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ABSTRACT:

Red snapper, *Lutjanus campechanus*, a highly prized commercial and recreational fish in the northern Gulf of Mexico (GOM), is considered overfished, but no overfishing is currently occurring. Stock assessment data rely on both fisheries dependent and independent data; however, fisheries dependent data are truncated due to regulatory size limitations and fisheries independent data lack information on two to five year age classes. This investigation reports on the development of a fisheries independent survey, which identified concentrations of two to five year age classes, and uses standardized bandit reel sampling gear at oil and gas structures in federal waters of the northern GOM from Alabama to western Louisiana. Red snapper captures during 2005 and 2007 surveys were 77% and 72% of the total catch with catch per unit effort (CPUE) of 0.7246 and 0.6864 fish/hook hour and coefficient of variance (CV) values were 0.15 and 0.17 respectively, demonstrating that these data are suitable for stock assessment purposes. Direct aging of captured snapper revealed age classes one to seven years. Further, age classes two and three constituted 80% of snapper otoliths sampled. Simplicity and adaptability of the survey on platform structures and other habitat types can provide a rich source of red snapper data throughout the northern GOM.

INTRODUCTION:

Red snapper (*Lutjanus campechanus*) support an important commercial and recreational fishery in the northern Gulf of Mexico (GOM). Currently, the stock is considered overfished, but, no overfishing is occurring (Cowan *et. al*, 2010). As part of the stock assessment, population indices are derived using information from fisheries dependent and independent data. Fisheries dependent data (e.g. landings records) tend to omit younger age classes due to catch quotas and size limitations required by fishing regulations. National Marine Fisheries Service (NMFS) fisheries independent data are collected from bottom trawl, bottom longline, stationary reeffish camera, and ichthyoplankton surveys with each survey collecting data on red snapper at specific life history stages. While the combined data sets offer an overall snapshot of red snapper stocks, the data under-represent red snapper in two to four year age classes (SEDAR 7, 2005).

Oil and gas structures are well known to harbor red snapper by commercial and recreational fisherman, as well as the science community (Reggio and Kasprzak, 1991; Patterson, 1995; Nieland and Wilson 2003). Currently there are nearly 4000 platforms from Alabama to Texas (Bureau of Ocean Energy Management, Regulation and Enforcement, 2012) and data collected from platform removal operations (Gitschlag *et al.* 2003) indicate that two to five year age classes of red snapper inhabit these structures (Nieland and Wilson, 2003; Szedlmayer and Schroepfer, 2005, Wilson *et al,* 2006). Furthermore, it is thought these structures could serve a significant role in the life history of red snapper (Gallaway *et. al*, 2009, Shipp and Bortone, 2009). Previous attempts to sample platforms have met with limited success (Stanley and Wilson, 1995, 2004; Szedlmayer, 1997; Rademacher and Render, 2003) due to visibility, diver avoidance, equipment limitations, and skill level biases.

This investigation seeks to develop a fisheries independent survey for red snapper in an effort to enhance red snapper indices of abundance for under-represented two to five year age classes using standardized gear at oil and gas platforms in the northern GOM, which could be adaptable to other habitat types.

MATERIALS AND METHODS:

Bandit reel gear was selected because it can be standardized, easily deployed and no operator skill bias was introduced to the operation of the gear. Each bandit reel was loaded with 152.4 m (500 ft) of 1.6 mm (1/16 in) stainless steel wire as the mainline. The detachable bandit gear section (backbone) for port and starboard reels were constructed of ten sections of the same material in 0.61 m (2 ft) sections, each connected with 6/0 Rosco® three-way swivels. Gangions were constructed of 30 cm (12 in) 36.29kg (50 lb) test monofilament line, a circle hook (size 11/0), a 2/0 black anodized swivel snap, and attached to the backbone at the three-way swivels. A 2.27 kg (5lb) weight was placed at the terminal end of the backbone to insure stability and vertical fishing throughout the water column. The backbone for the stern reel was constructed of a single length of the same stainless steel wire 6.71 m (22 ft). Two crimps were placed every 0.61 m (2 ft) from the terminal end. Each end of the backbone was fitted with a 4/0 black anodized swivel snap to secure the gangion in place. The gangions were made similarly as above but used a 6/0 model 120, 308 stainless 5 inch longline clamp with swivel to secure them to the backbone. This modification was made to facilitate deployment and retrieval of gear and captured specimens over the dive platform on the R/V Gandy only and does not affect the gear's ability to perform. In waters deeper than 75 meters, a 4.54 kg (10lb) weight replaced the standard weight to keep the line vertical due to stronger deep water currents.

