Science Consortium for Ocean Replenishment (SCORE)
Semi-Annual Progress Report
for the period 1 July through 31 December 2007

Submitted to NOAA / NMFS

Submitted by
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Mote Marine Laboratory

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Semi-Annual Progress Report
To National Marine Fisheries Service, NOAA, DoC
Reporting on Activities in the Unallied Science Project:
DFDA No. 11.472

Science Consortium for Ocean Replenishment (SCORE)

(Multi-Year) Award Number NA04NMF4720434
For the period 1 July through 31 December 2007

Brief Project Overview:

The Science Consortium for Ocean Replenishment (SCORE) is a science-based approach to stocking hatchery-reared marine organisms to help rebuild depleted marine fisheries (marine fisheries enhancement). SCORE scientists are conducting research to resolve critical uncertainties about the effectiveness of culture-based marine enhancement as a fishery management tool. It is anticipated that significant progress will be made by SCORE scientists, leading to greater and greater success from marine enhancement programs in the U.S.

As scientific gains are made in understanding the potential, SCORE scientists have partnered with NMFS and regional fishery-management agencies to develop policy and apply fishery-enhancement science to rebuilding depleted coastal stocks. Linkages with local fishing communities provide the cadre of citizens needed to support and expand enhancement as a fishery management strategy. Much of the enhancement technology developed here will be supported by funds generated by contributions and license fees paid by stakeholders and user groups. To fully embrace and use stocking as a marine enhancement management tool, demonstrated success stories are needed in a few key states. SCORE research is planned and coordinated to achieve such successes. Built around the principles of "a responsible approach to marine stock enhancement" (Blankenship and Leber; and see Leber, 2002, 2004), SCORE scientists are conducting key experiments to resolve critical uncertainties about how to control the biological, ecological, and economic effectiveness of marine fisheries enhancement.

SCORE is an R&D initiative conducted by a consortium of national partners. It is a powerful alliance of scientists and fishery managers currently working in the field of marine stock enhancement in the U.S.A., which encourages improved utilization of their expertise and resources. Bringing these scientists and managers together through SCORE allows synergisms to develop that would not occur otherwise.

Multi-Year Contract Period and Relation to this Reporting Period

This Multi-Year contract commenced on July 1, 2004 for the 5-year period ending June 30, 2009. The funding period for the current year of the Multi-Year contract began on July 1, 2006. This interim report covers progress made during the period July 1, 2007, through December 31, 2007.

Project Accomplishments:

This no-cost extension period was needed by all four principal partner institutions to provide additional time needed to complete and publish the work done under this contract.

Mote Marine Laboratory Progress – July through December 2007

Aquaculture Research to Develop Rearing Technology for SCORE Species:

Controlled Maturation and Spawning of Common Snook

Maturation Trials

Throughout 2007, we continued our research using environmental manipulation to spawn captive snook on a routine basis at Mote Aquaculture Park (MAP). Three large tanks (54.3 m^3 per tank) were stocked with mature adult snook. These snook were wild caught fish that have been held in captivity since either the summer of 2003 or 2005. Of the three broodstock tanks, only two tanks (20-1 and 20-3) were included in trials to manipulate temperature and photoperiod to induce maturation.

In 2007 several modifications were made including those to total number of fish in a given spawning population; sex ratio; broodstock sampling schedule; diet; and photoperiod. Snook broodstock were sampled every six weeks, which varies from last year's monthly sampling, allowing the broodstock more time to recover from handling stress. Additional changes include those to tank populations. In early 2007 adjustments were made to the tank populations; and at present both 20-1 and 20-3 are each stocked with 14 fish (7 males, 7 females). Modifications were also made to the snook broodstock diet (fresh diet injected with vitamin premix emulsion; fresh soft moist pellet with vitamin premix; and encapsulated vitamin premix and arachidonic acid (ARA) in fresh diet). The encapsulated vitamin was designed to be placed in the fresh broodstock diet. This "vitamin pill" contains ARA, an essential fatty acid thought to be lacking in sufficient quantities in the fresh feed alone. A mean weight per each pill was identified and pills were added at 4% of the dry biomass of the fresh feed (3% vitamin premix and 1% ARA). This is being used to ensure that adequate levels of vitamins and nutrients are being administered to the snook broodstock for gonadal maturation and the production of high quality eggs. Lastly, artificial lunar illumination adjustments were made to both tanks; the lunar phase inside each room mirrored the natural phase occurring outside. Photoperiod for each tank was controlled by a Solar 1000 unit (Blue Line Products, Ambler, PA). The Solar 1000 series of light dimmers are microprocessor-base controllers designed to simulate solar and lunar events. They are compatible with incandescent lamps (lunar) and VHO lights (solar) using IceCap electronic ballasts (IceCap ™, Inc., Hamilton, NJ).

In late September, after the elongated seven month summer cycle (30°C and photoperiod of 13 hr light and 11 hr dark), the fish were cycled slowly back into a winter cycle. The winter cycle started by gradually decreasing the water temperature from 30°C to 24°C over 2 weeks and remained at this temperature for 2 months. A photoperiod of approximately 11 hr light and 13 hr dark was set for the winter, naturally occurring in our area. Upon completion of the winter cycle (November) the temperature was increased gradually over the course of 2 weeks to 26°C where it was maintained at a spring photoperiod at 12 hr light to 12 hr dark for one month in December.

