Usage of this form is not approved for other program offices.
OMB Approval No.
0648-0384
Expiration Date 12/31/2019

Annual Progress Report

A. Grant Number: NA16NOS4780202

B. Amount of Grant:$900,000

C. Project Title: NGOMEX 2016: User-driven tools to predict and assess effects of reduced nutrients and hypoxia on living resources in the Gulf of Mexico

D. Grantee Organization: George Mason University

E. Awarded period: From: 09/01/2016 To: 08/31/2020

F. Period Covered by this Report From 09/01/2016 To: 05/31/2017

G. Summary of Progress and Expenditures to Date:

1. Work Accomplishments: (as related to project objectives and schedule for completion)

a. Provide a brief summary of progress, including results obtained to date, and their relationship to the general goals of the grant

Overall Progress and Status:

An expansive hypoxic zone in the Northern Gulf of Mexico (NGOMEX) will affect ecologically and economically important living resources, but the magnitude, predictability and even the direction of these changes remain elusive. Managers and stakeholders alike need readily available and quantitative tools to assess the effects on living resources of planned nutrient reduction strategies aimed to minimize the hypoxic zone. Our proposed program couples spatially-explicit ecosystem, bioenergetics, and water quality models to evaluate alternative management strategies, interannual differences in water flows, nutrient loading and water temperatures, and longer-term climate changes on living resources.

Our work thus far and our plan for the future both focus on the development of user friendly, management-scale relevant forecasting tools and our project is on target as originally proposed. We have made substantial progress towards our goals in the first year. It has also been a very productive first year, with 4 papers published, 7 papers drafted, 7 scientific papers presented, and three special sessions accepted at major scientific conferences. We also held our first workshop at the Gulf of Mexico Oil Spill and Ecosystem Meeting, where we received valuable feedback from fisheries managers.

Application to Management:

A critical function desired in the RFP and highlighted in the proposal was a clear connection to management. As such, we outlined a plan to create an advisory panel composed of various individuals from state and federal management entities that could supply advice in regards to the application of Ecosystem Based Fisheries Management for their respective agencies. The advisory panel functions through quarterly webinar/conference calls, organized workshops, and through ad-hoc meetings (e.g. American Fisheries Society Annual Meeting).

We solicited help on the advisory panel from a broad list of management, academic and NGO entities including National Marine Fisheries Service (including personnel from resource surveys, sustainable fisheries, fishery management, and integrated ecosystem assessment groups), NOAA Sea Grant, Florida Wildlife Commission, Texas Parks and Wildlife, Louisiana Department of Wildlife and Fisheries, Louisiana State University, and The Water Institute (Table 1). Thus far, the advisory panel has conducted two of the planned quarterly webinars/conference calls with another planned for early July. The first call briefly presented the planned approach for the modeling effort, highlighted areas for which we desired input at the first workshop, and laid out the groundwork for advisory panel functions. The second call focused on the NMFS Integrated Ecosystem Assessment groups report on the status of ecosystem based management in the Gulf of Mexico and gave a brief update in regards to the first workshop and progress on the modeling effort.

The first of three workshops was held at the Gulf of Mexico Oil Spill and Ecosystem Science Meeting in New Orleans, LA. The first meeting was focused on educating user groups on model inputs, capabilities, and output with the intent to refine model inputs but tuned to user group input and desires. We also defined both manager needs and stakeholder expectations to focus on the question of how accurate and how often predictions are needed.

Participants of the first workshop included all project members, the advisory panel, program office representatives, the PI’s of the other two funded NGOMEX projects, and other interested parties as part of the GOMRI meeting in New Orleans. The workshop participants are listed in Table 1 as well. The workshop was designed to introduce our project, solicit advice on what to represent with the models (model area, species choices, etc.) and explore collaborative opportunities with the two synergistic projects.

Table 1. Advisory Panel (AP) members and workshop participants (WS).

Name	Affiliation	AP	WS
Alan Lewitus	NOAA Center for Sponsored Coastal Ocean Research		x
Angelina Freeman	Coastal Protection and Restoration Authority	x	x
Arnaud Laurent	Dalhousie University		x
Bonnie Ponwith	NMFS-SEFSC-Miami	x	
Brian Cameron	BOEM		x
Brian Dixon	ECOGIG (Ecosystem Impacts of Oil and Gas Inputs to the Gulf)		x
Cassandra Glaspie	Oregon State University		x
Cholena Ren	BOEM		x
Chris Kelble	NOAA		x
Cynthia Sellinger	Oregon State University		x
Daniel Obenour	North Carolina State University		x
Dave Lindquist	Coastal Protection and Restoration Authority of Louisiana		x
David Hilmer	NOAA Center for Sponsored Coastal Ocean Research		x
Demetri Spyropulas	Medical University of South Carolina		x
Doug Daigle	Louisiana Hypoxia Working Group		x
Dubravko Justic	Louisiana State University		x
Haosheng Huang	Louisiana State University		x
Idrissa Boube	BOEM		x
James H. Cowan	Louisiana State University	x	
James Nance	NMFS SEFSC-Galveston	x	
James Tolan	Texas Parks and Wildlife Department	x	x
Jeff Rester	Gulf States Marine Fisheries Commission	x	x
John Walter	NMFS-SEFSC-Miami	x	
Kenny Rose	Louisiana State University		x
Kim de Mutsert	George Mason University		x
Kirsten Larsen	NOAA		x
Lisa Desfosse	NMFS-SEFSC-Pascagoula	x	
Mandy Karnouskas	NMFS-SEFSC-Miami	x	
Mark Belter	BOEM		x
Mark Schexnayder	Louisiana Department of Wildlife and Fisheries	x	x
Matt Campbell	NOAA Fisheries		x
Melissa Baustian	Water Institute of the Gulf	x	x
Michael Schirripa	NMFS-SEFSC-Miami	x	
Pat Makoski	Calhoun County - Public Health Dept.		x
Rick Hart	NMFS SEFSC-Galveston	x	
Robert Twilley	Louisiana Sea Grant	x	
Ross Del Rio	BOEM		x
Rusty Gaude	Louisiana Sea Grant		x
Shannon Martin	NOAA Fisheries	x	x
Skyler Sagarese	NMFS-SEFSC-Miami	x	
Steve Ashby	Northern Gulf Institute	x	x
Steve Brandt	Oregon State University		x
Steve DiMarco	Texas A&M University		x
Thomas DeWitt	Texas A&M University		x
Ted Switzer	Florida Fish and Wildlife Conservation Commission	x	

The ultimate goal of this research is to develop management tools in collaboration with fisheries managers that can be readily applied to test alternative management strategies to reduce hypoxic volume, and investigate subsequent effects on fish growth, population dynamics (e.g. abundance and biomass), and fisheries catches. We received valuable feedback from the workshop at GOMOSES and are incorporating this feedback into our approach. Attendees offered feedback regarding model drivers, validation, species, and products (Figure 1). Salinity was identified as an important driver of shrimp, and we intend to include salinity in our GRP model for brown shrimp. We identified several sources of data for model validation, including acoustic tag data, lipids, and SEAMAP data. The top species identified for new GRP models were the original species listed in our proposal (red snapper, Atlantic croaker, brown shrimp). Additional species recommended for modeling were Atlantic bumper, spotted seatrout, Spanish mackerel, red drum, lady fish, and lion fish. We have looked into data availability for these species and anticipate creating GRP models for Atlantic bumper, red drum, and spotted seatrout in the future.

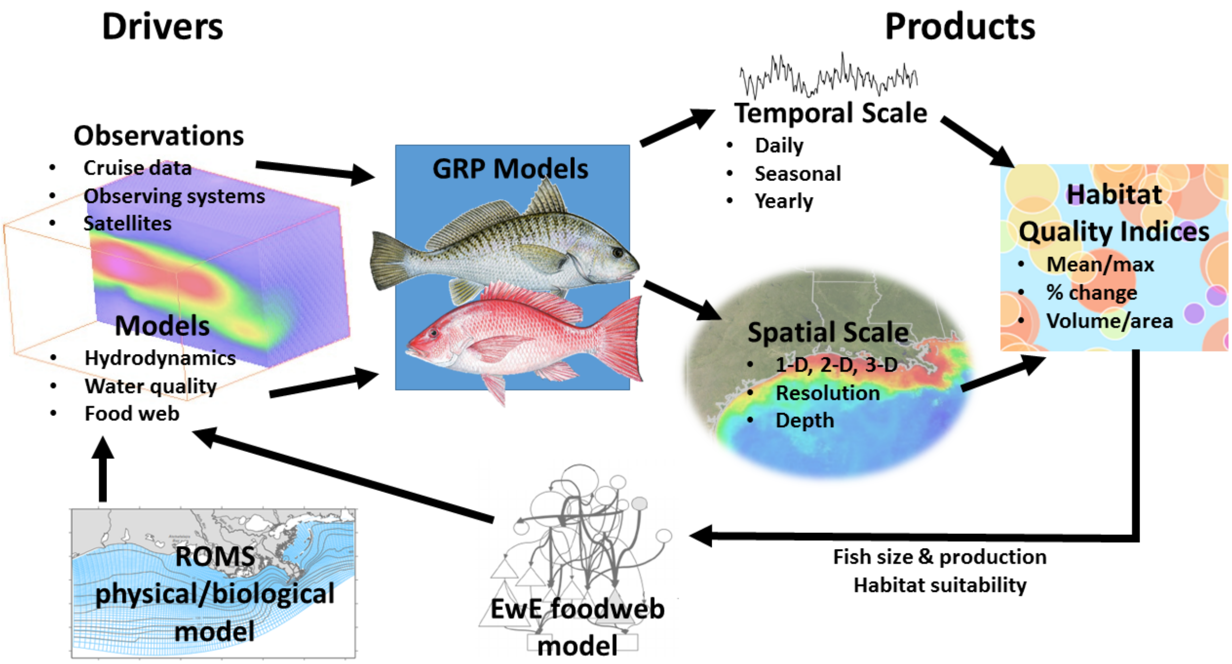


Figure 1. Flow chart of feedback requested from workshop participants. Arrows demonstrate how model components fit together. We solicited feedback on drivers, models (including species to include in modeling efforts), scale of products (temporal and spatial), and what the desired format for habitat quality indices.

