applications) along with the challenges of instrument integration with a commercial, outside entity counted by the LRAUV's long endurance, buoyancy maintenance capabilities, and in house knowledge for integration and deployment make the LRAUV a far superior choice.

Publications (from other projects over the last 5 years)

Benoit-Bird, K.J. & McManus, M.A. 2012 "Bottom-up regulation of a pelagic community through spatial aggregations" Biology Letters, 8: 813-816.

Benoit-Bird, K.J. & Gilly, W.F. 2012 "Coordinated nocturnal behavior of foraging jumbo squid, *Dosidicus gigas*" Marine Ecology Progress Series, 455:211-228.

McManus, M.A., Sevadjian, J.C., Benoit-Bird, K.J., Cheriton, O.M., Timmerman, A.V., & Waluk, C.M. 2012 "Observations of Thin Layers in Coastal Hawaiian Waters" Estuaries and Coasts, 35:1119-1127.

Sevadjian, J.C., McManus, M.A., Benoit-Bird, K.J., & Selph, K.E. 2012 " Shoreward advection of phytoplankton and vertical re-distribution of zooplankton by episodic near-bottom water pulses on an insular shelf: Oahu, Hawaii" Continental Shelf Research, 50-51:1-15

Benoit-Bird, K.J., Battaile, B.C., Heppell, S.A., Hoover, B., Irons, D., Jones, N., Kuletz, K.J., Nordstrom, C.A., Paredes, R.A., Suryan, R.M., Waluk, C.M.,. & Trites, A.W. 2013 "Prey patch patterns predict habitat use by top marine predators with diverse foraging strategies." PLoS ONE, DOI 10.1371/journal.pone.0053348.

Benoit-Bird, K.J., Battaile, B.C, Nordstrom, C.A., & Trites, A.W. 2013 "Foraging behavior of northern fur seals closely matches the hierarchical patch scales of prey." Marine Ecology Progress Series, 479: 283-302

*Kaltenberg, A.M** & Benoit-Bird, K.J. 2013 "Intra-patch size clustering in mysid aggregations revealed through multi-frequency acoustics." ICES Journal of Marine Science, 70:883-891.

Nordstrom, C.A., Battaile, B.C., Benoit-Bird, K. J., & Trites, A.W. "Northern fur seals augment ship-derived ocean temperatures with higher temporal and spatial resolution data in the eastern Bering Sea", Deep-Sea Research II, 94:257-273

Hoving, H.J., Gilly, W.F., Markaida, U, West-Brown, Z., Daniel, P., Campos, B., Benoit-Bird, K.J., and Li, B. 2013 "Extreme plasticity in life-history strategy of jumbo squid (*Dosidicus gigas*) allows a migratory predator to cope with El Niño." Global Change Biology, 19:2089-2103.

Benoit-Bird, K.J., *McIntosh, N.M.**, & Heppell, S.A. 2013 "Nested scales of spatial heterogeneity of juvenile walleye pollock (*Theragra chalcogramma*) in the southeastern Bering Sea." Marine Ecology Progress Series, 479:283-302.

Benoit-Bird, K.J., Shroyer, E.L, & McManus, M.A. 2013 "A critical scale in plankton aggregations across coastal ecosystems" Geophysical Research Letters, 40:3968–3974.

Paredes, R., Orben, R.A., Irons, D.B, Roby, D.D., Harding, A.M.A, Young, R.C., Benoit-Bird, K.J., Ladd, C, Renner, C., Heppell, S., Phillips, R.A., Kitaysky, A. 2014 "Foraging responses of black-legged kittiwakes to prolonged food-shortages around colonies in the Bering Sea Shelf" PLoS ONE, DOI: 10.1371/journal.pone.0092520

Benoit-Bird, K.J., McManus, M.A. 2014 "A critical time window for organismal interactions in a pelagic ecosystem" PLoS ONE, 9(5): e97763. doi:10.1371/journal.pone.0097763

Shroyer, E.L, Benoit-Bird, K.J., Nash, J.D., & Moum, J.M. 2014 "Stratification and mixing regimes in biological thin layers over the Mid-Atlantic bight" Limnology and Oceanography, 59(4), 1349–1363

*Cade, D.E.** & Benoit-Bird, K.J. 2014 "An automatic and quantitative approach to the detection and tracking of acoustic scattering layers" Limnology and Oceanography Methods, 12:742-756.