Spawning Trials

In review of 2007, March marked the first sampling of the captive snook spawning season. This spawning event was significant because it occurred 2 months before the natural spawning season. In May, slow and regular release type implants were used (gonadotropin releasing hormone analogue - GnRHa). GnRHa implants were provided by the Center for Marine Biotechnology (COMB) and we regularly consulted with John Stubblefield of COMB on implantation strategies. Twelve females were implanted with regular release GnRHa (6 females in 20-1 and 6 females in tank 20-3) and two were implanted with slow release GnRHa (1 female in 20-1 and 1 female in 20-3); all at a dosage of 50 $\mu g\ kg^{-1}$. The fourteen males sampled from tanks 20-1 and 20-3 were treated identically, but at a lower dosage of 25 $\mu g\ kg^{-1}$. In June, seven females and six males from tank 20-3 were implanted with regular release GnRHa and seven females and seven males from tank 20-1 were implanted with slow release GnRHa. More detailed information on spawns in March, May and June were previously reported. Summarized data from all of the spawns can be viewed in Table 1.

July was last sampling of 2007 for both 20-1 and 20-3 broodstock tanks. Injection types were reversed from June with 20-3 receiving the slow release implants and 20-1 receiving the normal release GnRHa implants. Doses also remained consistent with females receiving 50 $\mu g\ kg^{-1}$ and males at 25 $\mu g\ kg^{-1}$. Snook only spawned one day post-implantation in tanks 20-1 (16,750 eggs) and 20-3 (379,500 eggs). The fertilization rate for 20-1 was 70.1% with a 0.0% hatch rate and 69.2% fertilization rate and 100% hatch rate for 20-3 (Table 1). All of the larvae from the spawn in 20-3 were shipped to Dr. Joan Holt at University of Texas Marine Science Institute (UTMSI) and to Matthew Wittenrich at Florida Institute of Technology (FIT) for collaborative research.

Table 1. Results from the 2007 spawns from both snook broodstock tanks (20-1 and 20-3) including fertilization and hatch rates for each spawn; type of gonadotropin releasing hormone analogue (GnRHa) implant; total number of eggs collected; and number of fertilized eggs.

Tank 20-1

	March		May			June			July
Date of Spawn	3/21/2007	3/22/2007	5/4/2007	5/5/2007	5/6/2207	6/17/2007	6/18/2007	6/19/2007	8/1/2007
Type of GnRHa Implant	regular	regular	regular & slow	-	-	slow	slow	slow	regular
Total # Eggs collected	255,550	529,333	187,733	-	-	210,000	248,667	74,667	16,750
Total # Fertilized eggs	47,500	254,667	61,233	-	-	N/A	107,667	12,000	11,750
Fertilization Rate (%)	18.6	48.1	32.7	-	-	N/A	43.1	16	70.1
Hatch Rate (%)	12.5	55.8	0	-	-	N/A[1]	N/A[1]	3.5	0

Tank 20-3

Type of GnRHa Implant	regular	regular	regular & slow	regular & slow	regular & slow	regular	regular	regular	slow
Total # Eggs collected	667,650	365,117	1,305,067	382,400	1,293,333	844,767	338,600	226,000	379,500
Total # Fertilized eggs	106,717	264,773	1,138,667	317,600	586,667	486,200	176,533	187,333	266,167
Fertilization Rate (%)	16.0	72.6	87.2	83.4	45.5	55.8	52.1	82.8	69.2
Hatch Rate (%)	0	83.1	98.6	69.1	92.4[2]	N/A[3]	N/A[3]	82.6	N/A[1, 2]

[1] Shipped to FIT
[2] Shipped to UTMSI
[3] Stocked at MAP-No hatch rate available

Northwest Fisheries Science Center Progress – July through December 2007

The activities conducted during this time frame were all related to data-base development, data logging, data reduction, and data analysis / statistical evaluation of SCORE studies conducted over the course of the contract period. Also, several of the studies are now in various stages of publication in scientific journals, with much attention given towards publishing during this reporting period. Powerpoint presentations for scientific conferences were also prepared during this period.

University of New Hampshire Progress – July through December 2007

The long-term goal of our winter flounder stock enhancement program is to accelerate recovery of the fishery by increasing spawning stock biomass. To meet this goal, we have developed a multidimensional research program designed to produce large numbers of high quality juveniles, to optimize release strategies, and to understand how developmental morphology and live feed conditioning affects post-release survival of juvenile winter flounder. Elements of the program addressed in this reporting period have included:

Fish Production:

The wild-caught winter flounder broodstock was brought into the Coastal Marine Laboratory (CML) in March. Larvae were used in developmental morphology studies. Juvenile fish were used for weaning experiments and field trials in the summer and fall. Several hundred juveniles are being maintained for spring studies.

Temporal and Spatial Distribution of Juvenile Winter Flounder in the Estuary:

The objective of this study was to identify the areas within the estuary where juvenile fish are found and when, to characterize their habitat, and to study their temporal and spatial use of the estuary. To accomplish this goal, juvenile winter flounder were anesthetized, fitted with acoustic tags (VEMCO V7-2L-R256 coded pinger tags), and released. Each acoustic transmitter emitted a distinctive coded pulse (frequency 69 khz) that was detected by a hydrophone, thereby allowing the fish's location to be accurately determined, and the fish's movements to be tracked over time.

Sediment analyses where cultured and wild agel fish were located were completed during this reporting period. Sediment grain size composition analyses were processed according to protocol developed by Folk (1980). The mean percent gravel, sand, clay, and silt of the sediments at the location where fish were released and the locations where cultured and wild fish were found are reported below.