Products identified as desirable were habitat quality maps and a way to interface GRP modeling with observing systems. In addition, the bioenergetics models themselves were of interest to managers. Due to these end-user priorities, **we have drafted an open source version of the GRP model that can be freely shared with fisheries managers and adapted to interface with a variety of observing systems.** Example R model output is provided in Figure 1. We intend for these models to be used directly by conference participants and their colleagues. We also anticipate the R platform will allow us the flexibility to apply this modeling framework to existing observing systems.

Throughout the workshop, we identified opportunities for collaboration with Kenneth Rose (UMCES), who is also completing a project funded under NGOMEX. We have collaborated with the Rose lab to produce the Atlantic croaker GRP model, which uses the same parameters as their model. We anticipate comparing and contrasting our results to validate and assess if different approaches produce similar conclusions. This will strengthen products from both research programs.

Several workshop participants mentioned the need for a product (index) that will eventually be incorporated into stock assessment. Some models do not predict population size adequately, and there is increased interest in incorporating indices that reflect environmental variability and spatial mismatch of predators and prey. For example, the red tide index has been used to improve estimates for red grouper. Incorporating GRP as habitat quality index for stock assessment models may improve stock assessments.

Additional advice from workshop participants in breakout groups resulted in the following actionable items:

Ecospace model area:
-Develop a new basemap based on newer bathymetry/topography information available since the last iteration of this model
-Expand the NGOMEX model area slightly to the east to include the east side of the Mississippi River
-Continue with a 5km square grid, but also explore whether a 10km^2 grid and a 1km^2 grid would change model output. The 10km^2 grid would be useful as a basis for a management tool, since the model runs would be much quicker. The 1km^2 grid would be useful if we are exploring the estuarine zone, which may be the case if we get the opportunity to explore the synergistic activity of using FVCOM model output from the Rose et al. NGOMEX project as drivers in the Ecospace model.

Ecospace species choices:
-Keep current species list included in the Ecospace model, and add Gulf Butterfish

Hypoxia scenarios:
-Develop a scenario of a 20% reduction in Nitrogen load from the Mississippi River
-Develop a scenario of a nitrogen reduction that would lead

to a hypoxic area of 5000 km2

Calibration period:

-All three NGOMEX projects agreed upon focusing on the time period 2000-2016 as a calibration period, to facilitate model output comparison, possible use of each other's output, and/or model linking.

While these project coupling approaches are outside of the scope of each of the individual project, we strive to work in such a fashion that this option is possible.

The full summary of the first workshop is posted on a webpage dedicated to the project: (https://demutsertlab.wordpress.com/ngomex/). The following sections detail the progress made on the different components of the project, that either were listed in the proposal, or were an actionable item from the first workshop.

Workshop 2 and 3 will be hands-on and focus on bringing together the people who will actually use these tools, to ensure our products will be the most useful for fisheries management.

ROMS model progress:

Hypoxia scenarios are developed using a ROMS model. This water quality model is a high-resolution coupled circulation-biogeochemical model that include 9 biological state variable, temperature, salinity and velocity. The water quality model was set up and configured for the Northern Gulf of Mexico to simulate the effects of nitrogen (N) and phosphorus (P) river load from the Mississippi and Atchafalaya Rivers on the lower trophic levels. A 17 years long simulation (2000-2016) was carried out with observed river discharge and nutrient concentrations (baseline simulation). 30 other 17 years long simulations were carried

Table 2. Level of N and P loads in the 31 experiments of the water quality model. The loads are expressed as percent of original (observed) river load. The experiments carried out are shown in grey.

		TN load								
		100%	90%	80%	70%	60%	50%	40%	30%	20%
TP load	100%	▨		▨		▨		▨		▨
	90%		▨							
	80%	▨		▨		▨	▨	▨		▨
	70%				▨					
	60%	▨		▨		▨		▨		▨
	50%			▨			▨			
	40%	▨		▨		▨		▨		▨
	30%								▨	
	20%	▨		▨		▨		▨		▨

out with the same setup but with reduced nutrient concentrations in the rivers. The same reduction was applied to all N nutrients (NO3, NH4, organic N) and/or P nutrients (PO4, organic P). Thus, each experiment represents the reduction in total N (TN) and/or total P (TP) load. Table 2 shows the loads in the 31 experiments that were carried out.

Model validation and comparison with mid-summer hypoxic area observations was carried out with the baseline experiment (Figure 2). Preliminary results from the nutrient load experiments indicate a significant reduction in the size of the hypoxic area for a 20% and 40% co-reduction in TN and TP. The results also show that the positive effect of nutrient load reduction on oxygen is larger than the negative effect on the lower food chain (i.e. less primary production due to lower nutrient availability). This is important for higher trophic levels. This differential effect is presented in Figure 3. The 40% co-reduction scenario corresponds closely with a scenario where the hypoxic area is reduced to 5000 km^2. We will use these two scenarios (20% co-reduction and 40% co-reduction) as the first two hypoxia reductions scenarios in the Ecospace model. This corresponds with the workshop recommendations described above. Outputs from the baseline and nutrient reduction experiments are being transferred to the EwE and GRP groups in their original and processed versions to drive the higher trophic level models.

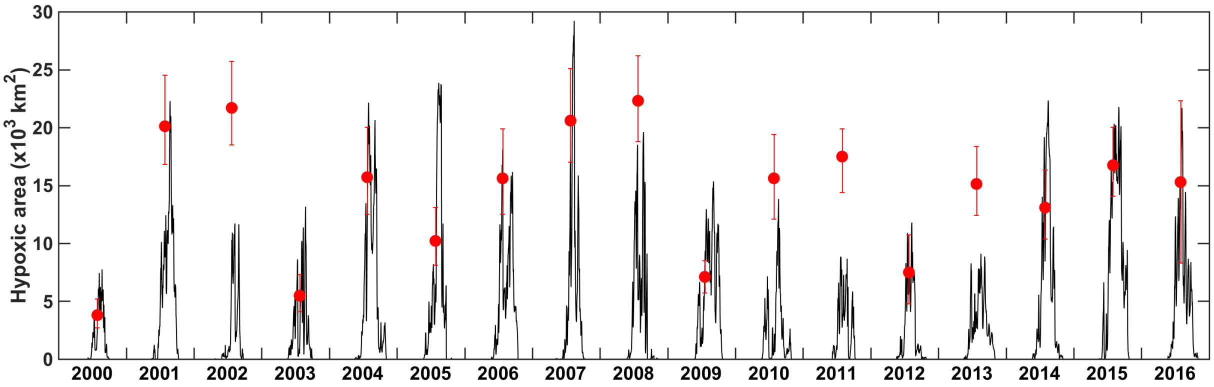


Figure 2. Comparison between simulated (black) and observed mid-summer hypoxic area from the LUMCON cruises (red). The 2016 data point is a multi model forecast from NOAA.

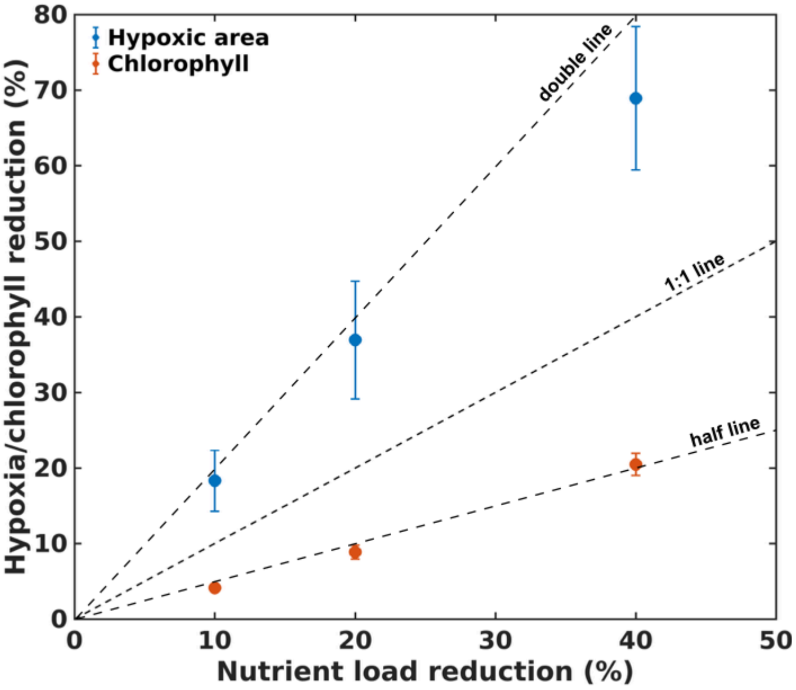


Figure 3. Effect of nutrient load reduction (N and P) on the size of the hypoxic area and chlorophyll concentration. The y-axis indicates the percent reduction in the hypoxic area and chlorophyll concentration.

