Continuation of a project of augment the data collection of an electronic logbook system used within the Gulf of Mexico shrimp fishery

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Continuation of a Project to Augment the Data Collection of an Electronic Logbook System used within the Gulf of Mexico Shrimp Fishery

NOAA/NMFS Award Number NA09NMF4540135 (GSAFFI #109)



FINAL REPORT



Lincoln Center, Suite 740 5401 West Kennedy Blvd. Tampa, Florida 33609-2447

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Title:	Continuation of a Project to Augment the Data Collection of an Electronic Logbook System used within the Gulf of Mexico Shrimp Fishery
Author:	Frank C. Helies, Program Director Judy L. Jamison, Executive Director
	Gulf & South Atlantic Fisheries Foundation, Inc. (Foundation) Lincoln Center, Suite 740 5401 W. Kennedy Blvd. Tampa, Florida 33609-2447
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I. Abstract

The Foundation was previously awarded funds through the Cooperative Research Program to enhance the data collection of red snapper bycatch in the shrimp trawl fishery in the Gulf of Mexico. The data were used to validate electronic logbook landings estimates by region and assisted fishery managers with assessing the red snapper stock. This project represents a continuation of that Award (NA05NMF4540044). Observers were placed aboard 9 vessels from 5 different ports located in Alabama, Florida, Louisiana, and Texas. A total of 12 trips ranging from 12 to 65 sea days were undertaken in 15 different statistical zones. Observers logged a total of 344 sea days with a total of 590 tows, of which, 439 contained red snapper. Updated analyses were conducted in December 2009 and July 2012 on all Gulf of Mexico data. The results of the analyses show that the juvenile red snapper bycatch in the Gulf of Mexico penaeid shrimp fishery in the first and third trimesters is still dominated by age-0 red snapper (about 82-84%), whereas the catch in trimester 2 (May-August) is split about evenly between age-0 (43%) and age-1 (57%) red snapper. Shrimp trawl effort in the statistical areas (10-21) and depths (10-30 fathoms) where juvenile red snapper are found has experienced significant reduction since 2002. A concurrent increase in juvenile red snapper abundance and decrease in juvenile mortality has not been observed. We believe density dependent mortality from habitat limitation explains the lack of relationship between shrimp trawl effort and total juvenile mortality. The existence of density dependent juvenile red snapper mortality has the potential to substantially alter management advice.

II. Executive Summary

The red snapper (*Lutjanus campechanus*) stock of the Gulf of Mexico has been classified as overfished since the first rebuilding plan was put in place by the Gulf Council in 1990 (GMFMC, 2010). Due to over two decades of management of the directed fishery, red snapper are no longer experiencing overfishing (SEDAR, 2009). However, the shrimp trawl fishery in the Gulf of Mexico was also found to impact the red snapper stock and is thought to bottleneck adult populations. Estimates of red snapper bycatch are directly dependent upon estimates of shrimp fishing effort. Due to discrepancies in shrimp fishing effort calculated from port agent collected data, the Foundation was appropriated funds to conduct a three-year research study to enable the

fishing industry to evaluate and address fishery management issues including the estimation of shrimp fishing effort and bycatch. A portion of these funds were granted to LGL Ecological Research Associates, Inc. (LGL) to allow the research and development of an electronic logbook (ELB) to directly measure shrimp fishing effort thereby reducing the dependence on modeling to provide better estimates of shrimp fishing effort and red snapper bycatch. Over the course of the pilot study, ELB systems were randomly placed onboard commercial shrimp fishing vessels to collect fishing effort data.

To augment the data collection, both paper logbooks and observers were utilized to collect shrimp landings and red snapper bycatch data on a tow-by-tow basis. Results from this study indicated that the ELB system accurately estimated the fishing practices of a vessel on a per trip basis and that individual tows could be identified. Based upon the results derived from the above-mentioned study and recommendations made by the SEDAR-7 Shrimp Fleet Bycatch Working Group (NMFS, 2004), LGL was granted funding by NMFS to further expand the ELB program within the shrimp fishery in the Gulf of Mexico. To date, there have been 677 ELBs placed aboard Gulf shrimp fishing vessels. Although the data collected through ELBs are invaluable to fishermen and fisheries managers in resolving effort related questions, no red snapper bycatch and shrimp landings data are collected. To ensure that ELB landings estimates were accurate and defensible, the Foundation received funding (NOAA/NMFS Cooperative Agreement #NA05NMF4540044) to compliment the ELB program through deployment of fishery observers to collect effort, bycatch, and landings data. This project was a continuation of that study.

The Gulf Coordinator, with the assistance of LGL, randomly selected vessels that were outfitted with ELBs to participate in the study; however, the process was not entirely random, as not all vessels outfitted with ELBs had the ability to accommodate observers. Participating captains/owners were compensated for accommodating the observer. Over a three year period, Foundation contracted observers were placed on 9 vessels from 5 different ports located in Alabama, Florida, Louisiana, and Texas. A total of 12 trips ranging from 12 to 65 sea days were undertaken in 15 different statistical zones. Observers logged a total of 344 sea days with a total of 590 tows. Observers recorded the weight (heads-on or heads-off) of all penaeid shrimp regardless of the quantity harvested. All incidentally harvested red snapper were counted, weighed, and measured to produce accurate abundance and size-frequency estimates. Efforts were taken to sort, weigh, size, and record all red snapper from individual nets. Additionally, all incidentally captured sharks were identified and measured. Any and all sea turtles incidentally taken during experimental tows were handled, measured, and tagged according to established NMFS protocols.

Dr. Benny Gallaway and LGL Ecological Research Associates staff were contracted to conduct the data analyses for this project. Data updates for the entire Gulf of Mexico were completed in December 2009 and July 2012.

For this project, 41,196 red snapper were collected. The average length of the snapper was 132.2 mm and the average water depth in which red snapper were captured was 142.4 feet. This equates to the majority of towing effort during this project occurring in the 10-30 fathom depth range (23.9 fa average). The shrimp catch per unit effort (CPUE) averaged 18.8 kg/hr (heads

off). The dominate species caught in these waters was brown shrimp. A single trip was conducted in southern Florida and the dominate species harvested was pink shrimp.

The results of LGL analyses show that the juvenile red snapper bycatch in the Gulf of Mexico penaeid shrimp fishery in the first and third trimesters is still dominated by age-0 red snapper (about 82-84%), whereas the catch in trimester 2 (May-August) is split about evenly between age-0 (43%) and age-1 (57%) red snapper.

The current management paradigm for red snapper recovery is through bycatch reduction from penaeid shrimp trawl gear. We believe density dependent mortality from habitat limitation explains the lack of relationship between shrimp trawl effort and total juvenile mortality. The existence of density dependent juvenile red snapper mortality has the potential to substantially alter management advice.

The Foundation is currently conducting a continuation of this project to further augment the data collection for the Gulf ELB program (Award #NA11NMF4540118). However, the ELB program is in serious jeopardy of losing funding due to the fiscal issues this country is facing, in particular the cutting of NMFS funds in the southeast. Hopefully, these funding issues will be resolved promptly, as this program is essential to the management of the red snapper stock in the Gulf of Mexico.

Dr. Benny Gallaway gave a presentation of the project results at the Gulf of Mexico Red Snapper SEDAR Assessment Workshop in Pensacola, FL in August 2012.