	Gravel		Sand		Silt		Clay		
Location	mean	sd	mean	sd	mean	Sd	mean	sd	n
release site	0.031	--	0.928	--	0.005	--	0.035	--	1
cultured fish	0.003	0.004	0.942	0.021	0.007	0.466	0.049	0.415	5
wild fish	0.012	0.011	0.956	0.001	0.001	0.548	0.031	0.316	3

Percent sediment composition data were arcsine transformed (Zar 1996). Differences in particle sizes between the sites where cultured and wild fish were found were tested with analyses of variance. No significant ($p>0.05$) differences were found between any of the grain size fractions. These results indicate that released cultured winter flounder will inhabit the same sediment types as similarly-sized wild fish.

A final synopsis of the home ranges, dispersal patterns, and habitat associations of tagged cultured and wild juvenile winter flounder was presented in October 2007 at the Second International Symposium on Tagging and Tracking Marine Fish with Electronic Devices in San Sebastián, Spain. We plan to publish this study in the conference proceedings.

Developmental Morphology and Weaning Studies:

A major challenge of any captive rearing program, whether for aquaculture or stock enhancement, is providing the appropriate diet regimes during development. Typically marine fish larvae are initially fed live food (e.g. rotifers, *Artemia*), and are then weaned onto formulated diets as they attain a size or developmental state that supports consumption of formulated diets. Weaning onto formulated diets is a stressful time for cultured fish, and this is especially true for flatfish that are concurrently undergoing dramatic morphological and physiological transformations associated with metamorphosis. Weaning occurs twice for fish that are used for stock enhancement; the second time occurs as they transition from formulated hatchery feed back onto live diets after release. To successfully wean fish for stock enhancement during these sensitive early life stages, we need to fully understand the ontogenetic development of the digestive system. We also need to identify diets that will optimize weaning success in the laboratory and minimize the effects of subsequent weaning in the wild. Finally, we need to examine the transition onto natural diets once reared individuals are released and investigate dietary differences between recently released and wild stocks. To begin to address these areas, the following studies were continued during this period.

Describing the development of the digestive tract of winter flounder:

The morphological changes of the digestive system and its associated structures from hatching through the post-metamorphic juvenile period are being described. Fish were sampled on a schedule covering the entire early life-history period. Individuals were sampled daily from 0 (hatching) to 20 DPH, three times per week from 20 to 40 DPH, and sampled once a week from 40 DPH to 80 DPH. For histological examination of the gut, five specimens were fixed in modified Davidson's solution on each sampling occasion. Gut epithelial cell development (stomach and intestine) will be observed using

light microscopy at various magnifications. An additional five specimens on each sampling occasion were preserved in 10% buffered formalin for examination of the morphometric changes in the digestive tract. The digestive organs will be digitally photographed under a microscope for relative size and orientation measurements (esophageal, stomach, and intestinal length, shape and area).

Examining weaning success of juvenile winter flounder:

We will determine how live diet regimes affect the success of weaning as indicated by growth rate and survival in juvenile winter flounder. Ninety, newly-settled, 55 dph juveniles were distributed on 28 June 2007 into each of nine 20-l flow through, circular tubs (46 cm dia. x 32 cm deep; 10 individuals per tub) and fed one of three different weaning diets (three replicates per weaning diet):

1) formulated commercially available microparticulate diet (Skretting "Gemma")
2) live white worms (*Enchytraeus albidus*)
3) control (no weaning - continued *Artemia*).

Fish were fed three times daily to satiation (approximately 10-15% of body weight/day). Water temperature, salinity and dissolved oxygen were monitored daily. In addition, in each tub, excess food was removed, and 30-50% of the water was siphoned out and replaced each day. A subsample of three fish/tank was measured and weighed weekly. Mortalities were removed daily. Weaning success will be measured throughout the five week experiment by examining specific growth rates and survival. Differences among treatments in specific growth and survival among the three weaning diets will be assessed with MANOVA followed by individual one-way ANOVAs (repeated measures design) and a Tukey's Post Hoc Test. In addition, a subsample of fish from each experimental unit (tub) and a sample of similarly-sized wild-caught fish from New Castle, NH were snap-frozen on dry ice and sent to the NMFS Milford Laboratory for RNA/DNA analyses as part of a collaborative research project.

A second similar, but preliminary, experiment was conducted during this reporting period. In it, fish were fed marine amphipods or grindal worms. The experiment will be analyzed and likely repeated in 2008.

Examining onset of wild weaning in pellet-reared fish

We will determine the onset of weaning onto natural diets in the wild as indicated by the presence and type of food in the gut and by gut fullness. Pellet-reared fish (45-65mm TL) were released in 90cm x 60cm x 45cm cages (N=10 fish per cage) in a mud-silt bottomed, eelgrass cove of the Piscataqua River Mouth, New Castle, New Hampshire. Fish were starved 24 hours prior to release to allow evacuation of the gut and to invoke hunger. Preliminary trials indicated that fish began feeding in the wild within 48 hours of release; therefore, cages were retrieved every 3 hours up to 51 hours post release (=17 cage retrievals). Fish were immediately frozen for later gut analyses. Wild fish of similar size were collected by seine net near the release site for dietary comparison. This protocol

was repeated in the Hampton-Seabrook estuary, 17 miles south of the initial release site where wild fish are more abundant; however, sediments are courser (silt-sand) and include scattered mussel beds.

Creating a Specific Diet for Winter Flounder:

No species-specific diet exists for winter flounder; we use a standard coldwater marine finfish diet produced by Skretting. In August, we began a cooperative venture with Cargill to formulate and manufacture a US made diet specific to winter flounder. Cargill's beta test diet did not perform as well as the Skretting diet; fish fed Skretting diet grew larger and faster than fish fed the beta test diet. Texture was a noticeable difference between the diets with the Cargill diet being rougher than the Skretting diet. We anticipate repeating this feeding trial in summer 2008 with a different formulated Cargill beta test diet.