Ecospace model progress:

Model area:

We have developed a new model area (Figure 4) and loaded it into Ecospace. The area within the ROMS domain (overlaid in Figure 4), will receive drivers from the ROMS model, and that will be the area from which we can interpret the output. An exclusion layer will be developed to cover the rest of the Ecospace model area that does not receive drivers from the ROMS model. This layer can easily be removed to activate the area outside the ROMS model area, so that it is flexible and usable in combination with other models/drivers that may have output for areas outside the ROMS model area (e.g. a portion of the Louisiana estuaries in the FVCOM model of Justic Dubravko).

Basic inputs:

Gulf Butterfish has been added as a multistanza group (juveniles and adults) in the Ecopath model. In addition to that, input biomasses of all groups have been recalculated based on 2000-2005 SEAMAP data (representing the year 2000, but a five year average is used rather than 1 year of data to create the Ecopath model), as we have agreed with the other NGOMEX groups to calibrate the period from 2000-2016, and we have therefor decided our ‘base’ model represents 2000. EwE basic input, such as consumption/biomass, productivity/biomass, and biomass (10^3kg/km^2/yr) values were estimated with SEAMAP data, literature searches from stock assessments (e.g., SEDAR, NOAA Fisheries), and using recommended equations(Heymans et al. 2016; fishbase.org;

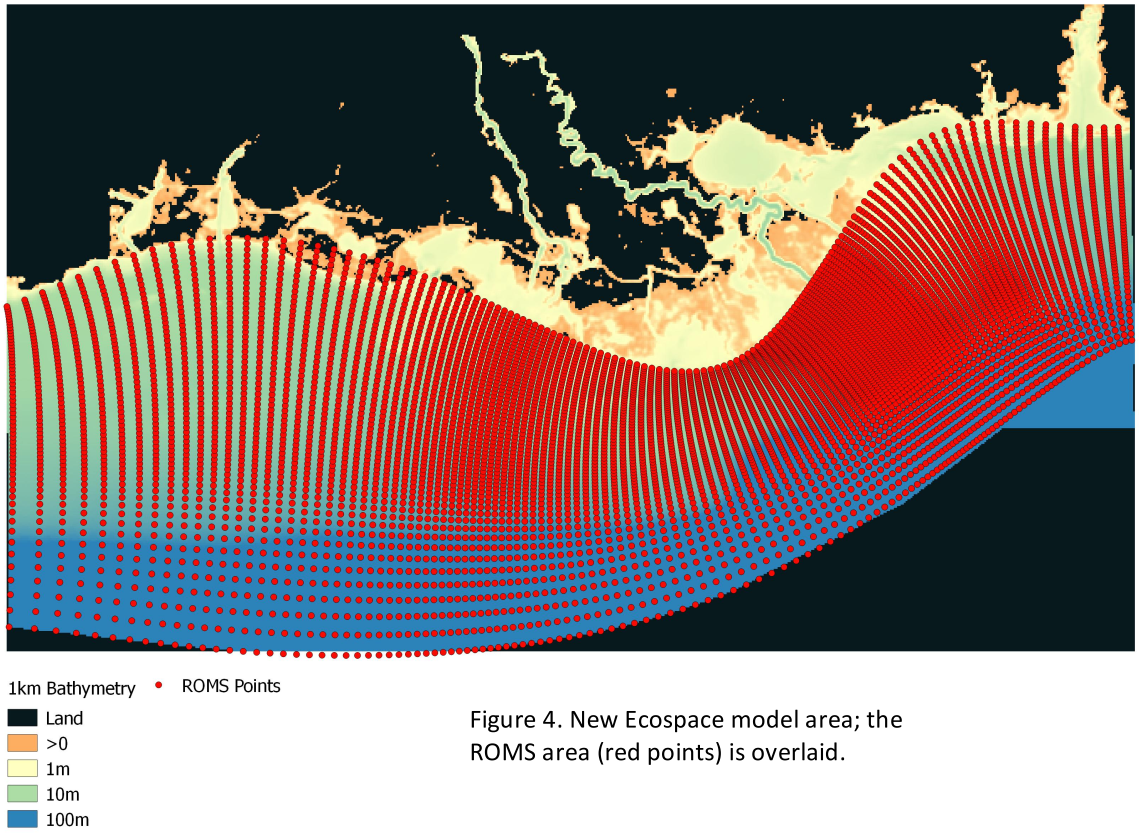


Figure 4. New Ecospace model area; the ROMS area (red points) is overlaid.

Palomares and Pauly 1998). NOAA commercial fisheries landings were aggregated for the model period of 2000-2005. Other changes underway include updating diets, since new information, notably the GOMEXSI website (http://gomexsi.tamucc.edu/) has come out since the original model was developed. All these changes require rebalancing of the Ecopath model, which is scheduled to be finalized in summer 2017.

In Ecosim, the temporal dynamic component of the model needed for calibration, the original model did not have representation of variable fishing effort or fishing mortality (as input), which is currently being added. Response curves of each of the groups (fish species) to environmental parameters such as dissolved oxygen are being updated and added.

Bioenergetics Models Progress:

We proposed that we would improve species bioenergetics, food web, and spatially/temporally explicit modeling capabilities of key living resources in the NGOMEX in response to changing hypoxic and climatic conditions. We have made substantial progress towards completion of this goal over the past year.

Species additions:

We have developed bioenergetics-based growth rate potential models for two new species, red snapper *Lutjanus campechanus*) and Atlantic croaker (*Micropogonias undulatus*). These models take very different forms according to how each species' metabolism responds to temperature and oxygen (Figure 5). Compared to bluefish (*Pomatomus saltatrix*), a species which we have modeled in the past, both red snapper and Atlantic croaker have higher GRP at lower temperatures (Figure 5, left panels). However, red snapper GRP was likely not as high as bluefish across the transect due to differences in foraging behavior (Figure 5, center panels, and see below discussion on sensitivity analysis of the foraging model). Atlantic croaker GRP increased with temperature (Figure 5, left panels), and croaker GRP was higher across the transect than for either of the other species (Figure 5, center panels). Where prey were available, the GRP of all three species was limited by dissolved oxygen, indicated by the near-zero GRP in the low DO zone between 20 and 30 m depth. The bioenergetics model and GRP results for red snapper were presented at the GOMOSES workshop (de Mutsert et al. 2017a).

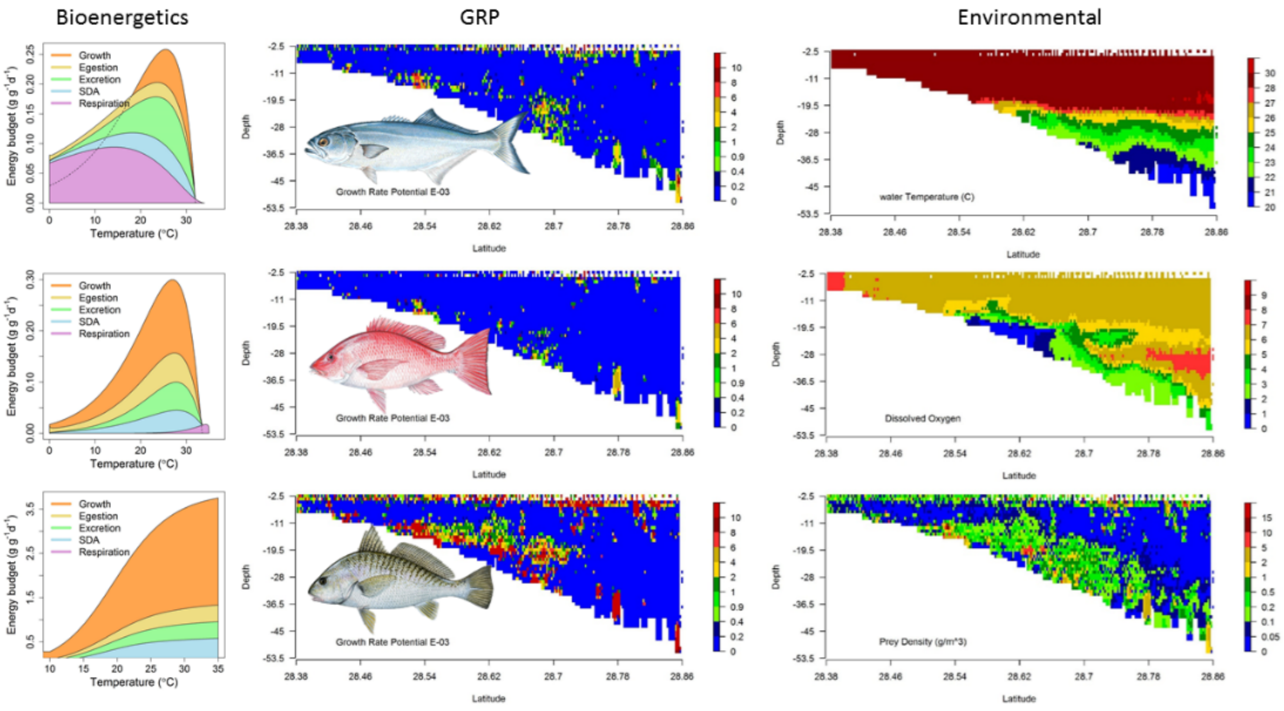


Figure 5. Bioenergetic model rates (left) and GRP (center) for bluefish (top), red snapper (middle), and Atlantic croaker (bottom). GRP was calculated for a transect with temperature, dissolved oxygen, and prey density shown on the right.