The sampling universe (Figure 1) was defined as oil and gas platforms and stand pipes in federal waters from Alabama to Louisiana (87^{o} W to 92^{o} W) at depths ranging from 6 meters (20 ft) and 152 meters (500 ft) in an effort to sample as much of the depth range of red snapper habitat as possible within the platform field. Sample stations were selected using a stratified-random selection method. The sampling universe was divided by longitude and by three depth strata (shallow 0-<30 m, midwater (30-<75 m) and deep (75-152 m). The number of sample sites selected in a given strata (S_{st}) were directly proportionate to the number of sites in a strata (N_{st}) divided by the total number of sites in the universe (N_t) multiplied by the total number of sites (S_t) to be sampled ($S_{st} = N_{st}/N_t$ x S_t).

Sampling hours were from dawn to dusk, between the hours of 0600 and 2000. To standardize sampling locations relative to the structure, the bow of the vessel was moored to the leeward side of the structure. A sample set at a station was comprised of three bandit reels (port, starboard, and stern) deployed simultaneously with ten hooks per reel for a total of 30 hooks per set. Each set had a soak time of ten minutes. In 2005 during a bait comparison test, all ten hooks of each reel were baited with the same bait (fresh frozen Atlantic mackerel, squid, or salted mackerel), and each reel baited with different bait. All three baits were fished simultaneously during each set. The baits were rotated sequentially through the reel positions insuring all three baits were used equally at each reel position. If fish were captured during the first set, two additional sets were made at the rig to increase the number of otoliths for age analysis. Subsequent sets were not used in analysis of CPUE values.

The 2007 survey was conducted using fresh frozen mackerel and followed standardized sampling protocols outlined above. Two gear changes were made in 2007, bandit reels were upgraded from hand crank to electric reels, and gangions were constructed using 45.36 (100lb) monofilament line.

Lengths, weights and sex data were recorded for all species caught and sagittal otoliths were taken from red snapper for direct age estimation. In 2005, otoliths were removed from all red snapper. Due to survey time constraints in 2007 a subset of was randomly selected at each station.

Ototliths were processed at the National Marine Fisheries Service Laboratory, Panama City Beach, Florida. Otoliths were processed with a high-speed thin sectioning machine utilizing the methods of Cowan et al. (1995). Two transverse cuts were made through the otolith core to a thickness of 0.5 mm. Ages were assigned based on the count of annuli (opaque zones observed on the dorsal side of the sulcus acusticus in the transverse plane with reflected light at 40x, including any partially completed opaque zones on the otolith margin) and the degree of marginal edge completion. Red snapper off the Southeastern U.S. complete annulus formation by late spring to early summer (Patterson et al., 2001; Wilson and Nieland, 2001; White and Palmer, 2004; Allman et al., 2005). Therefore, age was advanced by one year if a large translucent zone was visible on the margin and capture date was from 1 January to 30 June; after 30 June age was equal to opaque zone count. By this traditional method, an annual age cohort is based on a calendar year rather than time since spawning (Jearld, 1983; Vanderkooy and Guindon-Tisdel, 2003). Biological (fractional) ages were also estimated for use in fitting growth curves. Biological age accounts for the difference in time between peak spawning (defined as 1 July for red snapper) and capture date (difference in days divided by 365). This fraction is added to annual age if capture date is after 1 July and subtracted if capture date is before 1 July (Vanderkooy and Guindon-Tisdel, 2003; Wilson and Nieland, 2001).

