Name of Transition Project:
Untrawlable Habitat Strategic Initiative – Transitioning Optical Technologies to Improve Surveys for Red Snapper and Other Reef Fishes.

Name of Transition Leads and Team Members:
Matthew Campbell, Christopher Gledhill, Charles Thompson, Todd Kellison, Clay Porch

Name of Research Line Office:
NMFS

Name of R2X Recipient that project is transitioning to:
SEFSC

If internal to NOAA/NMFS, Name of specific Program and/or Region project is intended to transition to:
SEFSC

1. Purpose/Objective

Current surveys conducted in the Gulf of Mexico (GOM) provide measures of catch per unit effort (or, for videos, observations per unit effort) that can be compared over space and time, enabling the generation of relative abundance indices (Campbell et al. 2015). It would be preferable for the surveys to provide measures of the number of individuals per unit volume (i.e. density) that could be scaled-up to provide estimates of the total number of individuals in the stock. Management procedures that use observations of absolute abundance offer the best overall performance that is consistent across life history types, data qualities, and stock depletion levels (Carruthers et al 2015). The proposed transition project aims to operationalize a spherical camera system to improve density data for red snapper and other species. Integrating improved density estimates from video surveys that include data on the extent and distribution of reef habitats allow for such densities to potentially be scaled-up to absolute estimates of abundance (habitat-specific density x total area of habitat). Estimates of the absolute abundance of red snapper (and other reef fish) would improve stock assessments that otherwise must infer abundance indirectly based on the trends of the relative indices and uncertain catches.

The primary objectives for the transition plan are to (1) develop a capability of estimating true local density for red snapper and other reef fish species from video surveys, (2) classify the seabed that has been mapped, and use the resulting data to (3) scale-up to absolute abundance estimates. The generation of true density estimates from video surveys will require determination of the sampling volume, estimation of species specific detection probabilities, and estimation of the effect of gear attraction and avoidance. To accomplish the objectives the project will use a combination of spherical-cameras, stereo-cameras and acoustic telemetry to derive spatio-temporally coupled counts and densities. The fish density data will be further analyzed using a combination of distance sampling, and mark-recapture methods to deal with uncertainties associated with detection probability and to adjust density estimates (Burt et al. 2014, Barry and Welsh 2001, Barabesi and Fattorini 2013).

2. Research background

The generation of relative indices tells you something about the relative annual changes in abundance but those are not easily translated to estimates of population size. Indices (i.e. catch rates, I) are related to biomass (B) by assuming a linear relationship with the catchability coefficient (q) calculated as: $I = q * B$ (Maunder and Starr 2003). Unfortunately this relationship has been shown in many contexts to be nonlinear and q is either poorly estimated or assumed (Bannerot and Austin 1983, Harley et al. 2001, Hilborn and Walters 1992, Erisman et al. 2014, Campbell et al. 2015). Estimates of biomass are therefore uncertain and thus relative indices could be thought of as ascending or descending a ladder from an unknown starting point. Therefore if total abundance and/or biomass could be estimated directly then the issues associated with the index-biomass relationship and estimation of q become less problematic.

In the GOM, there are currently three fishery-independent surveys that provide indices of relative abundance for red snapper:(1) a shrimp/groundfish bottom trawl survey conducted along the GOM shelf provides a relative index of abundance for Age 0 and Age 1 red snapper, (2) a stationary baited stereo video camera survey provides an index for Ages 4-8 red snapper located on natural reefs, and (3) a bottom longline survey provides an index for age 8-50 red snapper located over low relief mud/sand bottom (SEDAR 2013). These Gulf-wide surveys are designed to sample a variety of fish species located in different depths and habitats and are an essential component of GOM stock assessments. The surveys described above provide measures of catch per unit effort that are then used to derive relative abundance indices. Relative abundance indices estimated from fundamentally different gear types can be compared because the indices themselves can be standardized and become unit-less. However, this model of population assessment is still reliant upon some understanding of how the indices themselves relate to abundance/biomass and this relationship is not well established (Pope and Garrod 1975).