*Cade, D.E.** & Benoit-Bird, K.J. 2015 "Depths, migration rates and environmental associations of acoustic scattering layers in the Gulf of California" Deep Sea Research, 102:78-89.

Moline, M.A., Benoit-Bird, K.J., Robbins, I.C. & O'Gorman, D. 2015 "Integration of scientific echosounders with a dynamically adaptable autonomous platform to extend our understanding of animals from the surface to the bathypelagic". Journal of Oceanic and Atmospheric Technology, 32:2173-2186

Benoit-Bird, K.J. & Lawson, G.L. 2016 "Ecological insights from pelagic systems acquired using active acoustic techniques" Annual Reviews of Marine Science, 2016.8:463-490.

Moline, M.A. & Benoit-Bird, K.J. 2016 "Sensor Fusion and Autonomy as a Powerful Combination for Biological Assessment in the Marine Environment" Robotics, 5: doi: 10.3390/robotics5010004.

Benoit-Bird, K.J., Southall, B., & Moline, M.A. 2016 "Predator guided sampling reveals biotic structure in the bathypelagic" Proceedings of the Royal Society of London B, 283: 20152457.

Southall, B., Benoit-Bird, K.J, Moline, M.A., & Moretti, D. "Deep-water biological heterogeneity affects beaked whale foraging energetics" In review.

Benoit-Bird, K.J. & Moline, M.A., "Schooling within sound scattering layers in the ocean" In review.

Benoit-Bird, K.J., Southall, B.L, Moline, M.A., Arranz, P., Tyack, P. "Predator-prey dynamics in the mesopelagic: odontocete foraging ecology and anti-predator behavior of prey" In review.

b) Continuing Projects

If the proposed project includes multiple individual projects, please list each of these projects as a subheading in the proposal. For each subheading, please address the following:

Current status of project and results to date

[Click here to enter text]

Significant changes from previous project proposal

[Click here to enter text]