Fish Diets:

To facilitate the creation of new GRP models, we compiled diet information for a variety of NGOMEX species collected in trawls during summer 2006, 2007, and 2008 (Figure 6). Diets of fish from hypoxic regions were significantly different from diets of fish from normoxic regions, and fish in hypoxic areas consumed more fish and tended to consume less benthic organisms than fish in normoxic areas (Figure 6). Low dissolved oxygen had consequences for zooplankton distribution and abundance. Large zooplankton (> 5 μg average dry mass) biomass was vertically compressed into the surface waters in hypoxic areas (Figure 7). Increased small zooplankton (< 5 μg average dry mass) in diets of fish in hypoxic areas suggests that zooplankton habitat compression led to increased predation by fish (Figure 7). Impacts of low DO on zooplankton biomass and fish diet did not affect fish CPUE; however, fish diversity was lower in hypoxic areas than in

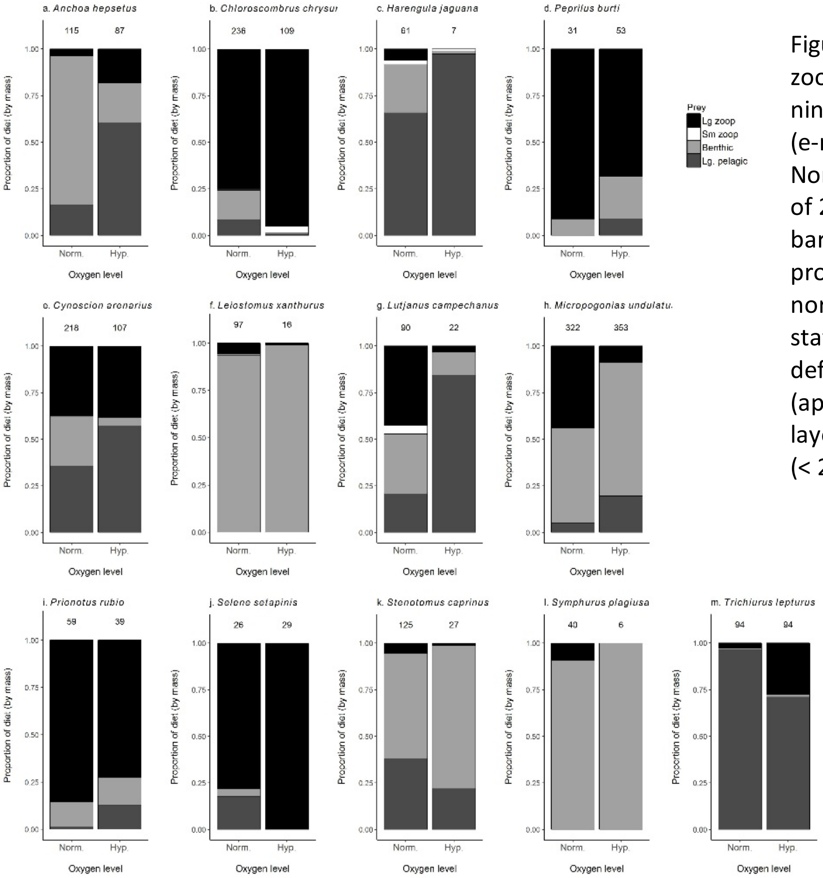


Figure 6. Diet composition for four zooplanktivorous fish species (a-d) and nine non-zooplanktivorous fish species (e-m) from samples taken in the Northern Gulf of Mexico in the summer of 2006, 2007, and 2008. Numbers above bars represent the total fish stomachs processed for that species, at either normoxic (Norm.) or hypoxic (Hyp.) stations. Hypoxic sampling stations were defined as those at which ≥15% (approximately half of the bottom 1/3 layer) of the water column was hypoxic (< 2 mg L^{-1}).

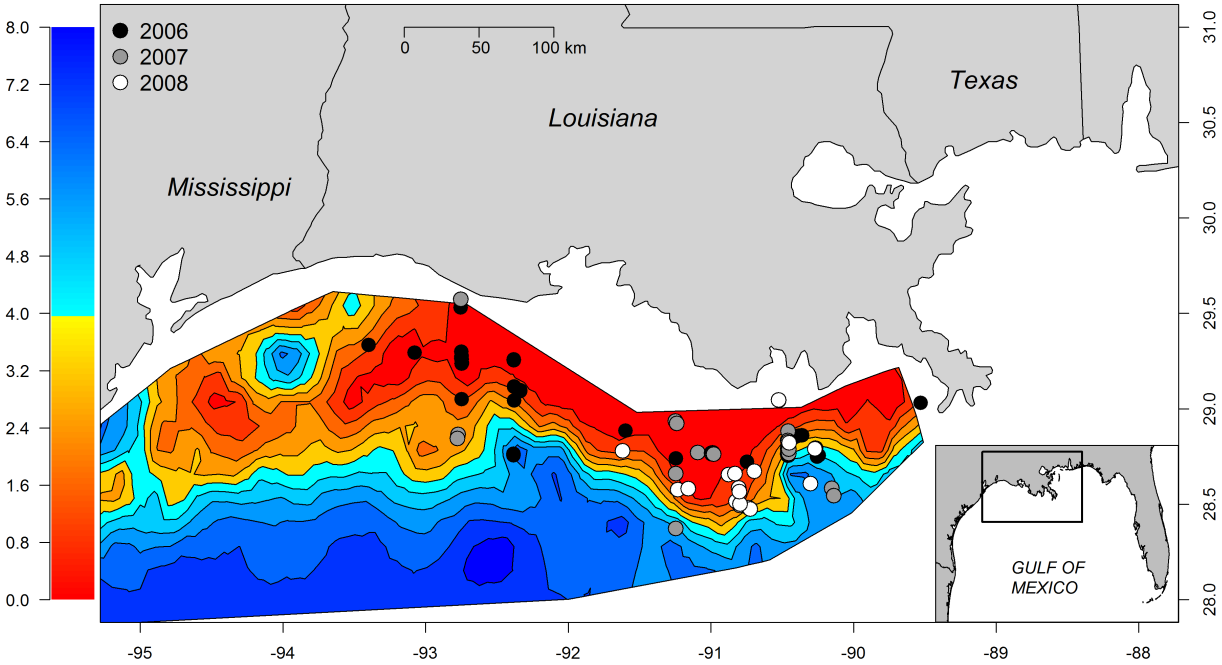


Figure 7. Oxygen contours (mg L^{-1}) from SEAMAP Groundfish Survey June 11 – July 16 2008, downloaded from http://www.ncddc.noaa.gov/ hypoxia/products/2005/, and trawl locations for each sampling year.

normoxic areas. These results are summarized Glaspie et al. (drafted-a).

Diet information is relatively lacking for the numerically dominant Atlantic bumper (*Chloroscombrus chrysurus*), a species appearing in the EwE model and under consideration for development of a GRP model. We analyzed Atlantic bumper abundance (CPUE) and diet as they relate to dissolved oxygen. Atlantic bumper CPUE was similar in hypoxic and normoxic regions, though fish in hypoxic areas tended to be smaller. Gut fullness was significantly greater in hypoxic areas than in normoxic areas, though this effect depended on fish size, with small fish in hypoxic areas having greater gut fullness than all others. Crustacean larvae made up the largest component of small Atlantic bumper diets by mass (Figure 8). Species that are notably intolerant to water column hypoxia, such as worms, small fish, and squid, were largely absent from Atlantic bumper diets in hypoxic areas (Figure 8). These results are summarized in the manuscript Glaspie et al. (drafted-b).