Stationary baited video camera surveys for reef fish are conducted by the SEFSC in the GOM and the South Atlantic (Schobernd et al. 2014, Campbell et al. 2015). The observational count data (i.e. not density data) from these surveys provide indices of abundance for multiple species of reef fish for use in Southeast Data, Assessment and Review (SEDAR) stock assessments for federally managed species (e.g., gag grouper, red grouper, and red snapper). While conceptually simple, estimation of density for the current deployment protocols is impossible because of the inclusion of bait and because of the restricted field-of-view (FOV) of the cameras. These two factors create a situation where the effective sampling area is not equal to the calculated sampling area (i.e. bait concentrates local densities over unknown distances, Cappo et al. 2006) and the spatial distribution of fishes around the cameras themselves are heavily influenced by local habitat, behavior, current direction and speed (Bacheler et al. 2013, Campbell et al. 2015). In other words, to enable the estimation of density we have to remove the effect of bait (or at least understand it better) and develop cameras that can view in all directions simultaneously while maintaining the ability to restrict counts within a known volume.

In FY14 and 15 the NMFS Advanced Science and Technology Working Group (ASTWG) funded the untrawlable habitat strategic initiative (UHSI) to execute a testbed study designed to evaluate the performance of transitional advanced technologies. This study included a testbed range of acoustic and optical sensors to measure sampling performance and fish reactions to alternative sampling platforms (e.g. stationary, AUV and towed optical systems) in untrawlable habitats (e.g. reef). Results from the first two years of the UHSI experiment are still being analyzed however coincident volumes have been established between the acoustic and optical gears giving reason to be optimistic that estimation of q for the stationary cameras is possible. While the experiment has shown a path forward for estimation of q, the value is still calculated against an unknown standard because prior densities in the testbed were not established. The scope of the UHSI experiment precluded the inclusion of a mark and recapture or an acoustic tagging component which would have enabled estimation of a detection probability function and a basal density in the test bed. Inclusion of acoustic telemetry in this study will enable this and the ability to estimate emigration/immigration and attraction/avoidance to the stationary camera gear.

In FY14 and FY15, the ASTWG funded a separate project to determine the feasibility of using an AUV with a side-scan sonar payload to expand the capability of mapping during annual reef fish surveys conducted by the SEFSC. An Iver AUV with side-scan sonar payload was acquired and tested successfully in FY14. In FY15, Iver AUV mapping off the U.S. South Atlantic (SA) coast was conducted during the SEFSC Southeast Fishery Independent Survey for reef fish conducted by the Beaufort Laboratory, and during the SEAMAP reef fish survey in the Gulf of Mexico (GOM) conducted by the Mississippi Laboratories. Results from this work indicate the AUV is producing high quality mapping products and is geared up for full production deployment on standardized surveys. Acoustic mapping is time consuming and therefore the deployment of the AUV is also boosting the efficiency of our surveys because multiple jobs are conducted simultaneously. More importantly habitat mapping and characterization is the cornerstone by which fish densities can be scaled up to basin wide estimates of absolute abundances.

Integrating improved density estimates from video surveys that include data on the extent and distribution of reef habitats allow for such densities to be scaled-up to absolute estimates of abundance (habitat-specific density x total area of habitat). Estimates of the absolute abundance of red snapper (and other reef fish) would improve stock assessments that otherwise must infer abundance indirectly based on the trends of the relative indices and uncertain catches.

This project will conduct a testbed on natural and artificial reefs in the GOM to calibrate video-derived estimates of fish density with estimates of true density determined using a combination of distance sampling and mark and recapture techniques. The ultimate goal is implementation of a new unbaited spherical-camera system to estimate reef fish density, which may be extrapolated to absolute abundance over reef habitat. The project will also incorporate an AUV to characterize habitat types and evaluate spatial heterogeneity at testbed sites.