Outreach:

In November, juvenile winter flounder were donated to the Seacoast Science Center in Rye, NH, an educational organization that focuses on coastal environmental history and exhibits. The flounder are being used in a "creature feature" display on indigenous fishes of the Gulf of Maine. Information about on-going winter flounder stock enhancement research at UNH is provided at the exhibit.

In December, approximately 200 juvenile fish were given to Rich Bell, a Mater's student at the University of Rhode Island. These fish will be used in a variety of aquaculture-related experiments.

Presentations:

Fairchild, E. A., N. Rennels, and W. H. Howell. 2007. Movements and habitat use of cultured and wild juvenile winter flounder *Pseudopleuronectes americanus* in a shallow estuary. Second International Symposium on Tagging and Tracking Marine Fish with Electronic Devices. October 8-11, 2007, San Sebastian, Spain.

Walsh, M. L. and W. H. Howell. 2007. Winter flounder movements off southern New Hampshire. Second International Symposium on Tagging and Tracking Marine Fish with Electronic Devices. October 8-11, 2007, San Sebastian, Spain.

Publications:

Fairchild, E. A., J. A. Sulikowski, N. Rennels, W. H. Howell, and C. W. D. Gurshin. (In Review). Distribution of winter flounder, *Pseudopleuronectes americanus*, in the Hampton-Seabrook Estuary, New Hampshire: observations from a summer field study.

University of Southern Mississippi Gulf Coast Marine Laboratory
Progress – July through December 2007

Objective 1: Select appropriate species

Workplan summary:
The seatrout's status as the most popular recreational fish in the Gulf of Mexico combined with its dependence on threatened inshore habitats make it potentially vulnerable to depletion. As such, USM along with the Mississippi Department of Marine Resources and recreational angling groups formed SPEC, the Seatrout Population Enhancement Cooperative, in 2004 to investigate the feasibility of using stock enhancement as an additional tool for management of the seatrout population in Mississippi.

Activity:
No activity this time period.

Objective 2: Define Goals and Objectives of Enhancement, incorporating Regional Stock Rebuilding Goals

Workplan summary:
The goal of SPEC is to develop the technology for culture and release of seatrout to determine whether or not stock enhancement is a feasible option for management of seatrout populations in Mississippi. Should stock enhancement be shown to be a feasible option, the tool, along with creel and season limits, will be added to the Mississippi Department of Marine Resources' options for managing the seatrout population in Mississippi waters.

Activity:
No activity this time period.

Objective 3: Develop a Genetic Management Plan

Workplan summary:
Current objectives involve applying microsatellite markers known to be of use for seatrout to Mississippi seatrout to establish the population structure. Until the population structure is elucidated, hatchery procedures will involve using broodstock from a single site, releasing juveniles in the same site, and periodic rotation of broodstock to maintain genetic diversity. As the technology is developed, the genetic makeup of juveniles for release will be evaluated and the population structure of the receiving population will be monitored for changes. The development of a genetic tag that will allow tracing of a fish's contribution to the wild population is desirable.

Activity:
A broodstock population from a geographic locality separate from the sites of our current work was collected. Approximately 75 females and 25 males from St. Louis Bay, MS were placed into quarantine in December and should be available for populating a

maturation and spawning tank by Feb 2008. Also, approximately 25 adult fish (males and females) from our current site were collected and quarantined in December for use in rotating approximately 25% of the current broodstock population. The two groups will treated as separate populations pending completion of genetic analyses.

Objective 4: Develop Culture Technology

Workplan summary:
Typically seatrout are cultured by introducing pre-feeding larvae into brackish water ponds containing wild, mixed zooplankton. In coastal Mississippi, which is estuarine, pond culture is not feasible for a variety of reasons including the highly variable salinities, the lack of available space, and the shallow water table. Thus, our program has focused on developing intensive tank culture that produces a result comparable to extensive culture.

Activity:
Brood fish began spawning in late May 2007, after a 150-day photoperiod cycle, and spawned until October when the 150-day photoperiod cycle was restarted. Two tanks (approximately 20 fish each in a 1:1 sex ratio) produced approximately 1.3×10^8 eggs with an average fertility of 73%. Four production batches and four research batches of larvae were hatched and grown from those eggs during summer 2007. One production and one research batch was lost due to unexplained mortality, thus average survival through larval rearing (25 days) was approximately 11%, considerably lower than in the past. Larvae in 2007 averaged 31.5mm total length and 0.33g wet weight, slightly larger than in the past. Approximately 15,000 taggable fish resulted from the production batches (one batch suffered from excessive mortality probably related to cannibalism). Those fish were tagged with a coded-wire tag and released at two sites during late summer and early fall. The three research batches were used to examine 1) the effect of larval density on survival and growth over the first 25 days of culture, 2) the effect of density on survival and growth during days 25-90 and 3) the effect on survival and growth of replacing live feed with an appropriately-sized prepared microdiet during the first 14 days of larval rearing. Results of these experiments are currently being analyzed.

Objective 5: Manage Disease and Health

Workplan summary:
Our broodstock consists of locally caught wild animals treated and quarantined for at least 30 days to remove dangerous ectoparasites that pose a danger to long-term maintenance in closed systems. Briefly, fish are freshwater dipped, treated with praziquantel, and quarantined for approximately 30 days during which time they are transitioned to frozen food and further treated with formalin to ensure the absence of dangerous ectoparasites. Suspicious symptoms are investigated and treatments administered. After quarantine, the fish enter the maturation system where they are cycled on a temperature and photoperiod regimen to induce spawning.