Mean CPUE was calculated based on the number hooks retrieved on three reels per station (10 hooks/reel) multiplied by minutes fished effort and expressed as the number of fish captured per hook hour. In the case of lost gear when a complete or partial backbone was lost, or hooks were missing upon retrieval of a set, the number of hooks remaining was used to calculate the mean for that unit effort. For CPUE and CV comparisons for both survey years was computed from first sets only at stations with like gear.

To determine the effectiveness of bait type, red snapper mean CPUE and fork length were tested against the three bait types used in 2005 and frozen mackerel in 2007. Reel position was also tested for any significant difference between CPUE and fork length. The General Linear Model (GLM) procedure (SAS Institute Inc, 2011) was used to perform the Analysis of Variance (ANOVA) test due to the difference in number of stations for each year. The Student-Newman-Keul (SNK) test was used to examine significant difference in CPUE or size-at-capture for among-bait types and reel positions.

The coefficient of variation, a measure of dispersion for sample data, was defined as the population standard error divided by the population. Coefficient of variation (CV) for mean CPUE was calculated for red snapper from simulated sample sizes ranging from 1 to 100 stations. This was accomplished by assuming the mean CPUE for red snapper and its variance obtained during each survey year was accurate for the population in the sample area.

RESULTS:

In 2005, a total of 316 fish (16 species) were captured at 67 stations, with red snapper representing 77% of the total catch (Table 1). Overall mean CPUE for red snapper was 0.72 fish per hook hour (CV = 0.15). Bait type comparison demonstrated no significant effect on red snapper captures CPUE ($p = 0.47$). Fresh frozen mackerel had a slightly higher overall CPUE (0.83) than squid and salted mackerel, 0.74 fish per hook hour and 0.60 fish per hook hour respectively. Analysis of mean CPUE by reel position also indicated no significant effect among positions ($p = 0.34$). The starboard reel had the highest CPUE of red snapper at 0.86 fish per hook hour, followed by the port and stern reels with 0.72 and 0.59 fish per hook hour, respectively. Comparison of bait type to reel position interactions was not significant ($p = 0.20$). Mean CPUE values of interactions indicated that fresh frozen mackerel had highest CPUE on the port (0.88) and stern (0.92) positions while squid had a higher catch rate on the starboard position (1.09). Fresh frozen mackerel had the lowest catch rate (0.64) at the starboard position, salted mackerel was lowest (0.64) on the port position, and squid had the lowest catch rate (0.12) on the stern position.

In 2007, a total of 408 fish (25 species) were captured at 76 stations, with red snapper representing 72% of the total catch (Table 1). Overall mean CPUE for red snapper was 0.6864 fish per hook hour (CV=0.17). There was no significant difference between reel position with respect to red snapper mean CPUE (p = 0.36). The SNK test indicated the starboard reel position had the highest CPUE (0.80), followed by the stern reel (0.72) and the port reel (0.54).

When comparing catch rates year to year, no significant effect (p = 0.79) in overall CPUE (0.6995) was indicated despite using three baits in 2005, as opposed to using only mackerel in 2007. Yearly mean CPUE values exhibited a higher mean CPUE in 2005 (0.72) than in 2007 (0.68). When yearly CV values were examined over 100 stations (Figure 2) for each year consistently low variance was demonstrated.

Mean fork length (FL) was examined as the dependent variable for 2005 data, overall mean fork length of red snapper captured was 356.55 mm (p=0.42). No significant effect was indicated when comparing mean FL to bait types, although salted mackerel caught slightly larger fish (360.8 mm) than fresh frozen mackerel (359.8 mm) and squid (349.4 mm). However, an effect was noted in mean FL between captures at reel positions (p = 0.0011). SNK test indicated the effect was demonstrated between captures on the stern reel (377.4 mm) and those of the port (356.8 mm) and starboard (341.8 mm) reels. In 2007, mean FL for the survey was 367.5 mm and exhibited no significant effect with respect to reel positions (p = 0.32). The stern reel captured the largest (373.7 mm) red snapper, followed by the port (366.2 mm) and starboard reel captured the smallest mean fork length (362.7 mm). Overall mean FL for combine years was 362.1 mm and demonstrated a significant effect in mean FL between years (p = 0.03), with larger mean fork length caught in 2007 (367 mm) compared to 2005 (356 mm).