3. Business case

The proposed project will transition NOAA/NMFS R&D on a spherical camera system to improved NOAA/NMFS fishery independent survey operations for reef fish in the Gulf of Mexico. The target system is the SouthEast Data, Assessment, and Review (SEDAR) which is the cooperative process by which stock assessment projects are conducted in NMFS Southeast Region. This project addresses NOAA's 5-year plan for: 1) Healthy Oceans; marine fisheries, habitat, and biodiversity are sustained within healthy and productive ecosystems; and 2) Accurate and Reliable Data from Sustained and Integrated Earth Observing Systems. This proposal also addresses the announcements area of focus: Resource Stewardship and

Management and Testbeds, and NOAA priorities relevant to the SRGM Ocean System Optimization and AGM Provide Information and Services to Make Communities More Resilient.

Matthew Campbell, Charles Thompson, Christopher Gledhill and Clay Porch from NMFS SEFSC will conduct the research to test a spherical/stereo camera system. Habitat classification of the mapped and groundtruthed regions of the GOM will be conducted by Brandi Noble (NMFS SEFSC). The SEFSC will be the recipients of the camera system. End users of the data to conduct red snapper stock assessments will be the SEFSC Sustainable Fisheries Division, Gulf of Mexico and Caribbean Branch led by Shannon Cass-Calay. Information from the SEFSC red snapper stock assessment will be provided to the Gulf of Mexico Fishery Management Council, the Gulf States Marine Fisheries Commission, and Gulf states to improve management of red snapper stocks throughout the Gulf of Mexico.

Stock assessments of red snapper and other reef fish typically estimate the number of fish in the population indirectly through the use of statistical models that integrate information from relative abundance indices, catches and other data that are subject to a variety of uncertainties (SEDAR 2013). Consequently, the status of these stocks relative to overfishing reference points and the level of catch that will prevent overfishing is difficult to quantify. The Magnuson-Stevens Reauthorization Act and associated guidance requires characterization of and mitigation for scientific uncertainty in the management process. This most often comes in the form of buffers that impact the size of annual catch limits, and as such, can have large economic consequences to the fishing industry. Estimates of absolute abundance would reduce uncertainty in the stock assessment and improve our ability to monitor the status of red snapper and other reef fish relative to the fishery management plans of the Gulf of Mexico Fishery Management Council. Improved fisheries management may result in greater commercial and recreational fishing opportunities, which provide an important component of the GOM economy.

The final products of this study will be estimates of reef fish density along with absolute abundance estimates of Ages 4-8 GOM red snapper, and the use of these improved estimates in GOM red snapper stock assessments. Information from improved red snapper stock assessments will be presented to the Regional Fishery Management Councils for use in developing fishery management strategies. This approach would represent a fundamental shift in the conduct of stock assessments in the GOM. Success of the methods used in the project will be determined by their use in the SEDAR process. An additional measure of success will be adaptation of this approach in other ecosystems and fishery management council jurisdictions.

4. Capabilities and Functions

The technology improvements to be tested are presently at RL-5. Video camera surveys have been conducted since 1992, with stereo cameras added in 2001. A spherical camera system will be tested in 2016. The level is expected to be at RL-6 at the end of FY17 with testbed work to generate fish density estimates from the camera system using acoustic transponders and tagging. This can be moved to RL-8 with additional test bed experiments using the requested FY18 funds, and fully implemented into improved survey operations RL-9 after a third year of funded test bed experiments in FY19. Transition funding will provide the resources and sea time to conduct experiments to calibrate estimates of fish abundance from current stereo cameras, and fish density determined from a spherical/stereo system with estimates of local fish density.

Experimental work would require an additional three to four years without transition acceleration funding.