III. Purpose

Description of Problem:

The red snapper (*Lutjanus campechanus*) stock of the Gulf of Mexico has been classified as overfished since the first rebuilding plan was put in place by the Gulf Council in 1990 (GMFMC, 2010). The National Marine Fisheries Service (NMFS) has regulated the directed (commercial and recreational) red snapper fisheries to reduce mortality of large fish through fishing seasons and quota management (IFQ program). Due to over two decades of management, the red snapper fishery is no longer experiencing overfishing (SEDAR, 2009). However, the shrimp trawl fishery in the Gulf of Mexico was also found to impact the red snapper stock and is thought to bottleneck adult populations. To reduce the fishing mortality of small juvenile fish, the NMFS has also regulated this fishery. Disagreement had existed regarding the magnitude, age composition, and monthly distribution of shrimp trawl red snapper bycatch in time and space (Goodyear, 1995; Schirripa and Legault, 1997, 1999; Gallaway et al., 1998; Gallaway and Cole, 1999; Ortiz et al., 2000). However, better and more complete observer data have provided the basis for reaching agreement (e.g., NMFS, 2004).

Estimates of red snapper bycatch are directly dependent upon estimates of shrimp fishing effort. Historically, port agents have collected shrimp landings and value data from dealer records. Fishing effort data are collected by port agents through detailed interviews with fishing vessel captains and/or crew. Interview data provides resolution on shrimp fishing effort at the trip level. Due to the large number of shrimp fishing trips occurring within the Gulf of Mexico, a comprehensive survey of the shrimp fleet is not feasible and sub-sampling occurs. Monthly, port agents visit all shrimp dealers within their region and collect landings information for individual fishing trips. Port agents then sub-sample these trips by randomly selecting interviewees to obtain further information regarding effort and catch location (Nance, 2004).

Because shrimp effort estimates were primarily based on port agent data, inaccuracies in trip interviews, time fished, or reported catch data often resulted in skewed fishing effort calculations (Nance, 2004) and created biases in the assessment of the red snapper stock (NMFS, 2004). In 1998, the Gulf and South Atlantic Fisheries Foundation, Inc. (Foundation) was appropriated funds to conduct a three-year research study to enable the fishing industry to evaluate and address fishery management issues including the estimation of shrimp fishing effort and bycatch. A portion of these funds were granted to LGL Ecological Research Associates, Inc. (LGL) to allow the research and development of an electronic logbook (ELB) to directly measure shrimp fishing effort thereby reducing the dependence on modeling to provide better estimates of shrimp fishing effort and red snapper bycatch. Over the course of the pilot study, ELB systems were randomly placed onboard commercial shrimp fishing vessels to collect fishing effort data.

To augment the data collection, both paper logbooks and observers were utilized to collect shrimp landings and red snapper bycatch data on a tow-by-tow basis. Results from this study indicated that the ELB system accurately estimated the fishing practices of a vessel on a per trip basis and that individual tows could be identified. Combining the ELB data with paper logbook and observer collected landings data, it was demonstrated that total vessel landings (on a per trip basis) could be divided accurately on a tow-by-tow basis and allocated to specific statistical zones. Of the 135 trips where ELBs recorded effort data, port agents collected data on 62 of these trips. A comparison of the ELB and port agent data allowed for a direct comparison of fishing effort estimation methodologies (i.e. NMFS/State port agent data vs. ELB data). This analysis indicated that a directional bias exists and that port agent data overestimated effort in midshore regions (areas abundant in juvenile red snapper; between 10-30 fathoms) while underestimating effort in nearshore and offshore regions (areas where juvenile red snapper abundance is low; 0-10 fathoms and 30+ fathoms, respectively). These studies proved that an ELB system was accurate at recording shrimp-trawl fishing effort and estimating and allocating landings data (Gallaway et al., 2001; Gallaway et al., 2003a; 2003b).

Based upon the results derived from the above-mentioned studies and recommendations made by the SEDAR-7 Shrimp Fleet Bycatch Working Group (NMFS, 2004), LGL was granted funding by NMFS to further expand the ELB program within the shrimp fishery in the Gulf of Mexico. To date, there have been 677 ELBs placed aboard Gulf shrimp fishing vessels. Although the data collected through ELBs are invaluable to fishermen and fisheries managers in resolving effort related questions, no red snapper bycatch and shrimp landings data are collected. To ensure that ELB landings estimates were accurate and defensible, the Foundation received funding (NOAA/NMFS Cooperative Agreement #NA05NMF4540044) to compliment the ELB program through deployment of fishery observers to collect effort, bycatch, and landings data. This project was a continuation of that study.

Objectives:

- 1) Complement the current ELB study with onboard observers to collect data on fishing effort, red snapper bycatch, and shrimp landings within the Gulf of Mexico;
- 2) Analyze all observer collected data to further ensure that ELB landings estimates are accurate and defensible;
- 3) Determine the spatiotemporal abundance of juvenile red snapper, compute a total mortality (Z) estimate for shrimp-trawl red snapper bycatch, and conduct a formal cohort analysis (VPA) on all observer collected red snapper data; and
- 4) Provide improved data collection on the extent of bycatch of small coastal sharks.

IV. Approach

Statement of Work:

ELB Description:

The LGL Electronic Logbook was developed to track the fishing effort of shrimp trawlers operating within the northern Gulf of Mexico. The ELB system is currently in version 4.0 and each version has increased the systems functionality. Data formats and software have been altered to complement the ELB system and allow for all data formats to be read. This most recent version of the ELB incorporates major revisions in both hardware and software. The Parallax Javelin Stamp processor was upgraded to the Systemics JStamp and increased processing speeds and RAM availability 30 and 14 times, respectively, than that of the Javelin. Additionally, STMicroelectronics has released a new 512 kb EEPROM memory chip (M24512-B) compatible with the 24LC256 pin layout allowing observation periods to exceed 520 days. Although it is expected that data will be on a semiannual basis, this version would allow a vessel to be late in returning memory modules with no data being lost.

The most significant improvement in Version 4.0 is the inclusion of point-in-polygon calculation capabilities. This program, which runs at the same time as the data collection program, can warn the vessel Captain when he is approaching a designated area, and provides a different warning when he actually enters the area. This allows the unit to be preprogrammed with areas (polygons) that are to be avoided, for regulatory reasons (MPA's or closed areas) or because they contain reefs or other trawl hangs.

Fishery Observer Training:

Two sets of Observers were contracted over the course of this project. All contracted Fishery Observers underwent specific and detailed training prior to their deployment on any commercial fishing vessel. It was the responsibility of the Observer/Vessel Coordinator to schedule and train all Fishery Observers. Protocol training consisted of review of Foundation and NMFS protocol

for observer conduct, administrative tasks, and ELB data collection. Observer gear, consisting of both safety and data collection instruments, were distributed to the observers. At-sea training was conducted on-board the R/V Georgia Bulldog and included a review of all fishing gear, i.e. types and installation of TEDs/BRDs, gear measurement instructions, how the nets are towed/operated, back deck operations on shrimp vessels, and potential issues encountered with the gear. A training tow was executed and the subsequent catch was characterized by the trainee Observers with supervision by the Regional Coordinator (Captain) and Observer Coordinator.