Connecting Nutrient Loading to Fish Habitat Quality:

We proposed that we would determine effects of nutrient loading and hypoxic volume reduction scenarios on growth rate potential, habitat quantity and quality, and fish population size. While most of the simulations addressing this goal will be completed in future work, we have made progress toward this goal using statistical modeling. Links between seasonal hypoxia in the NGOMEX and fish are unclear, and little is known regarding the impacts of hypoxia on small pelagic fishes, which provide the foundation for commercially and recreationally important fishes in the GOM and link primary production to higher trophic levels. We investigated the impact of seasonal hypoxia on small pelagic fish density and biomass in the NGOMEX from 2003-2010 using

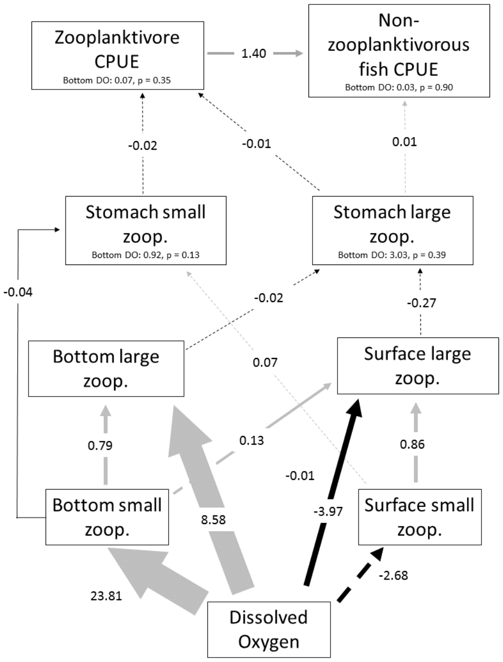


Figure 7. Path diagram from a fitted structural equation model showing how fish catch per unit effort (CPUE; number of fish min^{-1} trawl) are associated with dissolved oxygen (DO), zooplankton (zoop.) abundance in the lower water column (bottom) and upper water column (surface), and zooplankton mass in fish stomach contents. Solid paths are statistically significant at α = 0.05. Black lines represent a negative correlation, and gray lines represent a positive correlation. For clarity, some path coefficients are included in variable boxes rather than being drawn directly on the diagram.

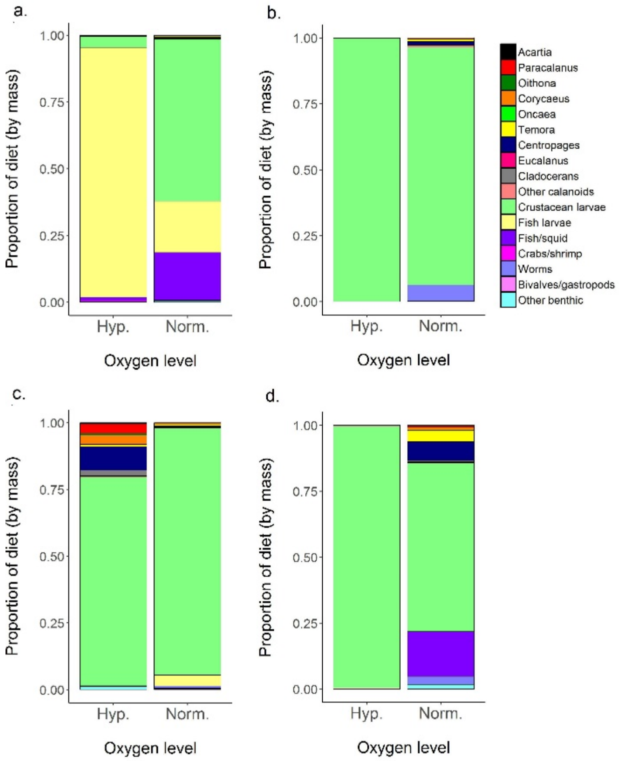


Figure 8. Diet composition for Atlantic bumper in the Northern Gulf of Mexico in either normoxic (Norm.) or hypoxic (Hyp.) regions. Hypoxic sampling stations were defined as those at which ≥15% (approximately half of the bottom 1/3 layer) of the water column was hypoxic (< 2 mg L^{-1}). Diet is shown for a) large fish (≥140 mm) caught during the day, b) large fish caught during the night, c) small fish (< 140 mm) caught during the day, and d) small fish during the night.

data from dual frequency split-beam acoustics. Dissolved oxygen < 4 mg L^{-1} was most prevalent in 2010 (4.26% of the water column) and 2008 (3.69% of the water column). Small pelagic fish density increased with temperature and dissolved oxygen, and forage fishes were mainly found in water temperatures >28 °C and dissolved oxygen levels >5 mg L^{-1}. Small pelagic fish biomass increased to a temperature of 26 °C and dissolved oxygen levels of 8 mg L^{-1}, and then declined, indicating relatively smaller fish were dominant in the warmest waters with the most dissolved oxygen. These results will be included in the presentation by Glaspie et al. (2017) at the American Fisheries Society meeting in November.

Interannual Fish Habitat Quality:

We have made substantial progress towards our goal of reconstructing the inter-annual fish habitat quality for each of the key species using historical data on temperature and oxygen conditions. We compiled water temperature, salinity, and dissolved oxygen data from NOAA's World Ocean Data Base for 1922-2015 (Figure 9). As a first look at these data, we calculated temporally and depth-averaged temperature, salinity, and dissolved oxygen for the entire Gulf of Mexico (Figure 10). Salinity and dissolved oxygen varied considerably in nearshore areas, while temperature and dissolved oxygen varied in offshore waters (Figure 10). A few regions exhibited average dissolved oxygen of 3 mg L^{-1}, including coastal Louisiana where our research cruises took place between 2003 and 2010 (Fig 10).

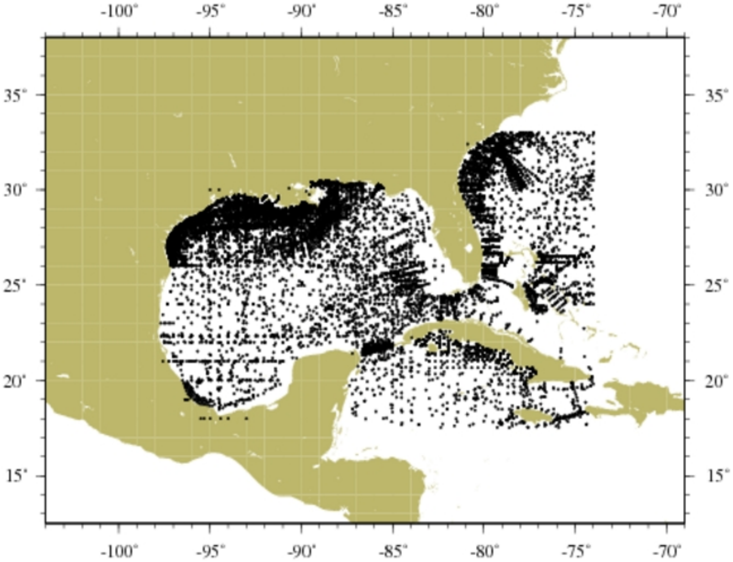


Figure 9. Locations of 20,776 CTD, XBT, and PFL casts between 1922 and 2015. Data from NOAA NODC Ocean Climate Laboratory.

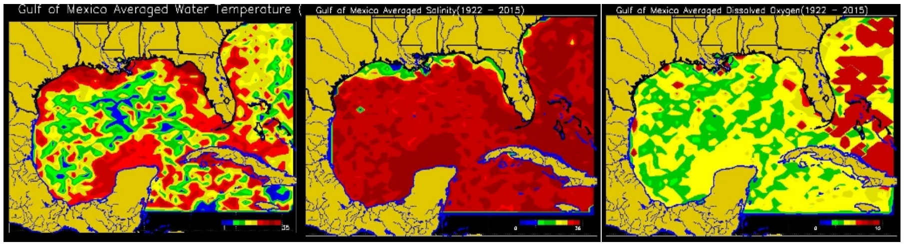


Figure 10. Temporally averaged (1922-2015) and depth-averaged temperature (left), salinity (middle), and dissolved oxygen (right).

We analyzed historic field data from research cruises (2003, 2004, 2006, 2007, 2008, 2009 & 2010) to identify fish habitat quantity and quality in the Gulf of Mexico. We plotted dissolved oxygen, water temperature and salinity data for the entire seven years of data and for depths ranging from 0 – 29 meters at one meter intervals. We estimated prey densities throughout the water column using acoustic profiles from a Simrad EY-500 120-kHz split-beam echosounder (3 pings s^{-1}; 0.4 ms pulse length; –66 dB minimum acoustic backscatter threshold). The acoustic data array represents an extensive dataset of measured fish densities and sizes throughout the water column spanning the hypoxic area. In 2006-2008 (3 out of the 7 total years we conducted surveys), we collected over 234 h of acoustic profiles, amounting to over 2.5 million acoustic data points. All transects were processed to remove noise caused by non-biological sources (e.g., surface turbulence caused by waves or ship wakes, methane gas bubbles, bottom return effects). These transects have undergone an extensive QA/QC process have now been used to construct horizontal and vertical transects of growth rate potential for both bluefish and red snapper (1,827 plots). Preliminary results show that both prey and top predators likely avoid the areas of low hypoxic levels (Figure 11). Habitat quality for both bluefish and red snapper are substantially degraded when dissolved oxygen levels are low (< 2 mL L^{-1}) (Figure 11).