5. Transition Activities:

Implementation Plan

In FY17, spherical/stereo camera systems will be assembled, acoustic telemetry equipment will be acquired and fisheries biologists will be hired. Initial test bed locations will be selected (artificial and natural reefs) and the acoustic tagging and mark and recapture portion of the experiment will be initiated. Once sufficient numbers of fish have tagged the acoustic telemetry equipment will be set up and camera drops in the selected testbed sites will be conducted. Upon completion of field work the videos will be analyzed and estimates of sampling volume, mean fish densities, and fish size and age calculated. Mark and recapture testbed work will assess the relationship(s) between video-measured densities and true densities using multiple concurrent approaches, including mark and recapture (Pollock et al. 2002), distance sampling and acoustic telemetry on natural and artificial reefs. Red snapper will be collected to determine the age distribution of video-surveyed fish. Habitat at testbed sites will be classified using an AUV equipped with a side-scan sonar. Habitat will be classified using available GOM multibeam sonar and side scan sonar data. Initial absolute abundance estimates of test bed sites will be estimated using the densities and habitat maps.

To prevent interruption of the ongoing video survey time series that use baited systems, a subset of experimentation will include baiting the camera systems. We will use the acoustic tags to evaluate the differences in attraction to baited and unbaited systems that will allow for better understanding of the effective sampling area of baited systems. This comparison is required to calibrate the new approach against the current sampling approach (use of baited camera systems) to protect the integrity of the 24-yr time series. We intend to begin simultaneous deployment of the current camera systems and the spherical camera systems in FY16 during the SEAMAP reef fish video survey of the GOM (MS Labs currently has a test spherical system).

In FY18 and FY19, spherical/stereo camera systems will be repaired or replaced and the testbed experiments repeated to reach a level of replicated experiments needed to determine statistical significance. The work to classify habitat along the GOM shelf will continue using multibeam sonar data collected during annual reef fish surveys. Coupled with the true density estimates emanating from the work described in the previous paragraph, the improved estimates of habitat distribution will enable scaled-up estimates of absolute abundance (perhaps bounded within specific age classes).

Identify any testbed and proving ground that will be involved

This project will conduct a testbed on natural and artificial reefs in the GOM to calibrate video-derived estimates of fish density with estimates of true density determined using mark and recapture techniques. Experiments will be conducted at selected sites along the Gulf of Mexico shelf. A NOAA testbed will not be used.

6. Schedule and deliverables

Milestones

FY17	Milestone
1st to 4th quarter	Habitat classification using multibeam sonar data collected in FY16 during SEAMAP reef fish survey
2nd or 3rd quarter depending on release of funds	Acquisition of equipment and supplies
	Hiring of contractors
3rd quarter	Multibeam sonar mapping during SEAMAP reef fish survey. Habitat classification.
3rd or 4th quarter	Assembly of camera systems
3rd or 4th quarter	Field experiments
4th quarter	Data analysis and Annual report
FY18	
1st to 4th quarter	Habitat classification using multibeam sonar data collected in FY16 during SEAMAP reef fish survey
1st or 2nd quarter depending on release of funds	Acquisition of equipment and supplies
3rd quarter	Multibeam sonar mapping during SEAMAP reef fish survey. Habitat classification.
3rd quarter	Field experiments
4th quarter	Annual report
FY19	
1st to 4th quarter	Habitat classification using multibeam sonar data collected in FY16 during SEAMAP reef fish survey
1st or 2nd quarter depending on release of funds	Acquisition of equipment and supplies
3rd quarter	Multibeam sonar mapping during SEAMAP reef fish survey. Habitat classification.
3rd quarter	Field experiments
4th quarter	Annual report

Mechanism for updating the plan
Project PIs will meet quarterly to discuss progress and issues to address. At that time milestones will be evaluated against proposed timeline and adjustments to the plan made if needed.

7. Roles and Responsibilities (for the TRANSITION)
NOAA/NMFS/SEFSC scientists Dr. Matthew Campbell, Dr. Christopher Gledhill, Dr. Todd Kellison, Dr. Clay Porch and Charles Thompson will lead the research to test a spherical/stereo camera system, and will deploy the system once testing is completed. End users of the data will be the NMFS/SEFSC Sustainable Fisheries Division, Gulf of Mexico and Caribbean Branch led by Dr. Shannon Cass-Calay.