There were a total of 687 otoliths aged from 2005 captures and 171 otoliths aged from 2007 captures. Total length (TL) of red snapper ranged from 245 mm to 801mm (Table 2). Direct age estimates revealed red snapper in age classes one through seven were captured. Age class one snapper comprised 13% both years. Age class two comprised the highest capture percentage in both survey years. Together, ages two and three make up about 80% of captures. Age class four represented about 34%, and ages five through seven marginally represented by one or two fish (Table 2).

Age class distribution by capture depth indicated that age one snapper were captured at all sampled depths and most (86.96%) captured at less than 30 m. Age class two snapper were captured at similar depths, and demonstrated highest ubiquity of age classes captured throughout sampled depths. Age class three snapper were captured from slightly deeper water at the shallow end of the capture spectrum with a mean capture depth of 41.16 m. Age class four snapper were captured at similar depths to age three fish with a mean capture depth of 54.21 m. Older snapper were captured at increasingly deeper depths (Table 2).

DISCUSSION:

During the 2005 survey year there were no stations sampled beyond 70 meters. This was by design to limit travel time and distance in order to sample as many stations as possible in the first year for aging data and limited funds. During 2007 there were only five stations completed between 70 meters and 143 meters. Safety concerns during operations and logistic matters precluded completing more stations in this depth range and it is acknowledged that this may be of concern. Safety concerns, reduced number of platforms in deeper water, and capture data from bottom longline and other survey efforts which indicate few red snapper captured beyond 110 meters, could relegate the reduction of platforms in deep water from the sample universe in the future.

Despite the use of multiple baits in 2005 there was no significant difference in mean capture rates between survey years. This demonstrated use of three baits, or any of the three baits singularly, could be used successfully and supports use of multiple baits by commercial fisherman who understand prey preference. A notable difference appeared to be a switch in capture rates between port and stern positions in 2007. In 2005 the stern reel position had the lowest CPUE; in 2007 the port reel had the lowest CPUE. In this instance, prey preference at time of presentation caused by a “mixed bait effect” between reel positions in 2005 could have been a contributing factor, in addition to the further distance of the stern from the rig.

Comparison of CV values of mean CPUE were examined to demonstrate the reliability of the survey as a tool for establishing red snapper abundance indices at oil and gas structures in the northern GOM. This was emphasized by a consistent and near-mirror reflection of CV values from 67 stations in 2005 (CV=0.15), to 76 stations in 2007 (CV=0.17) (Figure 2).

The mean fork length comparison between baits of 2005 indicated no significant effect was expressed. In 2007, when frozen mackerel was the single bait used there was no significant effect expressed in FL between reel positions. In a year to year comparison of mean FL a significant effect was expressed (p = 0.03). Mean FL increased in 2007

(367.5mm) from 356.5 in 2005). The stern still captured snapper of larger mean FL, but the mean FL of captures increased slightly at the starboard (341.9mm to 362.7mm) and port (356.9 to 366.197mm) reel positions. This could be attributed to the "mixed bait effect", in which the two baits were eliminated in 2007; squid which captured more and smaller mean FL snapper than salted mackerel which captured fewer but larger snapper. This was further illustrated when compared to catch rates and mean FL captures at the starboard reel position which indicated a higher mean catch rate but smaller snapper captured at the starboard position. It was also empirically noted during sampling operations that fish most often struck the baits on the starboard reel position before striking the other two positions. This could have been in part due to bait type at reel positions at time of presentation, and the attitude of the vessel as it settled into position against the winds and currents when moored on the leeward side of the structure. It could have been that smaller snapper arrived first at the starboard reel position which was closer to the submerged portion of the structure. The larger snapper in smaller numbers were captured at the stern position which was always furthest from the structure. This purports consistency with previous studies that indicate larger fish in smaller numbers venture further from the structures during foraging efforts (Rademacher and Render 2003, Stanley and Wilson 2003) while smaller fish remain closer to the platform.