Observers were required to have up-to-date CPR/Adult First Aid training, Safety at sea / Survival training, and official NOAA Fisheries Sea Turtle Safe Handling training. The first set of Observer trainees previously completed these courses and the protocols were reviewed during their training session. At the suggestion of a NMFS Fishery Biologist, the second set of trainee Observers completed their Safety at sea / Survival and NOAA Fisheries Sea Turtle Safe Handling training in Galveston, TX, in conjunction with scheduled NOAA Fisheries Observer training.

After all training sessions were completed; the Observers received letters from National Marine Fisheries Service, officially certifying them as trained Fishery Observers.

Permit Applications & LOAs:

Foundation staff requested and received the following state permits: Alabama Scientific Collection Permit; Florida Special Activities License; Florida Fish and Wildlife Conservation Commission Consent Permit regarding handling of sea turtles in Florida state waters; Louisiana Department of Wildlife and Fisheries Scientific Collection Permit; Louisiana Department of Wildlife and Fisheries Scientific Collection Permit/Marine Mammal; Mississippi Department of Natural Resources Scientific Collection Permit; and Texas Parks and Wildlife Scientific Permit. The National Marine Fisheries Service issued authorization for Foundation Observers to handle encountered sea turtles in Federal Waters.

An Exempted Fishing Permit (EFP) was requested and received from the National Marine Fisheries Service, with Gulf of Mexico Fishery Management Council approval, allowing the collection and permanent retention of 500 undersized, out-of-season, and/or illegal fish for identification purposes.

An additional EFP was requested and received from NMFS Highly Migratory Species Division for retention of juvenile sharks for identification purposes (if needed).

Vessel Selection:

It was the responsibility of the Gulf Regional Coordinator to solicit participation from industry. A "master list" of the participating vessels was continuously updated as new vessels agreed to participate. The Gulf Coordinator, with the assistance of LGL, randomly selected vessels from the list that were outfitted with ELBs to participate in the study; however, the process was not entirely random, as not all vessels outfitted with ELBs had the ability to accommodate observers. Participating captains/owners were compensated for accommodating the observer.

Data Collection:

Observers recorded the weight (heads-on or heads-off) of all penaeid shrimp regardless of the quantity harvested. All incidentally harvested red snapper were counted, weighed, and measured to produce accurate abundance and size-frequency estimates. Efforts were taken to sort, weigh, size, and record all red snapper from individual nets. In the event that individual net sorting became impractical, Observers sorted, weighed, and sized red snapper taken from all nets combined (i.e., catch from all fished nets were combined and red snapper separated). Additionally, all incidentally captured sharks were identified and measured. Any and all sea turtles incidentally taken during experimental tows were handled, measured, and tagged according to established NMFS protocols. Observers also noted the degree to which trawl nets were tuned and checked for proper gear installation.

Over a three year period observers were placed on 9 vessels from 5 different ports located in Alabama, Florida, Louisiana, and Texas. A total of 12 trips ranging from 12 to 65 sea days were undertaken in 15 different statistical zones. Observers logged a total of 344 sea days with a total of 590 tows, of which, 439 contained red snapper. The tows containing red snapper comprised seventy four percent (74%) of the total tows sampled. All data were entered into the NMFS Galveston Laboratory Shrimp Fishery Observer Database and analyzed by LGL Ecological Associates, Inc.

Zone	# of Sampled Tows
1	7
2	35
3	6
4	2
8	68
11	64
13	3
14	80
15	83
16	71
17	33
18	103
19	25
20	8
21	2

Data Analysis:

Dr. Benny Gallaway and LGL Ecological Research Associates staff were contracted to conduct the data analyses for this project. Data collected during this project are reported separately in addition to a full update of all available data from the Gulf of Mexico shrimp trawl fishery. Data updates were completed in December 2009 and July 2012. Data analysis methodology for the full updates is located in Appendix A.

Project Management:

Principal Investigator:	Europatino Director
Ms. Judy L. Jamison	Executive Director
Foundation Staff:	
Mr. Frank C. Helies	Program Director
Ms. Gwen Hughes	Program Specialist
Ms. Charlotte Irsch	Grants/Contracts Specialist
	Administrative Assistant

Overall project quality control and assurance was assumed by the Gulf & South Atlantic Fisheries Foundation, Inc. through its office in Tampa, FL. The Foundation's Executive Director had ultimate responsibility for all Foundation administrative and programmatic activities, with oversight by the Foundation's Board of Trustees. She ensured timely progress of activities to meet project objectives and confirmed compliance of all activities with NOAA/NMFS. The Foundation's Program Director had overall responsibility for all technical aspects of the project and coordinated performance activities of all project personnel, including contractors. The Program Director prepared all progress reports concerning project performance.

It was the responsibility of the Foundation's Executive and Program Directors to ensure quality control and assurance were maintained for all aspects of this program. This was accomplished through regular phone and email communications with project Contractors.

The Grant/Contracts Specialist was responsible for maintaining general financial accounting of all Foundation funds including all Cooperative Agreements and contracts, as well as communicating with NOAA Grants Management personnel, and assisting auditors in their reviews. She conducted/documented internal and program (single and desk) audits, prepared backup documentation for fiscal audits, and drafted award extension requests. She provided the Executive and Program Directors with projected budgets concerning program performance and ensured that these budgets adhered to the proposed project budget. Finally, she prepared the annual administrative budget, NOAA Financial Reports, and confirmed compliance of all activities with NOAA/NMFS and OMB guidelines.

The Program Specialist was responsible for tracking programmatic activities, monitoring funding, and distribution of funds. She processed requests for reimbursement to conform with federal guidelines and prepared and maintained all contracts, subcontracts, agreements, and amendments.

The Foundation contracted with several persons in conjunction with this project. These essential personnel were:

Mr. Gary Graham, Gulf of Mexico Regional Coordinator/Vessel Coordinator (Texas A&M University Sea Grant)
Mr. Daniel Parshley, Observer Coordinator
Mr. Phil Diller, Data Manager (former)
Mr. James Feid, Data Manager (current)
Dr. Benny Gallaway (LGL Ecological Research Associates) and Staff, Data Analyst
Fishery Observers
Mr. Shaun Donovan
Mr. Christopher Hladis

Mr. Joshua Paylor Mr. Mark Bane

Through years of experience, the Foundation has found that working closely with the local Sea Grant – Marine Extension Service personnel who have years of experience with the local fishing industry, is an efficient way to achieve rapid communication and cooperation with local shrimp fishermen. As such, the Gulf of Mexico Regional Coordinator, with assistance from the Observer Coordinator, (1) acted as liaison between the Foundation and vessel owners, relaying information about the goals of the project and securing vessel participation in the project; (2) reviewed, with the Data Analyst and Program Director, incoming data for completeness and accuracy; and (3) monitored Observer performance.

The Observer Coordinator assisted the Foundation's Program Director and Regional Coordinator in their day-to-day activities, with all activities coordinated through continual communication with Foundation staff. The Observer Coordinator recruited, trained, and coordinated Fishery Observers in the field.

Only Observers that underwent rigorous NMFS certification training were contracted by the Foundation. It was the job of the onboard Observers to collect all landings and red snapper bycatch data and proof all collected data for completeness and accuracy before forwarding to the Observer Coordinator.