Assessing Minimum Data Needs for Forecasts:

Our progress on the goal to assess the minimum (monitoring or modeling parameters, and time and space scales) data needs to make forecasts to the degree of accuracy required by decision-makers and stakeholders has focused on sensitivity analysis of the foraging model in our bioenergetics framework. We conducted sensitivity analyses of the parameters related to foraging behavior in the bluefish GRP model. Bluefish are highly mobile and predatory, and data on reactive distance or swimming speeds are scarce in the literature, even though these parameters appear in our foraging model. For bluefish, we conducted two single parameter analyses of sensitivity to examine the

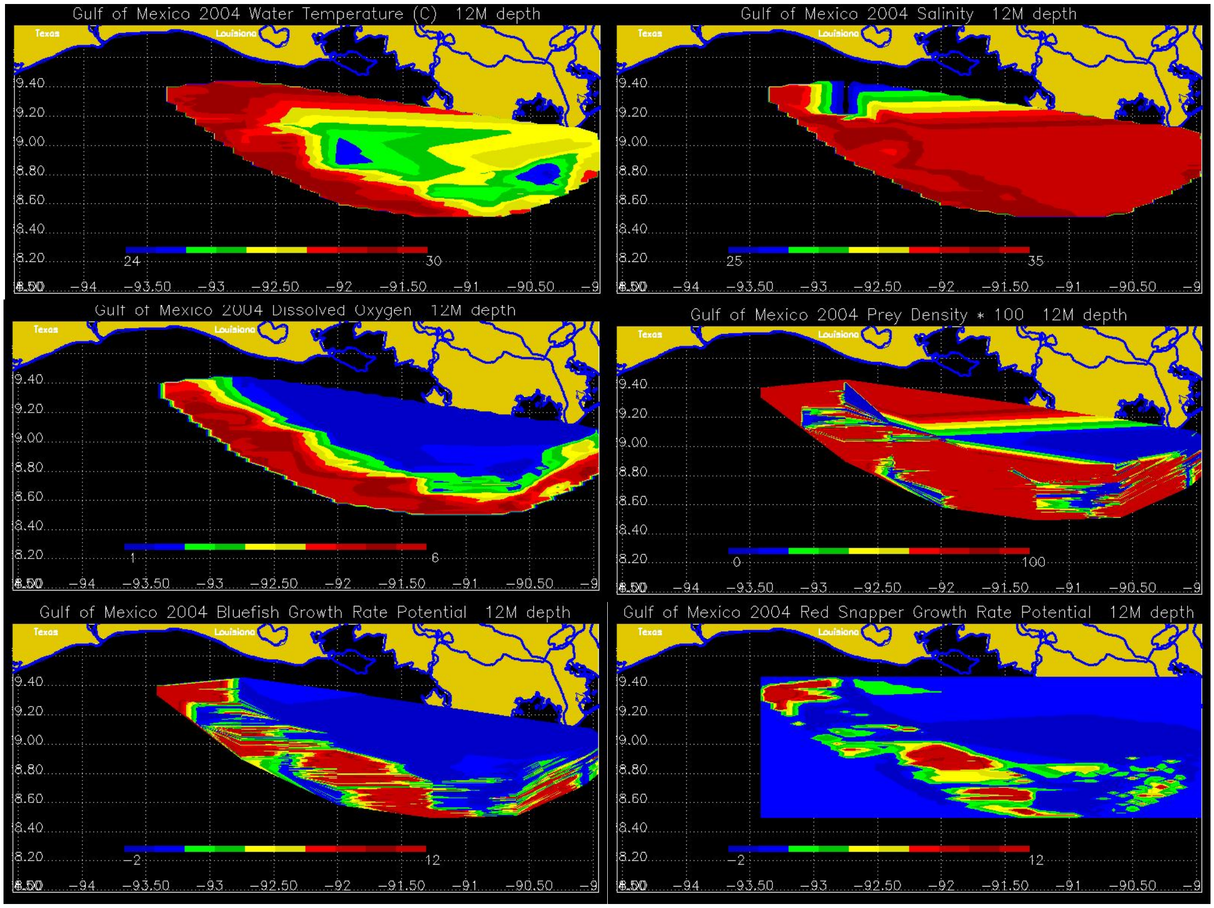


Figure 11. Water temperature (°C, top left), salinity (top right), dissolved oxygen (mL L^{-1}, middle left), prey density (g m^{3}, middle right), bluefish GRP (g g^{-1} d^{-1}, bottom left), and red snapper GRP (bottom right) for 2004 in 12 meters of water.

impact of swimming speed (body lengths per second) and reactive distance (body lengths) on consumption rates along a single transect. Swimming speed and reactive distance were set to 1, 2, or 3 in simulations to determine the impact of these parameters on consumption rates, taking into account prey availability as well. Consumption rates varied with

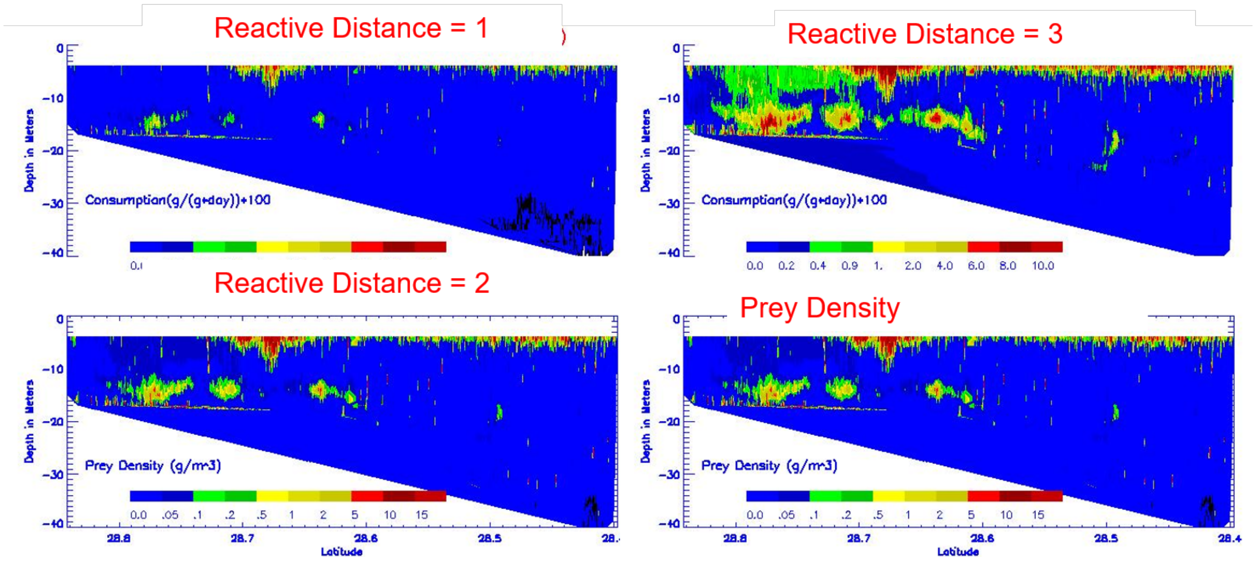


Figure 12. Growth rate potential maps resulting from sensitivity analysis of reactive distance in the foraging model portion of the GRP framework. Bluefish GRP is shown for reactive distances of 1, 2, or 3 fish body lengths, as well as prey density in the transect.

different swimming speeds and reactive distances (Brandt et al. drafted). Underestimating swimming speed resulted in some areas with high prey densities having minimal consumption, including surface waters over most of the transect. Lower reactive distance (1 body length) resulted in much lower consumption rates that would result in under-utilization of prey hotspots (Figure 12). The results indicate that fish feeding rate is highly sensitive to predator swimming speeds and reactive distance to prey (Brandt et al. drafted).

b. Provide a brief summary of work to be performed during the next year of support, if changed from the original proposal; and indication of any current problems or unusual developments that may lead to deviation of research directions or delay of progress toward achieving project objectives.

The changed Ecospace model will be balanced in Ecopath, and recalibrated in Ecosim. These model improvements will not delay the progress towards achieving project objectives, rather we have found time within the project timeline to scrutinize all input parameters. Other work to be performed during the next year of support on the ecosystem modeling is outlined in the original proposal.

In the next year of funding, we will also continue to improve species bioenergetics, food web, and spatially/temporally explicit modeling capabilities of key living resources in the NGOMEX in response to changing hypoxic and climatic conditions. Additional GRP models focusing on some of the key ecologically and economically important species of the region will be developed for this project. In particular we will develop a new model for brown shrimp, using available data. We also plan to develop models for Atlantic bumper, spotted seatrout, and red drum according to suggestions from workshop participants.

We will continue to make progress examining the effects of nutrient loading and hypoxic volume reduction scenarios on growth rate potential, habitat quantity and quality and make direct linkages of Fish Habitat models to 3-D water quality model output under various nutrient loading scenarios. We will begin the process of running the GRP model for each species on a daily basis for each spatial cell in the 3D hydrodynamic/water quality model. We have received the 60N/60P, 80N/80P, and 100N/100P model run output from A. Laurent. This output is currently being processed to be used as input in GRP models.

We will reconstruct the inter-annual fish habitat quality for each of the key species using the historical temperature and oxygen data we have compiled from NOAA's World Ocean Data Base. Annual indices will be compared to ROMS model output, historical catches, and monitoring information of fish sizes (from SEAMAP). This information will allow us to validate modeled output.

The next major workshop will include training and testing of the developed management tools, and the last workshop will focus on technology transfer and applications. This approach, and the use of adaptive science where feedback during workshops will be incorporated into work priorities, ensures transition of research to management throughout the scope of this project.

2. Applications:

This section should describe specifically the outputs and management outcomes achieved. Outputs are defined as products (e.g. publications, models) or activities that lead to outcomes (changes in user knowledge or action). In cases where proposed management outcomes are not fully achieved, indicate the progress made during the reporting period. Also, indicate expected outputs and management outcomes for the next year of support.

a. Outputs

i. New fundamental or applied knowledge
ii. Scientific publications

Goto, D., Roberts, J. J., Pothoven, S.A., Ludsin, S. A., H. A. Vanderploeg, Brandt, S. B. and T. O. Hook. 2017. Acoustic size-mediated regulation of demersal predator-prey coupling in Lake Erie transient dead Zones. **Accepted with revision.** Environmental Biology of Fishes.