Direct age estimates revealed red snapper in age classes one through seven were captured during the study. Age classes two and three comprised about 80% of aged snapper with age two cohorts dominating at around 60%. The presence of age class one (13%) supports reports that red snapper recruit to high relief structure at age one (Gallaway *et al*., 1981, 2009; Stanley and Wilson, 1991; Stanley, 1994; Szedlmayer and

Shipp, 1994; Render, 1995; Stanley and Wilson, 1995; Gallaway *et al*., 1999; Hernandez *et. al*, 2003; Nieland and Wilson, 2003; Patterson and Cowan, 2003). The number of age one snapper is likely higher at these structures but captures less than 245mm (Table 2) could have been truncated due to hook selectivity. Analysis of ages by capture depth revealed that age classes one through four were fairly ubiquitous at all sample depths. This was evidenced by deeper minimum capture depths of older, larger snapper (Table 2). The correlation of age and TL demonstrate the general trend of snapper to migrate at sizes corresponding to age toward deeper more expansive habitat, and eventually depart from gas and oil structures. This migration to and from platform structures could suggest red snapper use these structures similarly to that of natural reef or other artificial reef structures during their life history progression moving to deeper and more spatially expansive habitat as they age (Figure 4) (Patterson *et al*, 2001; McEachran and Fechhelm, 2005; Gallaway *et al*, 2009; Szedlmayer, 2007; Cowan *et al*, 2009; Gallaway *et al*, 2009; Shipp and Bortone, 2009). Regulatory minimum size limits for harvest (16 inches, 406.4mm) of red snapper overlaps the mean TL of red snapper (Table 2) at age three (429mm) and four (442mm), and could have contributed in part to the decline from platforms during regulated harvest seasons (Nieland and Wilson, 2003).

Bottom longline age data processed at the same Panama City Beach, FL facility from 2000 - 2010 was used to illustrate red snapper captures of age classes between the two surveys (Figure 3). This study illustrated that the bandit reel survey and the bottom longline survey produce a more complete snapshot of red snapper captures as they recruit to platform structures at age one, and migrate to deeper more spatially expansive habitat at about age four as they grow .

The bandit reel gear is versatile as modifications to the gear were simple and economical to suit survey specific requirements. Rigging the backbone gear with fluorocarbon monofilament for a comparison to stainless steel on 25 sets did not significantly affect catch rates for red snapper. Capture rates for red snapper on monofilament increased 1.3 percent more red snapper. Regular monofilament can be used instead of fluorocarbon at a greatly reduced cost.

The gear can be modified to meet a number of needs. Demands to meet more exhaustive stock assessments due to the under-represented age groups in stock assessment data have shown great interest in the adaptability of this survey.

CONCLUSION:

Bait performance in 2005 demonstrated no significant effect in CPUE or FL between bait types, and an effect only in FL between reel positions indicated any of the three baits could be used as the standardized bait for the survey. Indicators such as range of FL as related to fish age, and higher CPUE at reel positions for fresh mackerel were considered when choosing a standardized survey bait for 2007. Other considerations included bait cost, availability of restocking at ports away from home, and the ability to compare bandit reel survey results with other surveys (NMFS bottom longline survey), led to the decision to use fresh frozen mackerel as the stand alone bait in 2007. The elimination of significant effect in FL at reel positions in 2007, and logistical considerations demonstrated fresh frozen mackerel to be commensurate with needs of the survey.

The survey effectively addressed issues of red snapper abundance and population dynamics at platforms and offered fisheries independent data on red snapper and other species previously limited or unavailable. The study demonstrated the reliability of this survey to capture red snapper across age classes presently under-represented with acceptable CPUE and CV values. The study also demonstrated the flexibility of the gear to meet changing requirements. The bandit reel gear has been shared with NFMS Laboratory, Panama City Beach, FL, Dauphin Island Sea Lab, AL, Florida Fish and Wildlife Commission, Tampa, FL, and is now being successfully deployed on natural reef habitat and other submerged artificial reef habitats.

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Figure 1. Station locations for 2005 and 2007 surveys at oil and gas platforms.