All data were gathered through the cooperation and direct participation of the commercial shrimp fishing industry of the Gulf of Mexico region. Without the cooperation of industry, this project would not be possible. The use of fishing vessels as research platforms, not only reduced the costs associated with this project, but ensured that industry was aware of the research and allowed them to be involved in all steps of the scientific method. By allowing fishermen to actively participate in the collection of data, they will be more trusting of the results produced from this research and will be more willing to assist in future research.

Observer collected data for this project was electronically entered by a Foundation contracted Data Manager and archived at both the Foundation and NMFS Galveston Laboratory. The Data Manager was responsible for checking and transferring all the collected raw data into a

manageable computer database for analysis and data archive at the Foundation's office and the NMFS Galveston Laboratory.

Dr. Benny Gallaway, of LGL Ecological Research Associates, Inc., worked closely with the Foundation's Coordinators and Program Director with this project. In addition, Dr. Gallaway and LGL staff/contractors (including Mr. Bill Gazey and Mr. John Cole) conducted all data analyses on landings and red snapper bycatch data.

V. Findings

Results:

Foundation Observer Data Collection

Summary statistics for red snapper collected during Foundation observer trips are as follows:

Total Red Snapper	Red Snapper <= 100 mm	Red Snapper > 100 mm	Red Snapper => 130 mm
41196	12081	29115	15441
	29%	71%	37%

Table 2: Number of red snapper collected by size range and percentage of total.

Using the data from Table 2, collected red snapper can be placed into age classes based on length frequency information. For this project, 37% of all red snapper measured greater than or equal to 130 mm. This percentage constitutes individuals in yearly age class-1 and older. That means 63% would be classified as year age class-0. The average length of the snapper was 132.2 mm and the average water depth in which red snapper were captured was 142.4 feet. This equates to the majority of towing effort during this project occurring in the 10-30 fathom depth range (23.9 fa average). Table 3 shows the red snapper catch per unit effort (CPUE) for all size ranges, delineated by tow and per hour.

Table 3:	Red snapper	CPUE for all	tows by	size range.
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Total Red Snapper	Red Snapper <= 100 mm	Red Snapper > 100 mm	Red Snapper => 130 mm
69.8/tow	20.5/tow	49.3/tow	26.1/tow
11.7/hr	3.4/hr	8.3/hr	4.4/hr

The shrimp catch CPUE averaged 18.8 kg/hr (heads off weight). The dominate species caught during this project was brown shrimp. A single trip was conducted in southern Florida and the dominate species harvested was pink shrimp.

Although the majority of our observing effort was directed in the western Gulf offshore of Louisiana and Texas, it is apparent that the majority of red snapper catches occur in that area (Figure 1). It is also worth noting that nearly half of the total red snapper (19,808) collected during this project occurred during one trip (FE281) out of Freeport, TX in the third trimester of 2010.



Figure 1: Total red snapper catch in each stat zone.

Full Gulf of Mexico Red Snapper Bycatch Update

Given that the red snapper stock assessment is being updated, there is an increased importance to better understand the red snapper density dependent mortality issue. Substantial data have been collected since the previous Award and resulting Gazey et al. (2008) publication. An additional 7,942 tows were sampled that produced 57 monthly length frequency data sets and 153,012 juvenile red snapper length measurements. The result has been a substantial increase in the power to compare alternative models. For instance, the Von Bertalanffy growth model with density dependent mortality is in the order of a thousand times more likely than the model with linear growth and a million times more likely than the model with density independent mortality.

Besides extending the data set, the December 2009 and July 2012 updates also added and amended data for earlier dates (i.e., lagged data update and amendment). These changes have altered the parameter estimates (see Appendix A for specifics). The results of LGL analyses show that the juvenile red snapper bycatch in the Gulf of Mexico penaeid shrimp fishery in the first and third trimesters is still dominated by age-0 red snapper (about 82-84%), whereas the catch in trimester 2 (May-August) is split about evenly between age-0 (43%) and age-1 (57%) red snapper (see Table 5, taken from LGL report, Appendix A).

		Jan-Apr				May-	Aug		Sep-Dec			
Year	Age-0	Age-1	n	SE	Age-0	Age-1	n	SE	Age-0	Age-1	n	SE
1999	-	-	-	-	86.0	14.0	14,183	2.53	89.4	10.6	26,051	1.94
2000	76.0	24.0	3,695	5.42	67.2	32.8	7,233	4.25	85.7	14.3	32,181	2.16
2001	88.5	11.5	657	5.78	47.7	52.3	9,823	3.01	86.6	13.4	17,457	2.38
2002	77.0	23.0	1,893	5.62	40.8	59.2	15,015	3.69	87.9	12.1	35,473	1.84
2003	85.0	15.0	584	5.86	27.5	72.5	1,973	4.53	84.6	15.4	16,439	2.38
2004	90.8	9.2	4,225	2.55	19.4	80.6	9,547	1.35	58.3	41.7	6,268	3.84
2005	62.8	37.2	979	7.30	8.8	91.2	10,714	1.64	72.4	27.6	8,163	3.37
2006	67.8	32.2	979	6.16	19.5	80.5	5,684	3.50	90.7	9.3	16,534	2.42
2007	89.7	10.3	1,038	3.83	33.4	66.6	4,190	4.63	81.1	18.9	39,241	2.14
2008	88.3	11.7	9,101	3.29	40.8	59.2	8,804	1.93	62.6	37.4	13,276	3.50
2009	75.6	24.4	9,917	3.74	67.4	32.6	3,398	4.35	93.4	6.6	26,252	1.78
2010	92.5	7.5	7,001	2.43	39.9	60.1	3,108	2.52	39.3	60.7	878	5.53
2011	61.6	38.4	1,621	6.16	30.1	69.9	3,607	3.65	82.8	17.2	14,351	2.52
Mean	82.5	17.5	41,690	1.47	43.1	56.9	97,279	0.94	84.1	15.9	252,564	0.81

Table 5. Age composition (percent) by year and trimester where n is the sample size (number of fish measured) and SE is the standard error. The mean age composition is weighted by the sample size (n).

The current management paradigm for red snapper recovery is through bycatch reduction from penaeid shrimp trawl gear. Shrimp trawl effort in the statistical areas (10-21) and depths (10-30 fathoms) where juvenile red snapper are found has experienced significant reduction since 2002 (see Figure 2, taken from LGL report, Appendix A). A concurrent increase in juvenile red snapper abundance and decrease in juvenile mortality has not been observed. We believe density dependent mortality from habitat limitation explains the lack of relationship between shrimp trawl effort and total juvenile mortality. The existence of density dependent juvenile red snapper mortality has the potential to substantially alter management advice.



Figure 2: Yearly shrimp effort for the Gulf of Mexico.

Small Coastal Shark Bycatch

The final objective of this project was to characterize small coastal shark bycatch. A variety of species were caught during this project including: Atlantic angel, Atlantic sharpnose, blacknose, blacktip, bonnethead, finetooth, Florida smoothhound, scalloped hammerhead, smooth dogfish, and spinner sharks. Atlantic sharpnose dominated the characterization. The following table shows a breakdown of the small coastal sharks caught during the 3 years of this project and required reporting for the Foundation's Highly Migratory Species (HMS) Exempted Fishing Permit.

	2010	2011	2012	Total	Avg Length
Atlantic sharpnose	329	773	750	1852	61 cm
Blacknose	35	8	9	52	67 cm
Bonnethead	142	118	28	288	57 cm
Finetooth	0	4	0	4	92 cm

Table 4: Small coastal shark bycatch by year.