Publications based on the results of this project only

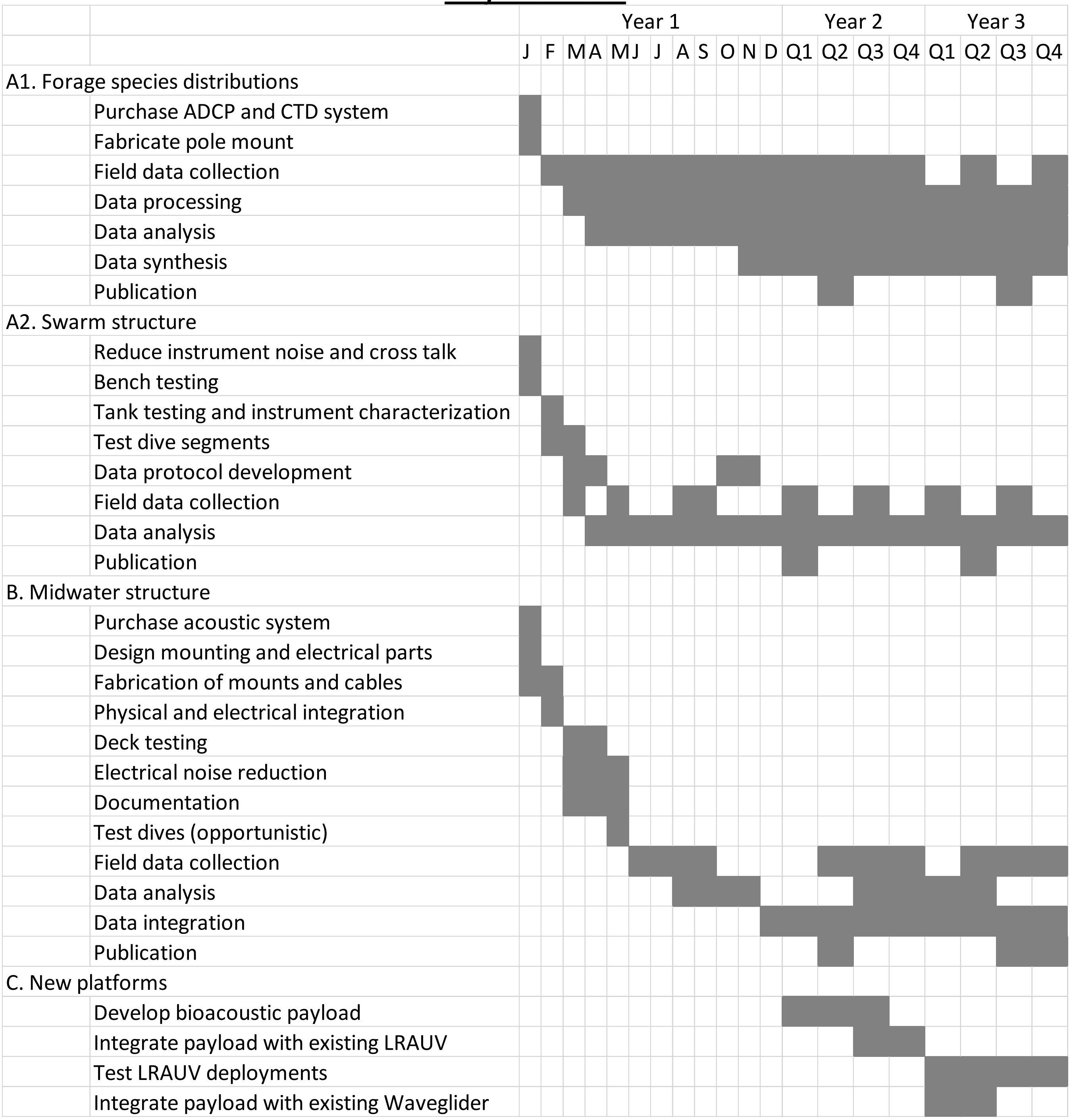
[Click here to enter text]

c) New and Continuing Projects: Plans for 2017

Overview and priorities

A complete look at the proposed project is included as a timeline. The project takes an integrated approach to addressing key ecological questions, developing and exploiting new technologies, and furthering acoustic theory and analysis while leveraging existing MBARI investments, both technical and in human resources. The vessel based activities from the Paragon are central to all efforts, serving as a baseline both technically and scientifically and are thus the first priority for 2017. To make progress on the longstanding goal of effectively integrating acoustics and imaging, an approach that will apply to many other efforts, the midwater structure work is priority 2. Priority 3 is furthering and exploiting the water column capabilities of the mapping AUV. This work has considerable impact on other groups at MBARI who are attempting to use multibeams in the water column, however, and has already begun in collaboration with Smith, Thomas, et al so it is timely to move this item forward in 2017. Finally, laying the groundwork for future efforts and integration with ongoing time series will follow, with efforts beginning in 2018.

Project Timeline



Research Activities

Research activities will focus on the collection of field data from aggregations both in the epi and meso-pelagic from the Paragon, the mapping AUV, and Ventana.

Engineering/technology development

Engineering and technology development in 2017 will include integration of a new acoustic sensor onto Ventana and continuing development of the water column multibeam capabilities of the mapping AUV. In addition, our group will work to refine the capabilities of broadband echosounders more generally, including the development of new data analysis protocols.

Field programs (detail ship requirements/deployments/diver requirements)

A1. Forage species distributions

We request 20 days for field efforts on the R/V Paragon, spread throughout the year. The surveys conducted from the Paragon will provide key data on the distribution of forage species and the mechanisms driving these patterns. This understanding will provide context and inform deployments of the mapping AUV which will examine these forage swarms in higher resolution but at a smaller scale. The Paragon will also serve as a testbed for the instruments deployed on the ROV, allowing testing not possible in a tank and aiding in the interpretation of the new broadband data collected from all platforms.