8. Budget overview

8.1. Cost of current system: The current stereo cameras cost $16,000 each to assemble. The camera array that is deployed at sample sites uses four stereo cameras mounted orthogonally. The total cost of the array is $68,700 (aluminum array, underwater battery and cameras). We have two complete stereo arrays. Annual maintenance is $25,000.

8.2. Cost of transition: Transition costs include assembling spherical/stereo camera systems, stitching software, conducting experiments to compare the current stereo cameras with new spherical/stereo cameras (with, and without bait), and conducting experiments to generate fish density estimates from the spherical/stereo camera system. Experiments will require the use of tagging, acoustic telemetry and sea time. The costs would require $80,000 per year over the next eight years. This does not include the use of acoustic telemetry, which would add $60,000 each year.

- 8.3. Cost of operational system and maintenance: Operational costs will depend on the development of automated image processing to identify and count fish from video images. Failure of completion of an automated image analysis toolbox to identify and count fish would lead to either additional programmatic costs (additional personnel) or delays in obtaining estimates of abundance. The spherical/stereo camera system uses GoPro cameras with a total cost of $16,000. Annual maintenance is expected to be $15,000.

9. Impacts of Transition

Budget--- spend plan

	FY17	FY18	FY19
A. Personnel			
Contract Fishery Biologists			
Salaries (loaded rates)	$440,000	$453,000	$466,000
NOAA Fisheries (in kind)			
20% Time capped ZP-III (four)	*$73,710*	*$73,710*	*$73,710*
10 % Time capped ZP-IV supervisors	*$27,479*	*$27,479*	*$27,479*
B. Equipment			
Cameras/Housings	$32,000	$32,000	
Camera Repair/Replacement	$10,000	$10,000	$10,000
Vemco Telemetry	$60,000	$60,000	$60,000
Supplies	$10,000	$10,000	$10,000
Software -Multibeam Sonar processing	$10,000		
C. Vessel (40 sea days)	$200,000	$210,000	$220,000
D. Travel.	$10,000	$10,000	$10,000
Totals (Does not include NOAA salaries)	$772,000	$785,000	$776,000

Budget Justification:
Personnel: Contract fishery biologists will be required to conduct experiments at sea, view videos, and analyze data. Salary and overhead are needed for four Fishery Biologist – I positions and one Fishery Biologist III position. Costs also include estimated overtime to conduct field work.

Equipment: Equipment includes cameras and underwater housings to assemble two spherical camera systems each year. Repair and replacement costs for cameras are included since they will be used in a rugged environment. The cost for VEMCO telemetry equipment includes transponders, receiving stations and positioning system. Supplies include materials to assemble frames for cameras, line and tags. Multibeam processing software is required to classify the seabed using multibeam and side-scan sonar data.

Vessel: Costs are $5,000 per day for 40 sea days, with a 10% increase each year.

Travel: Travel is needed for swapping out personnel during field work.

Risks and mitigation
Implementation of this project will produce a large amount of video images requiring either automated image processing, which is under development, or an increase in staff to identify and count fish. Image processing will include identification (to species or lowest possible taxonomic level) and enumeration of fish, as well as measurement of ranges to fish and objects near the seabed to estimate the volume of water sampled by the cameras. This additional processing, if not automated, will require additional labor and associated labor costs.

Technical risks include system failure, flooding of cameras, and the loss of cameras. These can be mitigated by developing redundant systems with multiple backups.

Programmatic risks: The Gulf of Mexico shelf has not been completely mapped. The location of all natural reefs is incomplete. Reef fish densities expanded will only be an estimate of the abundance on known natural reefs and therefore a minimum estimate of total abundance. The inclusion of artificial reefs into a survey will be hampered by entanglement of gear and poor visibility. Estimates of abundance over known natural reefs means it would remain a relative index of abundance or else would have to be handled in the assessment as a lower bound, requiring some reprogramming.

10. References
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11. Signature page

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