Additionally, three loggerhead sea turtles were caught in try nets. The animals were tagged and released in good condition. One Kemps Ridley sea turtle was caught in a trawl net containing a TED and BRD during the project. The animal was also tagged and released in good condition.

Problems Encountered:

No major problems were encountered during the extent of this project. Data collection was delayed due to the departure of the first set of contracted Observers and time was needed to train additional candidates. Also, in spite of the BP Deepwater Horizon oil spill, data collection trips were completed in waters outside the closed areas.

Additional Work Needed:

The Foundation is currently conducting a continuation of this project to further augment the data collection for the Gulf ELB program (Award #NA11NMF4540118). However, the ELB program is in serious jeopardy of losing funding due to the fiscal issues this country is facing, in particular the cutting of NMFS funds in the southeast. Hopefully, these funding issues will be resolved promptly, as this program is essential to the management of the red snapper stock in the Gulf of Mexico.

VI. Evaluation

Achievement of Goals and Objectives:

All project goals and objectives were met over the duration of this project. The dynamics of the red snapper fishery are complex and various interest groups (recreational, head boat, charter boat, direct and indirect commercial fisheries, and the shrimp trawl fishery) are thought to impact the stock. In previous stock assessments, shrimp trawl bycatch was thought to bottleneck adult populations. Through previous efforts funded by the Foundation, shrimp trawl effort was found

to be directionally biased, thus skewing shrimp trawl red snapper bycatch estimates (Award No. NA07NMF4330125). The continuation of the Foundation's ELB program helped to alleviate some of the confusion regarding shrimp trawl fishing effort and the F-mortality directly attributable to the shrimp trawl fishery operating in the Gulf of Mexico.

By augmenting LGL's current ELB research with onboard observers, red snapper bycatch and landings data were collected as before. Landings data were used to verify models used by scientists to allocate landings and effort on a trip-by-trip basis. The landings model was validated and found to accurately assess shrimp landings on a tow-by-tow scale, thus the ELB landings information can be used by fisheries managers to accurately assign landings data to individual statistical cells. Additionally, by allowing observers on their vessels, the shrimp industry has provided valuable data towards the management of red snapper in the Gulf of Mexico.

Dissemination of Results:

Summary reports of the project's findings were published as part of the "Foundation Project Update" section of the "Gulf and South Atlantic News", a publication of the Gulf & South Atlantic Fisheries Foundation, Inc. This newsletter was distributed to over 700 organizations and individuals throughout the region. An electronic version of this newsletter (PDF) was also included in the regular updates to the Foundation's website (www.gulfsouthfoundation.org).

Copies of this project's Final Report will be published and distributed to various federal and state fishery agencies, university extension/Sea Grant offices, and Industry associations. In addition, PDF copies of the Final Report will be made available for download from the Foundation's website.

Dr. Benny Gallaway gave a presentation of the project results at the Gulf of Mexico Red Snapper SEDAR Assessment Workshop in Pensacola, FL in August 2012.

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Appendix A

An Update of Age Composition, Growth and Density-Dependent Mortality in Juvenile Red Snapper Estimated from Observer Data from the Gulf of Mexico Penaeid Shrimp Fishery



Ecological Research Associates, Inc.

Prepared by

William J. Gazey W.J. Gazey Research 1214 Camas Court Victoria, British Columbia, V8X 4R1, Canada

Benny J. Gallaway And John G. Cole LGL Ecological Research Associates, Inc., 1410 Cavitt Street, Bryan, Texas 77801, USA

For

Gulf & South Atlantic Fisheries Foundation, Inc. 5401 W. Kennedy Blvd., Suite 740 Tampa, FL 33609

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TABLE OF CONTENTS

Page

INTRODUCTION	1
METHODS	1
RESULTS	2
DISCUSSION	3
LITERATURE CITED	5
APPENDICES	17

LIST OF TABLES

LIST OF FIGURES

Page

i

Figure 1.	Abundance index used in the analysis for the original paper and subsequent updates	10
Figure 2.	Percent age-0 composition by year	11
Figure 3.	Estimated recruitment index by year	12
Figure 4.	Estimated instantaneous mortality as a function of the recruitment index	13
Figure 5.	Estimated instantaneous mortality by year	14
Figure 6.	Estimated instantaneous mortality by year from Gazey et al. (2008 paper)	15
Figure 7.	Shrimp trawl effort in statistical areas 10-21 within depths 10-30 fathoms for 1960 to 2011	16

LIST OF APPENDICES

		Page
Appendix A.	Location of tows by month made in the western Gulf of Mexico	18
Appendix B.	Length frequency data for juvenile red snapper in the western Gulf of Mexico	
	and the model fit to these data	37

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INTRODUCTION

The National Marine Fisheries Service required that, beginning in May 1998, bycatch reduction devices be installed in penaeid shrimp trawl gear in the Gulf of Mexico. Changes in observer protocols were introduced and one change was that all red snapper *Lutjanus campechanus* collected would be enumerated and measured where possible. This change has yielded catch and length information from the Gulf of Mexico shrimp fishery. An integrated approach for dealing with age composition, growth and mortality of juvenile red snapper had not been previously attempted. To address this problem Gazey et al. (2008) constructed a length-based, age-structured model to objectively estimate growth and mortality parameters, and age composition of the shrimp trawl bycatch of red snapper in the western Gulf of Mexico from 81 monthly length-frequency data sets (a total of 239,521 fish were measured) from July 1999 to February 2007.

The objective here is to update these estimates for the observer data up to December 2011 using the methodologies developed by Gazey at al. (2008).

METHODS

The length frequency observations used in this analysis came from the NMFS's post 1998 Observer File, a database housed at the Galveston Laboratory of the Southeast Fisheries Science Center. A history and description of the Gulf of Mexico and Southeast Atlantic Shrimp Trawl Observer Program is provided by Scott-Denton (2005). Projects included in the file we obtained were coded: B = BRD Evaluation, E = Effort, G = BRD Certification, Gulf of Mexico, M = Modified Bycatch Characterization, R = Red Snapper Initiative, and T = TED Evaluation. In the Gulf of Mexico, most of the data collected from 1999 to the present came largely from the Red Snapper Initiative (R), Effort (E), BRD Certification (G), and TED Evaluation (T) studies. Scott-Denton (2005) describes the at-sea data collection methods for these studies.

We restricted our analyses to samples taken in the western Gulf of Mexico (NMFS Statistical Areas 13-21) following the SEDAR7 (2005) red snapper stock assessment. We used red snapper length and catch data and the effort data from all nets on each tow that had a positive value for penaeid shrimp catch recorded in the Station Sheet form; i.e., a positive shrimp catch was used to indicate an acceptable tow. In some studies (e.g., G and R), data from only two of the four nets were sampled and the BRD in one of the paired nets was disabled as a basis for evaluating BRD performance. We used data from these nets as well because 1) we wished to use as much of the red snapper length information as possible, and 2) the bias resulting from using data from a net where the BRD had been disabled was believed to be relatively small because of the poor performance of BRDs to date (Foster 2005).