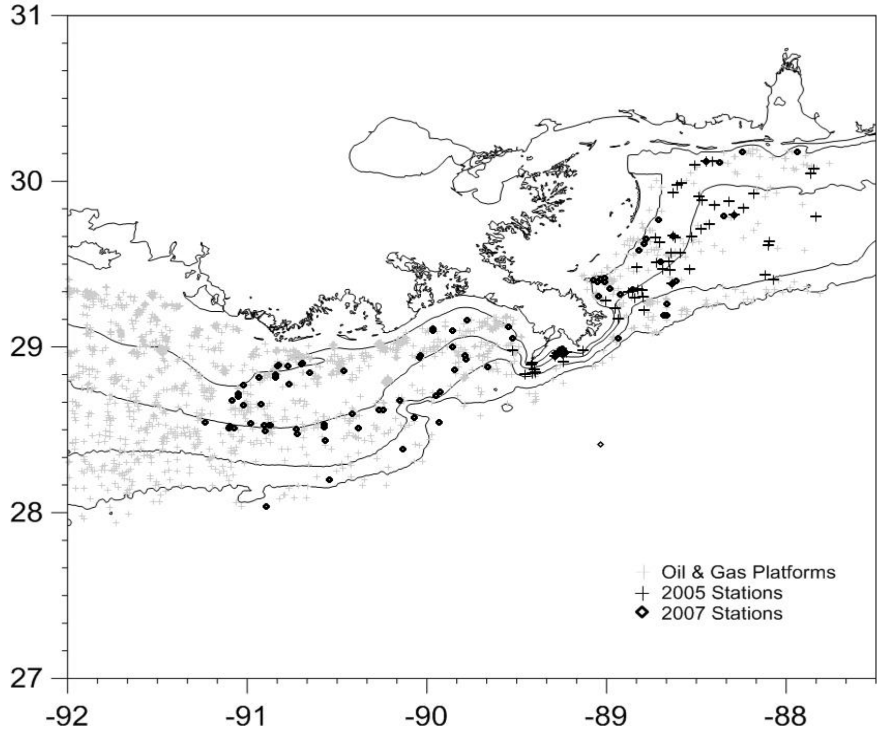

Figure 2. Comparison of Coefficient Values expressed for 100 stations for 2005 and 2007.

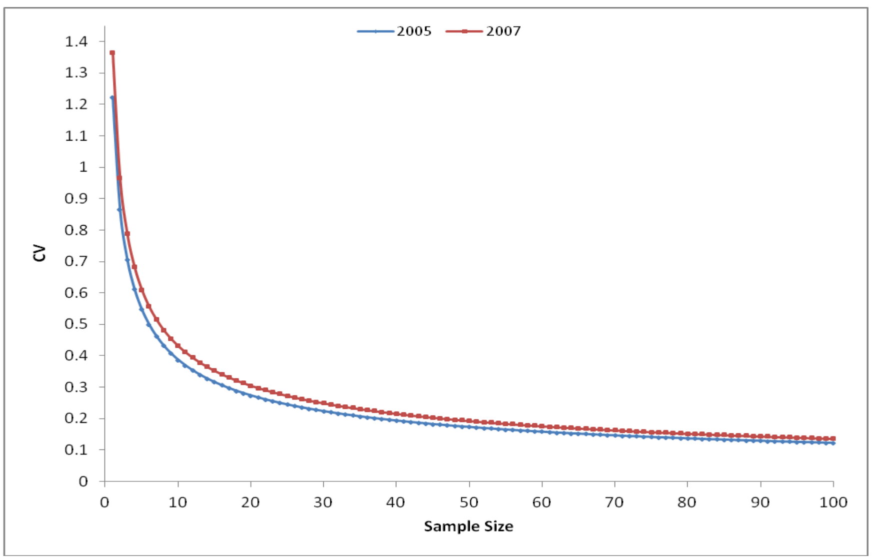

Figure 3. Bandit reel captures of red snapper by age at platforms during 2005 and 2007 compared to bottom longline surveys across the northern GOM from 2000 - 2010.