During larviculture, regular gross, histological, and microbiological examinations document the health of the fish. Treatments are administered only as necessary to preserve the stock. Before release, a sample is examined by a certified veterinarian and a health certificate which details the history of the stock is produced and submitted to the agency responsible for permitting the release. The goal is not to produce a disease-free stock, but rather to produce a stock which poses no additional risk to the receiving population.

Activity:
Samples of each of the three released batches were certified as healthy and suitable for release by John Slaughter, DVM using the Florida Department of Agriculture protocol.

Objective 6: Describe Life History Patterns and Ecological Interactions

Workplan summary:
Potential release sites will be monitored before, during, and after release to establish the parameters of the wild population and survival and relative contribution of the released fish. Release sites or methods will be modified as necessary to maximize the success of releases.

Activity:
Routine sampling in the vicinity of the two release sites continues. Approximately 400 seatrout in the size range of those released have been caught. Of those, approximately 40 have contained coded-wire tags. Tags have not yet been read, but all recovered fish are of the size range expected from the 2007 releases. Analysis to determine which release sites and batches are represented in the recovered fish is underway. Sampling gear has been problematic. Gill nets have not been effective in capturing small fish. Brill nets, while effective, are neither efficient nor sufficiently quantitative. Seines have been the most effective for small fish (i.e. from the 2007 year class). Trawls are being investigated as a method for capturing larger fish (i.e. the 2006 year class). Also, 2006 fish should soon be large enough to begin showing up in routine fisheries monitoring (gill net samples) and the recreational catch. Work is underway to refine the techniques and strategies for sampling. Alternatives include the use of traps and weirs and an expansion of the sampling area. We are cooperating with recreational fishing groups to begin assessing recreational catches for tagged fish.

Objective 7: Identify Released Hatchery Fish

Workplan summary:
All seatrout released in Mississippi will be coded-wire tagged. Some subset of the fish will be additionally tagged using elastomers or other externally visible tags to address experimental issues such as the effect of site of release, size at release, release method, or time of release. Acoustic tags will be employed on a small subset of cultured fish and wild fish to examine movement, behavior, and residence patterns.

Activity:

All fish released in 2007 were approximately 100mm in total length. Tag retention averaged about 75%. At least part of the tag loss can be explained by difficulties experienced by one individual tagger. Increased training is planned to address this issue.

Objective 8: Optimize Release Strategies

Workplan summary:
All seatrout released in pilot studies in Mississippi will be coded-wire tagged. Some subset of the fish may be additionally tagged using elastomers or other externally visible tags to address experimental issues such as the effect of site of release, size at release, release method, or time of release. Acoustic tags may be employed on a small subset of cultured fish and wild fish to examine movement, behavior, and residence patterns.

Activity:
No alternative methods of tagging were employed in 2007. Two new graduate students began programs in Fall 2007 to begin addressing the ecology of stock enhancement. Some alternative tagging strategies will be employed in their work.

Objective 9: Conduct Economic Analysis

No activities planned.

Objective 10: Develop Adaptive Management Strategies

Workplan summary:
Data from the monitoring of experimental releases will guide the adaptation of subsequent experimental plans.

Activity:
Work continues to refine the sampling techniques and strategies. Progress has been made as evidenced by our ability to catch relatively large numbers of seatrout in the size range of those released, including some tagged fish. The same sites used in the initial work continue to be used. Recovery data is being evaluated and that will be used to evaluate and/or adapt release strategies.

Objective 11: Communicate Results and Network Stock Enhancement Researchers & Managers

Workplan summary:
The 3rd International Symposium on Stock Enhancement and Sea Ranching (ISSESR) was held 18-21 September 2006 in Seattle. The SCORE consortium will use the opportunities afforded through the 3rd ISSESR and other scientific meetings to hasten the transfer of SCORE technology and SCORE research strategies to the rest of the USA and the international research community.

Activity:

Reg Blaylock presented a paper entitled "Intensive rearing of spotted seatrout, *Cynoscion nebulosus*, for release in Mississippi" at the 3rd International Sustainable Marine Fish Culture Conference, 15-17 October, Ft. Pierce, FL.

Semi-Annual Progress Report
To National Marine Fisheries Service, NOAA, DoC
Reporting on Activities in the Unallied Science Project,
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Science Consortium for Ocean Replenishment (SCORE)

(Broad Area Announcement) Financial Assistance Award Number: NA07NMF4720349
For the period 1 July through 31 December 2007

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Contract Period and Relation to this Reporting Period

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Project Accomplishments:

Mote Marine Laboratory Progress – July through December 2007

Evaluate Stock Enhancement Impact in Sarasota Bay and Tampa Bay:

Test of Density-Dependency Effects with Hatchery-Reared Juvenile Snook Released in Critical Nursery Habitats:

In recent years, we performed release experiments to evaluate the potential for augmenting ambient densities of wild snook stocks in various juvenile snook habitats through stock enhancement. We aimed to augment wild stocks by 100% (high augmentation, n=2) versus 10% (low augmentation, n=2) in estuarine creeks of southwestern Florida. We monitored in-creek abundance of age-1 snook 1 mo. before releases in May 2002 to estimate wild snook density and stocking magnitude. All sampling used seining standardized for effort, gear efficiency, and depletion-removal. After releases, sampling continued for 1 yr. Initially (1 mo. post-release), creeks with high augmentation showed a 126% and 74% increase in total age-1 abundance, and low augmentation creeks a 6% increase and an 18% decrease. Total age-1 abundance declined during fall in all creeks, but by winter, abundance increased again comparable to earlier levels (132% and 67% above the pre-release estimates in high augmented creeks and 8% and 5% in creeks with low augmentation). While overall density was elevated in both high augmentation creeks, hatchery-reared snook in one creek experienced a 64-85% loss within 1 mo. after release; loss of hatchery-reared or wild snook was negligible in other experimental creeks. Pre-release density was not a good predictor of creek productive capacity, suggesting variation in habitat production and localized recruitment. Further work is needed to understand inter-cohort density-dependent interactions, food chain responses, and variation in habitat productivity.