The raw length-frequency data for red snapper were placed in 5-mm length bins and summed across all tows for each month and year for the period covering July 1999 through February 2007. The programs differed in the number of nets sampled for red snapper count and length information. For example the Effort (E) program generally counted and measured all red snapper taken in all nets, usually four. In contrast, red snapper data from only the two outer nets were typically used in programs such as the G, R, and T studies. Whereas we did not believe this was a problem with respect to the length-frequency data, a standardization protocol was believed necessary for estimating catch and effort used for calculating abundance indices.

Based on Gallaway et al. (1999), we used red snapper catch and effort data for depths greater than 18.2 m as the basis for determining abundance in the western Gulf. For each tow, catch was calculated as catch per net times the number of nets towed. The catches from all tows were then summed to obtain total catch for each year/month combination. Effort (hours towed) for all observed tows, including tows without red snapper, was summed for the corresponding year/month combinations.

The mathematical model to predict the probability of a fish belonging to a length interval based on the fundamental parameters to be estimated is provided by Gazey et al. (2008). The main assumptions are:

- 1. Total mortality is either a function of recruitment (density dependent) or it is constant over the study.
- 2. The length-frequency data consist of only age-0 and age-1 red snapper.
- 3. Red snapper are vulnerable to the penaeid shrimp fishery for a maximum of 24 months.
- 4. The trend in growth over the age-0 and age-1 red snapper cohorts is either linear or tracks a von Bertalanffy curve.
- 5. Red snapper are not fully recruited to the shrimp trawl bycatch fishery until October (partial recruitment over July to September).
- 6. The lengths of red snapper in each age-class are normally distributed around their mean length.

The fundamental parameters estimated and the associated indices are listed in Table 1. Prior distributions for these parameters and the likelihood of observing the data are described by Gazey et al. (2008). Parameter estimates through maximization of the posterior distribution were obtained using the software package ADMB (ADMB 2010). The package allows for the restriction or bounding of parameter values, stepwise optimization, the estimation of user defined variables, report production of standard errors and correlation between all estimated variables. We evaluated three alternative models:

- 1. Von Bertalanffy growth with density dependent mortality.
- 2. Linear growth with density dependent mortality.
- 3. Von Bertalanffy growth with density independent mortality.

The alternative models were evaluated through Akaike Information Criteria (AIC) and Bay's Information Criteria (BIC) following Burnham and Anderson (2004). Corrections for lack of fit and effective sample were not used in the comparison of models.

An update similar to that presented here was made December, 2009. Comparative recruitment index and mortality plots based on the best fitting (available) model were made using the data as published by Gazey et al. (2008, hereafter the "Paper"), December-2009 and July-2012 (this analysis).

RESULTS

Overall, our analyses included data from 15,201 tows made in the western Gulf of Mexico from the penaeid shrimp fishery. The largest number of tows came from the Red Snapper Initiative and the Effort Studies followed by the BRD Certification Studies (Table 2). With the exception of 2006 (603 tows), each year was characterized by more than 700 tows with the peak number of tows recorded in 2008 (1,815 tows). Appendix A provides the monthly distribution of observer tows. A total of 391,533 juvenile red snapper were measured for length. Appendix B plots their length frequency. The abundance index

(standardized by the logarithm of catch-per-unit-of effort and subtraction of the mean) used in the anaysis for the original paper and subsequent updates are provide in Figure 1.

Parameter estimates, standard deviations (SE) and the correlations between parameters for the three model options are listed in Table 3. Model comparisions using the Akaike information factor (AIF) and the Bay's poserior factor (BPF) are provided in Table 4. Both criteria select the von Bertalanffy growth with density dependent mortality (model 1) as the best fit to the data. The linear growth model (model 2) is less than one in a thousand and the density-independent mortality model (model 3) is less than one in a million as likely as model 1. Model 1 fit to the length frequency data is provided in Appendix B for all months.

The estimation results that follow are based on von Bertalanffy growth with density-dependent mortality model option (model 1). Age composition estimates by calendar year and trimester are listed in Table 5. The first and third trimester average over 80% age-0 fish, while the age-0 fraction of the bycatch in the second trimester averaged less than 50%. The overall (yearly) age-0 composition is plotted by calendar year in Figure 2. The estimated recruitment index (mean = 1) by year is plotted in Figure 3. Estimated instantaneous mortality as a function of the recruitment index by age-class is charted in Figure 4. The subsequent predicted mortalities by year are provided in Figure 5.

DISCUSSION

Substantial data have accumulated since the Gazey et al. (2008) publication. An additional 7,942 tows were sampled that produced 57 monthly length frequency data sets and 153,012 juvenile red snapper length measurements. The result has been a substantial increase in the power to compare alternative models. The Von Bertalanffy growth model with density dependent mortality is in the order of a thousand times more likely than the model with linear growth and a million times more likely than the model with density independent mortality.

Besides extending the data set, the Dec-09 and Jul-12 updates also added and amended data for earlier dates (i.e., lagged data update and amendment). These changes have altered the parameter estimates. For example, the 1999 to 2006 mean age-0 and age-1 mortality estimates from Gazey et al. (2008) are 2.39 and 1.38, respectively. The updated estimates for the same period are 1.86 and 1.29, respectively. Gazey et al. shows that the length frequency data control population dynamics (e.g., growth, density dependent mortality) while the abundance index data serve to scale the parameters (e.g., level of mean mortality). In order to attribute the change in mortality to the data type (length frequency or abundance index) we created two bogus data sets over the 1999-2006 period: (1) a set with the original length frequency and updated abundance index and (2) a set with the updated length frequency and original abundance index values. The subsequent mortality estimates by year are plotted in Figure 6. Since the bogus data set with the updated length-frequency closely tracks Gazey et al. and the bogus data set with the updated abundance index closely tracks the fully updated estimates, we conclude that change in parameters is primarily generated by the altered abundance index (see Figure 1).

The results of our analysis show that the juvenile red snapper bycatch in the Gulf penaeid shrimp fishery in the first and third trimesters is still dominated by age-0 red snapper (about 82-84%), whereas the catch in trimester 2 (May-August) is split about evenly between age-0 (43%) and age-1 (57%) red snapper (see Table 5).

The current management paradigm for red snapper recovery is through bycatch reduction from penaeid shrimp trawl gear. Shrimp trawl effort in the statistical areas (10-21) and depths (10-30 fathoms) where juvenile red snapper are found has experienced significant reduction since 2002 (see Figure 7). A concurrent increase in juvenile red snapper abundance and decrease in juvenile mortality has not been observed (see Figures 1 and 5). We believe density dependent mortality from habitat limitation explains the lack of relationship between shrimp trawl effort and total juvenile mortality. The existence of density dependent juvenile red snapper mortality has the potential to substantially alter management advice.

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 Table 1. Fundamental parameters for estimation and associated indices.