Gruss, A., Rose, K.A., Simons, J., Ainsworth, C.H., De Mutsert, K., Himchak, P., Kaplan, I.C., Froeschke, J., Zetina Rejon, M.J., and D. Chagaris. 2017. Recommendations for ecosystem modeling efforts aiming to inform ecosystem-based fisheries management and restoration projects. Marine and Coastal Fisheries, DOI:10.1080/19425120.2017.1330786

De Mutsert, K., Steenbeek, J., Cowan, J.H. Jr., and V. Christensen. 2017. Using ecosystem modeling to determine hypoxia effects on fish and fisheries. Chapter 14 *In*: D. Justic, K.A. Rose, R.D. Hetland, and K. Fennel (eds). Modeling Coastal Hypoxia: Numerical Simulations of Patterns, Controls and Effects of Dissolved Oxygen Dynamics. Springer, New York

Vasslides, J.M., De Mutsert, K., Christensen, V., and H. Townsend. 2017. Using the Ecopath with Ecosim modeling approach to understand the effects of watershed-based management actions in coastal ecosystems. Coastal Management 45 (1):1-12. Published online: DOI: 10.1080/08920753.2017.1237241.

De Mutsert, K., Steenbeek, J., Lewis, K., Buszowski, J., Cowan, J.H. Jr., and V. Christensen. 2016. Exploring effects of hypoxia on fish and fisheries in the northern Gulf of Mexico using a dynamic spatially explicit ecosystem model. Ecological Modelling *331*: 142-150. doi:10.1016/j.ecolmodel.2015.10.013.

In-Progress

Brandt, S. B., Sellinger, C. E., and Glaspie, C. N. **Drafted**. Growth rate potential as a causal mechanism for North Pacific salmon returns in a changing climate. For submission to *PLOS One*.)
(further development of interannual assessment Techniques to be applied to the NGOMEX)

Brandt, S. B., Sellinger, C. E., and Glaspie, C. N. **Drafted**. Seafood diet: Linking fish feeding to habitat, prey availability and bioenergetics in a pelagic predator. For submission to *Environmental Biology of Fishes*.

Brandt, S.B. Growth rate potential as a Quantitative measure of Fish Habitat Quality. Status: *literature reviewed and partially written for Reviews in Fish Biology*.

Brandt, S.B. and C. S. Sellinger. Sensitivity of spatially-explicit growth rate potential models to predator swimming speed and reactive distance. Status: initial analyses done and figures drafted. Intended for *Trans. Amer. Fish. Soc*.

Glaspie, C. N., Elliot, D. T., Pierson, J. J., Roman, M. R., and Brandt, S. B. **Drafted**-a. Occurrence and diet of fish in relation to hypoxia in the northern Gulf of Mexico. For submission to *Marine Ecology Progress Series*.

Glaspie, C. N., Mason, D. M., Clouse, M., Brandt, S.B., Adamack, A. T., Stow, C. A., Ludsin, S. A., Cha, Y., and Roman, M. R. **Drafted**-b. Effect of hypoxia on the feeding habits of Atlantic bumper *Chloroscombrus chrysurus* in the Northern Gulf of Mexico. For submission to *PLOS One*.

iii. Patents
iv. New methods and technology
v. New or advanced tools (e.g. models, biomarkers)
vi. Workshops

De Mutsert, K., Campbell, M., and Brandt, S. February 2017. “Hypoxia effects on fish and fisheries.” Gulf of Mexico Oil Spill and Ecosystem Meeting, New Orleans, LA.

Brandt, S. B., and Mason, D. 2017. “Pelagic fish seascapes: Integration of new technology and modeling.” Symposium submission accepted, American Fisheries Society Meeting, 20 – 24 August, Tampa, FL.

Glaspie, C.N., Brandt, S. B. 2017. “Response of fishes to extreme climate events.” Symposium submission accepted, American Fisheries Society Meeting, 20-24 August, 2017, Tampa, FL.

De Mutsert, K., Brandt, S., and Roman, M. 2017. “Ecological impacts of hypoxia on coastal ecosystems.” Symposium submission accepted, Coastal and Estuarine Research Federation Biennial Conference, 5- 9 November, 2017, Providence, RI.

vii. Presentations

Brandt, S. B. November 2016. “Science Strategies in Large Programs, Invited Panelist to The Science Enterprise Workshop: Supporting and Implementing Collaborative Science”, 1-3 November, Davis, CA.

Brandt, S. B. and Sellinger, C. November 2016. “Variability in North Pacific Ocean conditions: Assessing habitat-specific vital rates and thresholds for fishes”. North Pacific Marine Science Organization (PICES) Annual Meeting, 9 – 15 November, San Diego, CA.

De Mutsert, K. 2017. Modeling a coastal environment with human elements. Keynote speaker at CSDMS annual meeting 2017: Modeling Coupled Earth and Human Systems – The Dynamic Duo. Boulder, Colorado, USA.

De Mutsert, K., Brandt, S., Campbell, M., Lewis, K., Laurent, A., Sellinger, C., Steenbeek, J., Buszowski, J., Cowan, J.H., and V. Christensen. 2017. Assessing effects of reduced nutrients and hypoxia on living resources in the Gulf of Mexico using a coupled ecosystem modeling approach. ASLO 2017: Mountains to the sea. Honolulu, Hawai`i.

De Mutsert, K. 2017. Hypoxia effects on fish and fisheries: Use of models: Ecospace. 2017 Gulf of Mexico oil spill and ecosystem science conference. New Orleans, Louisiana.

Glaspie, C. N., S. B. Brandt and C. S. Sellinger. 2017. Linking North Pacific Chinook Salmon habitat quality with Fish Production in a Changing Climate. Oregon American Fisheries Society, 1 – 4 March, Bend, Oregon.

Brandt, S.B. March 2017. “Time, space and habitats for pelagic fishes”. Invited Seminar to Fisheries and Wildlife Department Stream Team, Oregon State University, 13 March, Corvallis, OR.

viii. Outreach activities/products (e.g. website, newsletter articles)

A webpage has been set up dedicated to this project:

https://demutsertlab.wordpress.com/ngomex/

The February workshop has a dedicated page as well, that can also be reached from the main page:
https://demutsertlab.wordpress.com/ngomex/workshop1/

b. Management outcomes – I. Management application or adoption of:

i. New fundamental or applied knowledge
ii. New or improved skills
iii. Information from publications, workshops, presentations, outreach products
iv. New or improved methods or technology.
v. New or advanced tools.
  - New growth rate potential models were developed for red snapper (*Lutjanus campechanus*) and Atlantic croaker (*Micropogonias undulatus*).
  - Growth rate potential modeling framework has been created in an open-source environment (R statistical software).

c. Management outcomes - II. Societal condition improved due to management action resulting from output (examples: improved water quality, lower frequency of harmful algal blooms, reduced hypoxic zone area, and improved sustainability of fisheries).

d. Partnerships established with other federal, state, or agencies, or other research institutions (other than those already described in the original proposal).

3. Expenditures:

a. Describe expenditures scheduled for this period; and

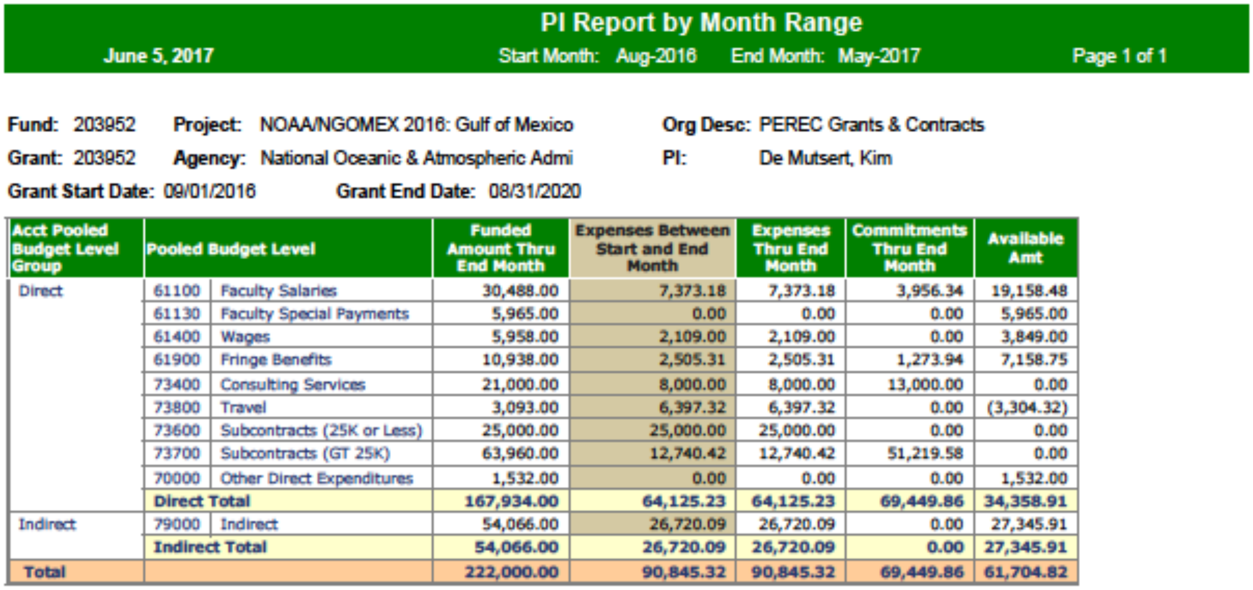
b. Describe actual expenditures this period.