A2. Swarm structure

To test the data capabilities of the mapping AUV in the water column, we will piggy back water column efforts on other missions, utilizing the ascent and descent to acquire data with a variety of settings. To explore the internal structure of swarms, we request 7 dedicated dives spread throughout the year. Because of the extensive check-out procedure required for the mapping AUV and the new challenges posed by the configuration changes necessitated by water column sampling, we request these launches and recoveries by conducted by the R/V Rachel Carson. Based on preliminary observations of krill and forage fish in the Bay, these deployments are likely to occur near the edges of the Canyon and, if locations are compatible, could be combined with deployments of the second mapping AUV.

B. Midwater structure

During 2017, we request a total of 5 dedicated, 10-hr science days with the Rachel Carson and Ventana to work within Monterey Bay. In addition, the acoustic system will ride along on cruises mounted by the Midwater Ecology group when it does not interfere with other operations.

Isotope Usage

Project teams must provide details regarding any planned isotope use on shore, on ships, in the Sanctuary, etc. Please review the guidance on isotope usage at http://www.mbari.org/at-sea/cruise-planning/hazardous-materials/ and policy at http://mww.mbari.org/safety/SafetyManual/Isotope_Use_Policy.pdf, and then provide details on plans below.

N/A

Specific deliverables

A1. Forage species distributions
Hardware and protocols for collection of acoustic data from the Paragon will be developed. Survey data will be processed (noise removed, seafloor detected and marked, integration bins defined, regions of interest flagged, geographic data corrected, etc.) and preliminary analysis will be compelte.

A2. Swarm structure
The noise floor on the multibeam sonar will be significantly reduced, allowing scattering >-70 dB to be measured from 1-50m. The instrument will be fully characterized and a primary data analysis protocol will be developed that can be shared across water column applications.

B. Midwater structure
The EK80 echosounder will be fully integrated into Ventana and the noise floor will be low enough to allow measurements of backscatter >-70 dB at 100 m across the full spectrum. First measurements will be available to characterize the performance of the instrument and data quality and preliminary analysis will be completed to examine the degree of target organization and behavioral impacts of the vehicle, permitting focused experiments to be planned for the second year of the project.

Milestones (see personnel classification list)

2017 Project Start Date: 01/01/2017	**Milestone 1**	**Milestone 2**	**Milestone 3**	**Milestone 4**	**Milestone 5**	**Total Resources**[4] for each resource category for all milestones listed here
Milestone Date	**1/31/17**	**2/28/17**	**3/1; 5/1; 8/1; 9/1/17**	**5/17**	**8/17-12/17**	
Milestone Description	**A1. Acoustic mount fabrication**	**A2. Multibeam noise reduction**	**A2. Water column multibeam data collection**	**B. Ventana acoustic integration**	**B. Ventana acoustic data collection**	
EE				**100**		**100**
SE		**57**	**20**			**77**
ME						
EE Tech				**20**		**20**
SE Tech						

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

ME Tech	**30**			**20**		**50**
Machine Shop						
Divers						

Budget justification

Echoview site license fees are requested to support all acoustic data analysis ($22,500). This special purpose software/platform has become the gold standard across the field and allows powerful, efficient, and flexible routines to be written and automated and data to be effectively visualized with relatively little computer power. Funds are also requested for a powerful, multi-core desktop computer ($3000) to facilitate data analysis and a laptop computer ($1500) to control instruments in the field along with general purpose software including SPSS statistics package, Microsoft, and Adobe products ($2600) for the laboratory. Support for lab supplies is requested totaling $16,000 for batteries, hard drives for data storage, microscopy supplies, misc. cabling, sample preservation materials, etc.

<u>A1. Forage species distributions</u>

An ADCP ($26,000) and an auto-profiling CTD system ($15,000) will allow us to characterize the physical habitat at the scales relevant to aggregations of forage species from small research boats, including the Paragon.