Contribution of snook rearing habitats to adult snook distribution and abundance:
We used releases of tagged hatchery-reared snook into various rearing habitats to evaluate resultant habitat-specific growth rates, survival and eventual contribution rates to adult life stages of common snook. A manuscript is being prepared that describes this work. See details below:

Brennan, N.P., and K. M. Leber. In review. Influence of rearing habitat on growth, survival, dispersal and relative stock contribution of juvenile common snook *Centropomus undecimalis*.

Hatchery-reared juvenile snook were released into various habitats to examine the resultant influence on growth, dispersal, and survival, both over the short-term (1-12 mo. post release), and through six years after releases. Mangrove habitat alone was not necessarily representative of high-quality juvenile snook habitat. Short-term standardized sampling in these habitats showed that snook released and reared in tidal creek habitat had significantly higher mean recapture rates compared to those released at barrier island habitat. More specifically, habitats that generally contained sediment with high organic

content, and waters of low salinity, and hypoxic conditions produced high recapture rates (high survival) but also lowest growth rates. We hypothesize that juvenile snook use their ability to tolerate hypoxic conditions as a physiological refuge from potential predators less able to tolerate these conditions. The physiological costs of tolerating hypoxic conditions probably contributed to the lower associated growth rates. Long-term recapture rates showed similar patterns. Juvenile snook densities in rearing habitats were a good predictor of short- and long-term recapture rates, and high-density rearing habitats produced highest contributions to the adult demes. Snook growth over the long-term was reflective of growth rates established early-on in rearing habitats. Snook also showed size-related dispersal patterns probably associated with predation risk and body size. Recaptures over the long-term showed that fidelity to rearing habitats was high, but dispersal tendencies increased with age and size.

Adapting Tag Technology toward Stock Enhancement of the Common Snook:

We are continuing to monitor the acoustic tag study with juvenile snook. Both hatchery and wild snook were implanted with transmitters and tracked from spring 2004-spring 2007. This work was designed to evaluate dispersal characteristics of wild and hatchery-reared juvenile snook. Synthesis and analysis of these data are revealing important ontogenetic habitat shifts and dispersal responses related to stocking congeners into various estuaries. Work during this period furthered these efforts as a scientific manuscript currently in peer review:

Pine, W.E., Brennan, N.P., and Leber, K.M.. In revision. Density-mediated survival, and movement patterns in an estuarine-dependent juvenile fish.

Feeding Ecology of juvenile snook:

In May through August, 2006 we performed a laboratory study, designed to further our knowledge on juvenile snook feeding ecology. This work was designed to provide information on evacuation will facilitate This study was designed to evaluate the effects of prey size, and prey type (shrimp versus fish) on stomach evacuation rates of juvenile snook. During this period, a manuscript describing this work was prepared and is currently in peer review:

Heinlein, J., and N.P. Brennan. In review. Influence of prey type and size on gastric evacuation rates of an estuarine predator *Centropomus undecimalis*.

Work was also progressed in two additional manuscripts describing wild juvenile snook feeding ecology. These works are offshoots from J.Rock's masters thesis:

Rock, J.E., Murie, D.J., Brennan, N.P., and Leber, K.M., In Preparation. Diel feeding periodicity of juvenile common snook in tidal creeks of southwest Florida. Masters Thesis. University of Florida, Department of Fisheries and Aquatic Sciences.

Rock, J.E., Murie, D.J., Brennan, N.P., and Leber, K.M., In Preparation. Feeding habits of juvenile snook in estuarine tidal creeks.

An evaluation of cannibalism risk in juvenile snook:

Cannibalism, common among piscivorous fish, can be a significant contributor to mortality and can play a strong role in structuring abundance and distribution of a cannibalistic species. In snook, cannibalism has been documented in aquaculture and is most intense during early life stages. We examined cannibalism as a potential force contributing to the dynamics of snook abundance and how unintended effects might stem from stock enhancement management practices.

Cannibalism-related field work occurred in November 2003 – March 2004. Over 2100 snook stomachs were examined for cannibalism in nursery habitats in Sarasota where stock enhancement experiments are conducted. Additionally, a metaanalysis of published and unpublished literature describing snook diet was conducted. Results of these efforts provided input into a model that predicted cannibalism intensity juvenile snook nurseries. Additional variables influencing the model included relative intercohort abundance, growth rates, and predation exposure. Results of this work are described in the following manuscript:

Brennan, N.P. In Review. Cryptic cannibalism in size-structured snook populations. Doctoral Dissertation. Fisheries and Aquatic Sciences, University of Florida.

Use of early-stage releases as a primer for understanding recruitment bottlenecks in juvenile snook stocks:

We began to field test early-stage releases of young-of-year snook released in fall as a comparison of historic releases of later-stage juveniles released after overwintering in the hatchery. Among other things, early-stage releases offer the potential to substantially reduce hatchery rearing costs.