Indices:	
а	- age $(a = 0, 1)$
h	- cohort age (months, <i>h</i> = 1, 2,, 24)
i	- length frequency sample (i = 1, 2,, l)
j	- length interval ($j = 1, 2,, J$)
Fundamental p	arameters to be estimated:
α	- over-dispersal coefficient
ΔI_h	 seasonal (monthly) length deviation for cohort of age h (24 parameters)
Δp_i	 logarithmic age composition deviation for sample i (I = 138 parameters)
$\Delta R_{\nu(i)}$	 logarithmic recruitment deviation for year y(i) (Y = 13 parameters)
δ	- coefficient of density dependence
К	- von Bertalanffy growth coefficient
λ_h	- recruitment selectivity coefficient for month <i>h</i> (Jul, Aug, Sep)
μ_a	- mean length of age a (2 parameters)
σ_a	 standard deviation of length distribution for age a (2 parameters)
Za	- instantaneous total mortality for age a (2 parameters)

Year	В	E	G	Μ	R	Т	Total
1999	0	448	261	0	0	0	709
2000	0	472	183	0	0	85	740
2001	116	102	210	60	243	43	774
2002	78	644	157	35	708	173	1,795
2003	76	179	179	0	446	107	987
2004	282	0	124	0	504	11	921
2005	0	0	258	0	389	325	972
2006	22	293	214	0	0	74	603
2007	0	8	174	0	828	243	1,253
2008	0	83	209	0	1,523	0	1,815
2009	27	0	172	0	1,509	0	1,708
2010	0	61	28	0	1,248	0	1,337
2011	99	0	0	0	1,488	0	1,587
Total	700	2,290	2,169	95	8 <i>,</i> 886	1,061	15,201

Table 2. Number of tows by year and study. (Study code B = BRD Evaluation; E = Effort; G = BRD Certification, Gulf of Mexico; M = Modified Bycatch Characterization; R = Red Snapper Initiative; T = TED Evaluation.)

Table 3. Parameter estimates by model option where MLE is the maximum likelihood estimate, SE is the standard error and the parameters are defined in Table 1.

			Correlation									
Parameter	MLE	SE	Ζ ₀	Ζ1	λ1	λ ₂	λ ₃	σ_{o}	σ_1	μ_{o}	μ_1	δ or K
VonB Growth 8	& Density D	Pependent M	Iortality									
<i>Z</i> ₀	1.26	0.202	1.000									
Ζ1	0.88	0.147	0.193	1.000								
λ 1	0.016	0.0050	-0.410	0.073	1.000							
λ_2	0.110	0.0289	-0.429	0.012	0.259	1.000						
λ_{3}	0.759	0.1916	-0.373	-0.046	0.220	0.232	1.000					
σ_{o}	21.2	0.32	0.047	0.288	-0.0035	-0.014	-0.010	1.000				
σ_1	33.7	1.00	-0.069	-0.255	-0.026	-0.005	-0.009	-0.238	1.000			
μ_{o}	80.8	2.22	-0.001	0.087	0.012	0.006	-0.002	0.095	-0.048	1.000		
μ_{1}	168.8	1.36	0.055	0.277	-0.002	-0.016	-0.012	0.336	-0.341	-0.221	1.000	
δ	2.42	0.552	-0.776	-0.158	0.299	0.304	0.260	-0.015	0.035	0.006	-0.023	1.000
К	0.37	0.093	-0.006	-0.240	-0.017	-0.002	0.011	-0.215	0.167	-0.676	0.171	-0.012
Linear Growth	& Density	Dependent N	Mortality									
Ζ ₀	1.26	0.201	1.000									
Ζ1	1.01	0.151	-0.360	1.000								
λ 1	0.016	0.0051	-0.400	0.043	1.000							
λ_{2}	0.110	0.0288	-0.420	-0.017	0.253	1.000						
λ_{3}	0.750	0.1888	-0.366	-0.072	0.214	0.226	1.000					
σ_{o}	21.5	0.32	0.046	0.245	-0.004	-0.013	-0.008	1.000				
σ_1	33.3	0.96	-0.064	-0.210	-0.027	-0.007	-0.012	-0.215	1.000			
μ_{o}	87.1	1.52	-0.002	-0.095	0.000	0.006	0.008	-0.067	0.045	1.000		
μ_1	167.3	1.30	0.053	0.316	0.004	-0.015	-0.015	0.397	-0.338	-0.067	1.000	
δ	2.46	0.558	-0.784	-0.229	0.300	0.305	0.262	-0.017	0.036	-0.005	-0.019	1.000
VonB Growth 8	& Density lı	ndependent	Mortality									
Ζ ₀	1.46	0.198	1.000									
Ζ1	1.69	0.243	-0.581	1.000								
λ 1	0.021	0.0070	-0.580	0.355	1.000							
λ_2	0.135	0.0378	-0.592	0.320	0.353	1.000						
λ 3	0.857	0.2285	-0.518	0.238	0.308	0.319	1.000					
σ_{o}	21.4	0.32	-0.015	0.282	0.024	0.016	0.016	1.000				
σ_1	33.2	0.97	-0.030	-0.204	-0.030	-0.017	-0.020	-0.224	1.000			
μο	81.3	2.21	-0.027	0.094	0.023	0.019	0.010	0.097	-0.042	1.000		
U 1	169.5	1.34	0.001	0.242	0.016	0.007	0.008	0.320	-0.311	-0.233	1.000	
r i K	0 32	0.001	0.062	-0.246	-0.046	-0.035	-0.019	-0.212	0.140	-0.681	0.200	1 000
N	0.52	0.031	0.002	-0.240	-0.040	-0.033	-0.019	-0.212	0.140	-0.061	0.209	1.000

Table 4. Model comparisons using Akaike information factor (AIF) and Posterior Bayes Factor (PBF) for inference.

Model Option	No. Param.	Function	AIF	BPF
VonB Growth & Density Dependent Mortality	186	20477.8	1.000000	1.000000
Linear Growth & Density Dependent Mortality	185	20486.3	0.000553	0.000288
VonB Growth & Density Dependent Mortality	185	20493.2	0.000001	< 0.000001

Table 5. Age composition (percent) by year and trimester where n is the sample size (number of fish measured) and SE is the standard error. The mean age composition is weighted by the sample size (n).

Jan-Apr					May-Aug				Sep-Dec				
Year	Age-0	Age-1	n	SE	Age-0	Age-1	n	SE	Age-0	Age-1	n	SE	
1999	-	-	-	-	86.0	14.0	14,183	2.53	89.4	10.6	26,051	1.94	
2000	76.0	24.0	3,695	5.42	67.2	32.8	7,233	4.25	85.7	14.3	32,181	2.16	
2001	88.5	11.5	657	5.78	47.7	52.3	9,823	3.01	86.6	13.4	17,457	2.38	
2002	77.0	23.0	1,893	5.62	40.8	59.2	15,015	3.69	87.9	12.1	35,473	1.84	
2003	85.0	15.0	584	5.86	27.5	72.5	1,973	4.53	84.6	15.4	16,439	2.38	
2004	90.8	9.2	4,225	2.55	19.4	80.6	9,547	1.35	58.3	41.7	6,268	3.84	
2005	62.8	37.2	979	7.30	8.8	91.2	10,714	1.64	72.4	27.6	8,163	3.37	
2006	67.8	32.2	979	6.16	19.5	80.5	5,684	3.50	90.7	9.3	16,534	2.42	
2007	89.7	10.3	1,038	3.83	33.4	66.6	4,190	4.63	81.1	18.9	39,241	2.14	
2008	88.3	11.7	9,101	3.29	40.8	59.2	8,804	1.93	62.6	37.4	13,276	3.50	
2009	75.6	24.4	9,917	3.74	67.4	32.6	3,398	4.35	93.4	6.6	26,252	1.78	
2010	92.5	7.5	7,001	2.43	39.9	60.1	3,108	2.52	39.3	60.7	878	5.53	
2011	61.6	38.4	1,621	6.16	30.1	69.9	3,607	3.65	82.8	17.2	14,351	2.52	
Mean	82.5	17.5	41,690	1.47	43.1	56.9	97,279	0.94	84.1	15.9	252,564	0.81	



Figure 1. Abundance index (standardized by the logarithm of catch-per-unit-of effort and removal of the mean) used in the anaysis for the original paper and subsequent updates.