<u>A2. Swarm structure</u>

No new equipment is requested for this effort and all required supplies/materials are included in general lab support.

<u>B. Midwater structure</u>

A wideband echosounder in a 1200 m housing and two, deep-rated transducers ($109,800) will be used from Ventana. This sensor package is highly portable, requiring only power and an Ethernet connection and will serve as an important tool for this project as well as future efforts from other ROVs and other platforms. Supplies for integration of the acoustic system with the ROV (cables/connectors, hardware for mounting, etc.) and supplies for data backup and storage and sample preservation are requested as part of the general supply budget ($5500).

Project team

- *Kelly Benoit-Bird* will serve as the lead for the project and will be responsible for directing instrument integration, data collection and analysis, and publication of results.
- *Chad Waluk* will be responsible for project coordination and will support engineering, data collection, and data analysis efforts.

<u>A1. Forage species distributions</u>

- *John Ryan* will participate in the field efforts from the Paragon and provide expertise in preparing remote sensing data and interpreting the relationship amongst physical and biological variables.

- *Jared Figurski* will serve as captain for the Paragon during the first year of the project to facilitate the integration of a large number of new instruments and sampling approaches (acoustics over the side, auto-profiling CTD, and profiled cameras). During this critical first year, the team will also rely on his extensive observations of the Bay to identify key areas for study and appropriate and timely testbeds for instruments. Biological hotspots are small and ephemeral and the expertise will greatly improve the success of the project.
- We request 30 hours of ME technician time to fabricate hardware to attach acoustic systems to the vessel

A2. Swarm structure

- *David Caress* will assist in the bench and tank testing required to reduce the noise and cross-talk observed in the water column data from the multibeam sonar. He will also assist with dedicated deployments of the mapping AUV and participate in data quality control from water column portions of deployments.
- *Hans Thomas* will lead the noise reduction efforts for the mapping AUV and support field deployments for water column efforts. His expertise is critical for the successful implementation of this existing technology to a new application.

B. Midwater structure

- *Paul McGill* will work with the team to integrate the acoustic system with Ventana including identifying sources of noise and implementing power filtering and other approaches to ensure high quality data. He will also lead efforts to document the integrated system.
- EE and ME technician will support the fabrication of brackets and cabling between Ventana and the acoustic system.
- The team will be coordinating with the Midwater Ecology Group and will rely on the extensive expertise of the video lab personnel to annotate videos from dives

Project lab and office space requirements

In addition to any changes to current space usage, please also include anticipated office and lab needs for students, postdocs, collaborators, etc.

No new space needs are anticipated.

Data storage requirements (see Todd Ruston for assistance)

Data collected as part of this project will be stored onsite using a hard disk array to support the data analysis approaches currently employed and secondarily, in an offsite backup. Costs are included as part of the supply budget.

Data availability outside project team, uniqueness

Data will be available to all interested MBARI personnel and data products will be shared with external collaborators. With consultation with MBARI leadership, data that impacts the Sanctuary or the State Lands Commission will be shared as appropriate.

R/V *Paragon* Requests
During the first year of the project (2017), we request that Jared Figurski serve as an operator for the vessel to ensure safe and effective integration of a large number of new tools on the vessel. The team will also be relying on his extensive observations of the Bay to identify key areas for study and appropriate and timely testbeds for instruments. Biological hotspots are small and ephemeral and the expertise he brings will greatly improve the success of the project. During this first year, Jared will also ensure that members of our research team are trained on boat operation to allow greater flexibility in operation in subsequent years.

Export Regulation
Does the project team anticipate any foreign collaborations or international travel? If so, please identify collaborators by name, institution, and country.

N/A

Does the project team plan or anticipate export controlled purchases, shipments, or transfers of items (e.g., research instruments, proprietary data, hand-carried tools or samples) outside the U.S. temporarily or permanently? If yes, please identify country or countries and indicate whether these items will remain under MBARI control while abroad or controlled by others. Will the items be exported to more than one country? Please include foreign collaborator information as described above.