On September 27, 2007 2,078 juvenile snook (about 60-130mm FL) were tagged at the Mote Aquaculture Park with coded-wire tags to identify release sites. Tagging was conducted by staff from FWC, SERF, with assistance from N. Brennan (MML stock enhancement program), and staff from MML Aquaculture program. After 1 week of recovery in their rearing tanks, these snook were release into four tidal creeks in Sarasota and Manatee Counties on October 4, 2007. Collaborative efforts of staff from SERF and MML successfully used land-based transport equipment (SERF) and boats to access the release sites. Only three fish were observed to succumb to mortalty during the transport activities.

Testing the capability of inland snook fisheries:

During summer 2007, we have been preparing and planning for experimental releases of hatchery-reared snook in inland ponds. Much of this work has involved obtaining the necessary permits, arranging release logistical details, and establishing cooperative relationships with stakeholders. Release of snook into inland ponds is planned for spring 2008.

Assist Florida Fish and Wildlife Conservation Commission (FWC) with Strategic Planning for the FWC Marine Stock Enhancement Program:

In line with the short and long-term objectives of strategic planning for the Fish and Wildlife Conservation Commission's (FWC) marine stock enhancement program, SCORE principals are being transferred to FWC to help improve the effectiveness of FWC's stock enhancement program, (2) adapting and refining the aspects of a "Responsible Approach to Marine Stock Enhancement" (Blankenship and Leber, 1995) that have not yet been fully implemented in Florida, and (3) identifying and prioritizing potential marine fish species for stock enhancement in Florida. The MML P.I. has been working closely with FWC's Stock Enhancement program as a chief advisor and a co-leader in strategic planning and research planning.

Florida's Fish and Wildlife Conservation Commission (FWC) and Mote Marine Laboratory (MML) are collaborating in the development and evaluation of the marine stock enhancement as an integrated fishery management tool in Florida. This collaboration is focused in part on the transfer of SCORE principles to FWC's Fish and Wildlife Research Institute's (FWRI) Marine Stock Enhancement program, which enables demonstration of SCORE technology at a scale that can affect fish populations. Much of the work performed in this project is (1) assisting in fully integrating a "Responsible Approach to Marine Stock Enhancement," (2) helping develop implementation plans and protocols for conducting marine stock enhancement in Florida (i.e., via FWC-FWRI' marine stock enhancement program, which is currently conducting enhancement with red drum), (3) planning and directing research and development of new species for stock enhancement in Florida (currently common snook), and (4) assisting in presenting the approach and R&D results of this collaborative effort at scientific meetings, agency meetings (such as the bi-annual FWC Marine Stock Enhancement Advisory Board meetings), and at agency and congressional workshops or summits.

During this reporting phase, emphasis was placed on several collaborative manuscripts. This included K. Leber working in Olympia, WA in September 2007 with Lee Blankenship to develop an outline for a manuscript to be presented at the American Fisheries Society Tagging symposium to be held in Aukland, New Zealand in February 2008. Information on this symposium is included on the following website: http://www.fisheries.org/units/tag2008/images/tag_2008_brochure.pdf. The manuscript will include information on marking systems used in Project Tampa Bay and in the Sarasota Bay snook project, and how these uniquely aided us in answering questions about red drum and release strategies.

During the report period K. Leber participated in multiple meetings with FWC management. The meetings were held to discuss the stock enhancement strategic plan in relation to the planned expansion of stock enhancement in Florida.

K. Leber was responsible for planning a seminar presentation at FWRI by Kai Lorenzen, Ph.D. K. Leber also met with Luiz Barbieri and the FWC Stock Enhancement Team to discuss implications of K. Lorenzen's work. In addition, K. Leber was involved in planning and making arrangements for a MSEAB meeting to be held in January 2008.

Publications

Bell, J.D., K.M. Leber, H.L. Blankenship, N.R. Loneragan, and Masuda and G. Vanderhaegen **(Editors)**. **In Press**. *A New Era for Restocking, Stock Enhancement and Sea Ranching of Coastal Fisheries Resources*. Special Issue, Reviews in Fisheries Science 16(1,2). xxx pp.

Bell, J.D., K.M. Leber, H.L. Blankenship, N.R. Loneragan, and R. Masuda. **In Press**. **(Lead Article)** A new era for restocking, stock enhancement and sea ranching of coastal fisheries. Reviews in Fisheries Science 16(1,2):xxx-xxx.

Brennan, N.P., C.J. Walters, and K. M. Leber. **In Press**. Manipulations of stocking magnitude; Addressing density-dependence in a juvenile cohort of common snook *Centropomus undecimalis*. Reviews in Fisheries Science 16(1-2): xxx-xxx.

Tringali, M.D., K.M. Leber, W.G. Halstead, R. McMichael, J. O'Hop, B. Winner, R. Cody, C. Young, C. Neidig, H. Wolfe, A. Forstchen, and L. Barbieri. **In Press**. Marine Stock Enhancement in Florida: A Multi-disciplinary, Stakeholder-supported, Accountability-based Approach. Reviews in Fisheries Science. 16(1,2):xxx-xxx.

Presentations

Brennan, N.P., 2007. Habitat and density-mediated influences on snook ecology: lessons learned from manipulative release experiments of juvenile snook. November 8, 2007. Mote Marine Laboratory, 2007 Fall Seminar Series.

Brennan, N.P., 2007. Habitat and density-mediated influences on snook ecology: lessons learned from manipulative release experiments of juvenile snook. November 13, 2007. University of Florida, Department Fisheries and Aquatic Sciences, Doctoral Exit Seminar.