Main grant:

The column "Funded Amount Thru End Month" in Table 3 below describes the expenditures scheduled for the first year. Note that the first year is until August 2017, not the end of the period covered by this report (which is May 2017). The column "Expenses Thru End Month" list the actual expenditures until May 2017.

The difference (surplus) in faculty salaries results from the fact that a new post-doc needed to be hired, which happened March 2017. What is available in post-doc salary will be used in year 2. Faculty special payments, and what is still available in wages, are schedule to be paid in summer 2017. One conference trip for Dr. de Mutsert to present in a relevant hypoxia session at ASLO was scheduled in year 1 rather than year 2, which resulted in going over travel allocation. This small deficit in the travel line item will be resolved in year 2. Consulting services are committed and either have been charged or are in the process of being charged during summer 2017. Details on the subcontract are listed below.

Table 3. Budget report main grant.



PI Report by Month Range

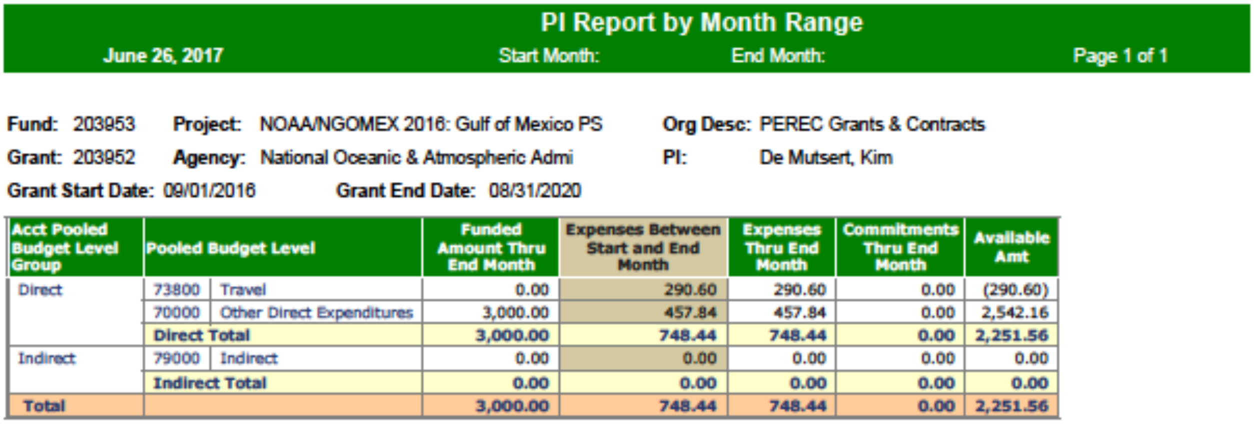
June 5, 2017 Start Month: Aug-2016 End Month: May-2017 Page 1 of 1

Fund: 203952 **Project:** NOAA/NGOMEX 2016: Gulf of Mexico **Org Desc:** PEREC Grants & Contracts
Grant: 203952 **Agency:** National Oceanic & Atmospheric Admi **PI:** De Mutsert, Kim
Grant Start Date: 09/01/2016 **Grant End Date:** 08/31/2020

Acct Pooled Budget Level Group	Pooled Budget Level		Funded Amount Thru End Month	Expenses Between Start and End Month	Expenses Thru End Month	Commitments Thru End Month	Available Amt
Direct	61100	Faculty Salaries	30,488.00	7,373.18	7,373.18	3,956.34	19,158.48
	61130	Faculty Special Payments	5,965.00	0.00	0.00	0.00	5,965.00
	61400	Wages	5,958.00	2,109.00	2,109.00	0.00	3,849.00
	61900	Fringe Benefits	10,938.00	2,505.31	2,505.31	1,273.94	7,158.75
	73400	Consulting Services	21,000.00	8,000.00	8,000.00	13,000.00	0.00
	73800	Travel	3,093.00	6,397.32	6,397.32	0.00	(3,304.32)
	73600	Subcontracts (25K or Less)	25,000.00	25,000.00	25,000.00	0.00	0.00
	73700	Subcontracts (GT 25K)	63,960.00	12,740.42	12,740.42	51,219.58	0.00
	70000	Other Direct Expenditures	1,532.00	0.00	0.00	0.00	1,532.00
	Direct Total		**167,934.00**	**64,125.23**	**64,125.23**	**69,449.86**	**34,358.91**
Indirect	79000	Indirect	54,066.00	26,720.09	26,720.09	0.00	27,345.91
	Indirect Total		**54,066.00**	**26,720.09**	**26,720.09**	**0.00**	**27,345.91**
Total			**222,000.00**	**90,845.32**	**90,845.32**	**69,449.86**	**61,704.82**

Table 4 shows the funds allocated to supporting our advisory panel and workshop participants attend meetings. Our first workshop was strategically planned during the 2017 Gulf of Mexico Oil Spill and Ecosystem Science Conference in New Orleans, Louisiana. Since the meeting space and facilities were provided free of charge, and most participants were planning on traveling to this conference, we have only needed a portion of our participant support budget. This will allow us to plan the next workshop in Miami, where we expect higher attendance of the NMFS SEFSC group located in Miami, which is are main target group for the hands-on component of workshop 2. A workshop in Miami will likely increase requests for travel support from other advisory panel members.

Table 4. Budget report participant support funding.



PI Report by Month Range

June 26, 2017 Start Month: End Month: Page 1 of 1

Fund: 203953 **Project:** NOAA/NGOMEX 2016: Gulf of Mexico PS **Org Desc:** PEREC Grants & Contracts

Grant: 203952 **Agency:** National Oceanic & Atmospheric Admi **PI:** De Mutsert, Kim

Grant Start Date: 09/01/2016 **Grant End Date:** 08/31/2020

Acct Pooled Budget Level Group	Pooled Budget Level		Funded Amount Thru End Month	Expenses Between Start and End Month	Expenses Thru End Month	Commitments Thru End Month	Available Amt
Direct	73800	Travel	0.00	290.60	290.60	0.00	(290.60)
	70000	Other Direct Expenditures	3,000.00	457.84	457.84	0.00	2,542.16
	Direct Total		**3,000.00**	**748.44**	**748.44**	**0.00**	**2,251.56**
Indirect	79000	Indirect	0.00	0.00	0.00	0.00	0.00
	Indirect Total		**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total			**3,000.00**	**748.44**	**748.44**	**0.00**	**2,251.56**

Subcontract detail:

May 31 marks the completion of 9 months of the first full year of this project. OSU Expenditures are right on schedule as described in the original proposal. In the original budget of $88,960, over 85% of costs were planned for salary for Brandt, Sellinger and a Postdoctoral Scholar, (C. Glaspie) and associated Fringe (OPE) and Overhead (F&A) with the balance for Travel and Supplies. There have been no unanticipated costs. We plan to spend funds as originally

allocated Salaries for Sellinger and Glaspie cover a percentage of their time and are paid monthly. Brandt's salary has not yet been charged and this will be paid during the summer months. A summary of expenditures and balance as of 31 May is listed in Table 5.

Table 5. Summary of expenditures Oregon State University subcontract.

	Expenditures by 31 May	Original allocation
Salaries	21,378.99	40,904.00
OPE	3,878.37	10,978.00
Supplies	782.07	1,935.00
Travel	5,645.12	6,700.00
F&A	14,891.70	28,443.00
Total	46,576.25	88,960.00

c. Explain special problems that led to differences between scheduled and actual expenditures, etc.

Prepared by:

K de Mutsert

6/29/2017

Signature of Principal Investigator Date

NOTICE

Subsequently, all NOAA COP recipients with approved grants will be asked to file a COP Project Final Report in the specified format upon expiration or termination of grant support. Consistency in reporting requirements for competitive research grant programs is desirable and this is behind COP's efforts in proposing a standardized format. The use of the Project Final Report format will provide the level of detail required to evaluate the effort invested by investigators and staff on project management; any actual accomplishments and research findings; and what goals and objectives were attained. The proposed final report format is compatible with the format in use by other agencies that participate in joint projects with COP, e.g. the National Science Foundation.

Public reporting burden for this collection of information is estimated to average 300 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed and completing and reviewing the collection of information.

Send comments regarding this burden estimate or any other aspects of this collection of information, including suggestions for reducing this burden, to the National Ocean Service, CSCOR/COP Office, 1305 East-West Highway, Silver Spring, MD 20910.

Grant files are subject to the Freedom of Information Act (FOIA).

Confidentiality will not be maintained--the information will be made available to the public.

However, unpublished research results shall not be published without prior permission from the recipient.

Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to comply with, a collection of information subject to the requirements of the Paperwork Reduction Act, unless that collection of information displays a currently valid OMB Control Number.