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Figure 2. Percent age-0 composition by year.



Figure 3. Estimated recruitment index (mean = 1) by year.



Figure 4. Estimated instantaneous mortality as a function of the recruitment index. Upper panel is for age-0 and lower panel is for age-1 juvenile red snapper.

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Figure 5. Estimated instantaneous mortality by year. Upper panel is for age-0 and lower panel is for age-1 juvenile red snapper.



Figure 6. Estimated instantaneous mortality by year from Gazey et al. (2008, Paper), update only the length frequency data (Update Len-Freq Only), update only the abundance index data (Update Abun Only) and update both length frequency and aubundance index data (Dec-09 Update). Upper panel is for age-0 and lower panel is for age-1 juvenile red snapper.



Figure 7. Shrimp trawl effort (nominal days fished) in statistical areas 10-21 within depths 10-30 fathoms for 1960 to 2011.

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APPENDICES

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APPENDIX A. Location of tows (red dots) by month made in the in the western Gulf of Mexico (source of length frequency and abundance index data).



Tows with Measured Fish 13-21 199802



Tows with Measured Fish 13-21 199708



Tows with Measured Fish 13-21 199905



Tows with Measured Fish 13-21 199712



Tows with Measured Fish 13-21 199906



Tows with Measured Fish 13-21 199801



Tows with Measured Fish 13-21 199907





Tows with Measured Fish 13-21 199909



Tows with Measured Fish 13-21 199910



Tows with Measured Fish 13-21 199911



Tows with Measured Fish 13-21 200001



Tows with Measured Fish 13-21 200002



Tows with Measured Fish 13-21 200003



Tows with Measured Fish 13-21 200004



Tows with Measured Fish 13-21 200007



Tows with Measured Fish 13-21 200008



Tows with Measured Fish 13-21 200009



Tows with Measured Fish 13-21 200010



Tows with Measured Fish 13-21 200011



Tows with Measured Fish 13-21 200012



Tows with Measured Fish 13-21 200101





Tows with Measured Fish 13-21 200105



Tows with Measured Fish 13-21 200106



Tows with Measured Fish 13-21 200107



Tows with Measured Fish 13-21 200108



Tows with Measured Fish 13-21 200109



Tows with Measured Fish 13-21 200110



Tows with Measured Fish 13-21 200111

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Tows with Measured Fish 13-21 200201



Tows with Measured Fish 13-21 200202



Tows with Measured Fish 13-21 200203

Tows with Measured Fish 13-21 200204



Tows with Measured Fish 13-21 200205



Tows with Measured Fish 13-21 200206



Tows with Measured Fish 13-21 200207



Tows with Measured Fish 13-21 200212



Tows with Measured Fish 13-21 200301



Tows with Measured Fish 13-21 200209

Tows with Measured Fish 13-21 200210



Tows with Measured Fish 13-21 200211



Tows with Measured Fish 13-21 200302



Tows with Measured Fish 13-21 200303



Tows with Measured Fish 13-21 200305



Tows with Measured Fish 13-21 200306



Tows with Measured Fish 13-21 200307



Tows with Measured Fish 13-21 200308



Tows with Measured Fish 13-21 200309



Tows with Measured Fish 13-21 200310



Tows with Measured Fish 13-21 200311





Tows with Measured Fish 13-21 200401



Tows with Measured Fish 13-21 200402



Tows with Measured Fish 13-21 200403



Tows with Measured Fish 13-21 200404



Tows with Measured Fish 13-21 200405



Tows with Measured Fish 13-21 200406



Tows with Measured Fish 13-21 200407



Tows with Measured Fish 13-21 200412



Tows with Measured Fish 13-21 200502



Tows with Measured Fish 13-21 200409

Tows with Measured Fish 13-21 200410



Tows with Measured Fish 13-21 200411



Tows with Measured Fish 13-21 200503



Tows with Measured Fish 13-21 200504



Tows with Measured Fish 13-21 200507



Tows with Measured Fish 13-21 200508



Tows with Measured Fish 13-21 200509



Tows with Measured Fish 13-21 200510



Tows with Measured Fish 13-21 200511



Tows with Measured Fish 13-21 200512



Tows with Measured Fish 13-21 200601

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Tows with Measured Fish 13-21 200603



Tows with Measured Fish 13-21 200606



Tows with Measured Fish 13-21 200607



Tows with Measured Fish 13-21 200608



Tows with Measured Fish 13-21 200609



Tows with Measured Fish 13-21 200610



Tows with Measured Fish 13-21 200611

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Tows with Measured Fish 13-21 200701



Tows with Measured Fish 13-21 200702



Tows with Measured Fish 13-21 200703



Tows with Measured Fish 13-21 200706



Tows with Measured Fish 13-21 200707



Tows with Measured Fish 13-21 200708



Tows with Measured Fish 13-21 200709



Tows with Measured Fish 13-21 200802





Tows with Measured Fish 13-21 200711

Tows with Measured Fish 13-21 200712



Tows with Measured Fish 13-21 200801



Tows with Measured Fish 13-21 200805



Tows with Measured Fish 13-21 200806





Tows with Measured Fish 13-21 200811



Tows with Measured Fish 13-21 200812



Tows with Measured Fish 13-21 200808

Tows with Measured Fish 13-21 200809



Tows with Measured Fish 13-21 200810



Tows with Measured Fish 13-21 200901

Tows with Measured Fish 13-21 200902



Tows with Measured Fish 13-21 200904



Tows with Measured Fish 13-21 200905



Tows with Measured Fish 13-21 200906



Tows with Measured Fish 13-21 200907



Tows with Measured Fish 13-21 200908



Tows with Measured Fish 13-21 200909



Tows with Measured Fish 13-21 200910



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Sec. 1

Tows with Measured Fish 13-21 200912



Tows with Measured Fish 13-21 201001



Tows with Measured Fish 13-21 201002



Tows with Measured Fish 13-21 201003



Tows with Measured Fish 13-21 201004



Tows with Measured Fish 13-21 201005



Tows with Measured Fish 13-21 201006



Tows with Measured Fish 13-21 201008



Tows with Measured Fish 13-21 201009



Tows with Measured Fish 13-21 201010



Tows with Measured Fish 13-21 201011



Tows with Measured Fish 13-21 201012



Tows with Measured Fish 13-21 201101



Tows with Measured Fish 13-21 201102

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Tows with Measured Fish 13-21 201104



Tows with Measured Fish 13-21 201105



Tows with Measured Fish 13-21 201106



Tows with Measured Fish 13-21 201107



Tows with Measured Fish 13-21 201108



Tows with Measured Fish 13-21 201109



Tows with Measured Fish 13-21 201110



Tows with Measured Fish 13-21 201112

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APPENDIX B. Length frequency data for junenile red snapper in the western Gulf of Mexico (bars) and the model fit to these data (lines). Each panel depicts a month and each page a year-class.



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