Brennan, N.P., 2007. Habitat and density-mediated influences on snook ecology: lessons learned from manipulative release experiments of juvenile snook. December 13, 2007. Florida Marine Research Institute, St. Petersburg.

Leber, Kenneth M. 2007. Advances in marine stock enhancement: Indications of widespread implementation of a responsible approach in attempts to avoid mistakes of the past. Invited talk, special session on Environmental Impacts of

Coastal Ocean Aquaculture, American Fisheries Society 137th Annual Meeting, San Francisco, California. September, 2007.

Northwest Fisheries Science Center Progress – July through December 2007

SCORE Washington scientists (from the University of Idaho and NOAA) concentrated on writing up the results of previous years studies. These studies include co-authors from the Northwest Fisheries Science Center's Manchester Lab, the University of Idaho, the Northwest Indian Fisheries Commission, and the Squaxin tribe. Titles of papers being written are:

1. Determining the optimal feeding interval timing in larval black rockfish (*Sebastes melanops*)
2. Apparent protein digestion of a microparticulate diet fed to cod larvae.
3. Movements of cultured acoustically tagged lingcod (*Ophiodon elongatus*) in Puget Sound, Washington
4. Movements of cultured acoustically tagged Pacific cod (*Gadus macrocephalus*) in Puget Sound, Washington
5. Survival and growth of cultured Pacific cod (*Gadus macrocephalus*) following surgical implantation of acoustic tags
6. A photometric method to measure leaching in microparticulate diets in real time
7. Structural complexity in relation to the habitat preferences, territoriality, and hatchery rearing of juvenile China rockfish (*Sebastes nebulosus*)
8. Stability of behavioral syndromes but plasticity in individual behavior: consequences for rockfish stock enhancement
9. Effects of the rearing environment on average behaviour and behavioural variation in steelhead

Progress to date for each paper is given below:

Determining the optimal feeding interval timing in larval black rockfish (*Sebastes melanops*).

Data has been analyzed which indicates that the optimal feeding frequency for larval black rockfish is about 2 hours. Feeding frequencies greater than or lesser than this resulted in poorer growth (Fig 1). This paper is now being written up for publication in Aquaculture Research by Matt Cook.

Apparent protein digestion of a microparticulate diet fed to cod larvae.

The findings from this research were presented at the World Aquaculture Society's Annual Meeting in February 2007. A draft manuscript written by Ron Johnson has

received approval with comments from internal review. A corrected version of the manuscript will be submitted to Aquaculture by the end of second quarter FY 2008.

Movements of cultured acoustically tagged lingcod (*Ophiodon elongatus*) in Puget Sound, Washington

Acoustic data show that after release, some cultured lingcod remained at target reefs and treated those reefs as their "home" reefs. While further work is obviously needed, these encouraging results suggests that the release of young, cultured lingcod has potential to be a viable method for replenishing depleted reefs. A draft manuscript has been written by Jon Lee and will be combined with a complementary study on Pacific cod (see below) once all the data for the cod study is available.

Movements of cultured acoustically tagged Pacific cod (*Gadus macrocephalus*) in Puget Sound, Washington

Data is still being collected for this study over the time period of this report. This study will likely be combined with the one above for publication.

Survival and growth of cultured Pacific cod (*Gadus macrocephalus*) following surgical implantation of acoustic tags

This paper is in the process of being written up for publication by Ken Massee.

A photometric method to measure leaching in microparticulate diets in real time

A manuscript by Pete Nicklason was submitted to Aquaculture Nutrition however it was not accepted. The paper has been revised and resubmitted and is currently out for peer-review.

Structural complexity in relation to the habitat preferences, territoriality, and hatchery rearing of juvenile China rockfish (*Sebastes nebulosus*)

This study investigated the social interactions and habitat preferences of juvenile China rockfish, and the relationship between rearing environment and future behavior. Juveniles were territorial over structured areas in aquaria. Rearing in barren environments affected habitat use, but the effects disappeared after a few weeks in structured habitat. A manuscript by Jon Lee and Barry Berejikian is currently under internal review. It will be submitted to Environmental Biology of Fishes shortly.

Stability of behavioral syndromes but plasticity in individual behavior: consequences for rockfish stock enhancement

This study documented behavioral variation in brown rockfish and tested whether the hatchery environment selects for certain behavioral types. No such selection was found, perhaps because behavior was very plastic over time. This manuscript by Jon Lee and

Barry Berejikian was accepted by Environmental Biology of Fishes on August 5, 2007. It is currently in press.

Effects of the Rearing Environment on Average Behaviour and Behavioural Variation in Steelhead

This study showed that the temporal variation in the rearing environment can affect both average behavior and variation around the mean behavior in steelhead. This manuscript by Jon Lee and Barry Berejikian is under review at the Journal of Fish Biology. The journal requested changes a few months ago. These changes have been incorporated into a revision that was resubmitted to the journal in December 2007.

University of New Hampshire Progress – July through December 2007

The long-term goal of our winter flounder stock enhancement program is to accelerate recovery of the fishery by increasing spawning stock biomass. To meet this goal, we have developed a multidimensional research program designed to produce large numbers of high quality juveniles, to optimize release strategies, and to understand how developmental morphology and live feed conditioning affects post-release survival of juvenile winter flounder.

No Activities were planned for this period of the Contract.

University of Southern Mississippi Gulf Coast Marine Laboratory Progress – July through December 2007

No Activities were planned for this period of the Contract.