N/A

Monterey Bay National Marine Sanctuary (MBNMS)

General Permit
Projects teams need to indicate if any work will be performed that is either: (1) currently authorized under our general permit; or (2) will require that we obtain authorization. The current permit can be viewed at http://mww.mbari.org/pco/permits/mbnms-2015-002_feb2015.pdf. Please see Mandy Allen for questions.

Is a permit with MBNMS required for your work?

Yes. Activities should be covered under existing permit.

SESAs (General map)
*Projects will need to indicate whether or not work will be conducted within one of the Monterey Bay National Marine Sanctuary's Ecologically Significant Areas (SESAs). An interactive map can be found on the Sanctuary's SIMoN webpages at http://sanctuarysimon.org/maps/sesa/. (*Note: It may take a moment for the page to load, so please be patient. Also, if prompted for a login, hit "Cancel" and then you will be able to access page.*) To determine if your work will occur in a SESA, specific coordinates can be entered using the locator function (click on the red "target" button in the toolbar at the top of the map). If your work will be conducted in one of these areas, please indicate which area, by number.*

None

Authorizations/Permits from other Agencies or Organizations

Is the project team aware of any other permits or authorizations that will be necessary to perform the proposed work? If so, please list below along with status of authorizations (obtained, pending, need to apply, etc.). Please see Mandy Allen if you have questions.

This work falls under general CSLC permits, no other permits are known to be required

Active Acoustics

We are compiling information on active acoustic use at MBARI. If the project involves using active acoustic instrumentation, please describe plans.

Rating*	System Name	Vendor	Source Type	Location	Transducer Type	Source Level (dB)	Frequency Range	Typical Ping Rate	Max Pulse Width
	AUV								
3	Reson7125	Teledyne Reson	Multibeam	Mapping AUV	Directional(downward)	223 dB re 1 upa @ 1 m	200/400kHz	3 Hz	.06ms
	ROV								
2/3	WBT - Tube	Simrad	Echosounder	Mini ROV	7-12 degree beam (looking sideways)	<180 dB re 1 upa @ 1 m	50-150 kHz	0.5 Hz	1 ms
	Paragon								
2/3	EK60 Echosounder	Simrad	Echosounder	Over the side mount	7-12 degree beam (downwards)	<180 dB re 1 upa @ 1 m	18, 38, 70, 120, 200, 333, 710 kHz	<1 Hz	1 ms
2/3	EK80 Echosounder	Simrad	Echosounder	Over the side mount	7-12 degree beam (downwards)	<180 dB re 1 upa @ 1 m	10-800 kHz	<1 Hz	1 ms
3	Workhorse ADCP	RDI	ADCP	Over the side mount	Directional (downward)	~200 dB re 1upa @ 1 m	600 kHz	<1 Hz	1 ms
	Western Flyer								
2/3	EK60 Echosounder	Simrad	Echosounder	Hull mounted	7-12 degree beam (downwards)	<180 dB re 1 upa @ 1 m	18, 38, 70, 120, 200, 333, 710 kHz	<1 Hz	1 ms
2/3	EK80 Echosounder	Simrad	Echosounder	Hull mounted	7-12 degree beam (downwards)	<180 dB re 1 upa @ 1 m	10-800 kHz	<1 Hz	1 ms
2	Remote Depth Sensor	Simrad	Modem	Trawl	Modem	176 dB re 1upa @ 1 m	10-20 kHz	1 Hz	2 ms

* Ratings utilize the following criteria
- 1 - Potential near source injury, broader behavior probability (220dB+, 2-20KHz, surface ship, side-looking, longer duration 100 ms)
- 2 - No direct injury, potential behavior changes
- 3 - No issue (based on frequency - upper hearing limit 160kHz-200kHz for whales, pinnipeds, dolphins, porpoises)

Risk matrix (development and infrastructure projects only)

	Technical Risk	Organizational Risk	Tech Transfer Risk	Labor Estimate Risk
High				
Medium				
Low				