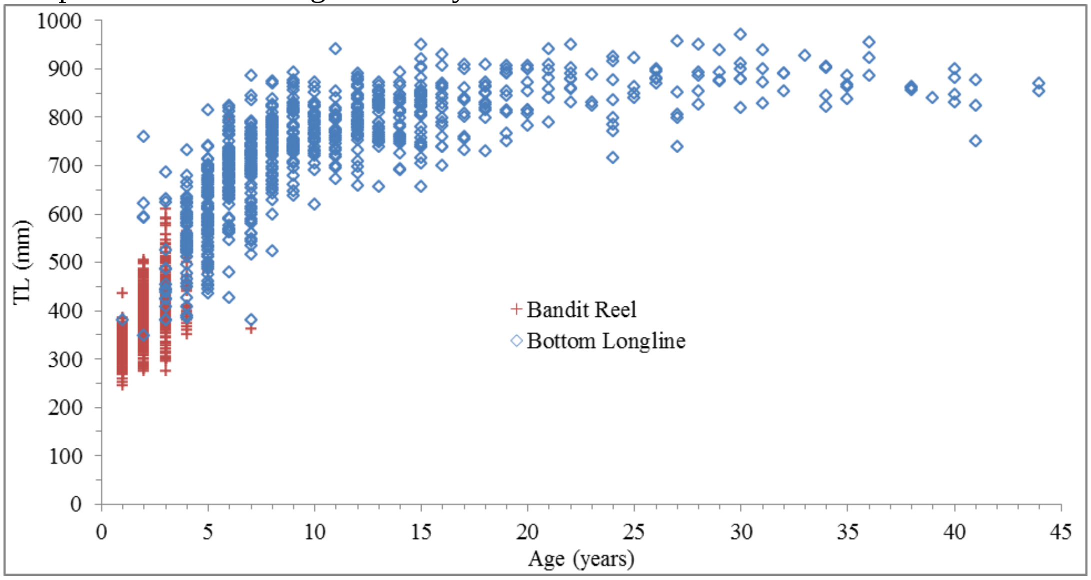

Table 1. Species composition from stainless steel first sets for 2005 and 2007 surveys. Numbers are total number captured with percent of catch in parenthesis.

Species	2005 #Captures(%)	2007 #Captures(%)
Arius felis	16 (5.0)	20 (4.9)
Bagre marinus	14 (4.4)	1 (0.2)
Balistes capriscus		1 (0.2)
Caranx crysos	11 (3.5)	6 (1.5)
Caranx hippos		1 (0.2)
Carcharhinus brevipinna	1 (0.3)	5 (1.2)
Carcharhinus falciformis		2 (0.5)
Carcharhinus limbatus	1 (0.3)	
Centropristus philadelphica		1 (0.2)
Cynoscion		2 (0.5)
Cynoscion arenarius	6 (1.9)	33 (8.1)
Lutjanus campechanus	**244 (77.2)**	**294 (72.0)**
Lutjanus synagris	10 (3.2)	5 (1.2)
Micropogonias undulatus	1 (0.3)	3 (0.7)
Mycteroperca microlepis	3 (0.9)	
Pomatomus saltatrix	1 (0.3)	5 (1.2)
Pristipomoides aquilinaris		1 (0.2)
Rachycentron canadum		1 (0.2)
Rhizoprionodon terraenovae		4 (1.0)
Rhomboplites aurorubens	2 (0.6)	
Sciaenops ocellatus	2 (0.6)	2 (0.5)
Scomber japonicus		1 (0.2)
Selar crumenopthalmus		2 (0.5)
Selene setapinnis	2 (0.6)	
Selene Vomer		2 (0.5)
Seriola dumerili	1 (0.3)	
Seriola fasciata		1 (0.2)
Seriola rivoliana		3 (0.7)
Sphyraena guachancho		9 (2.2)
Trachiurus lepturus	1 (0.3)	3 (0.7)
Total	316	408

Table 2. Red snapper age composition for bandit reel survey in 2005 and 2007. All lengths are in mm.

	2005				2007			
Age	N	Depth Range	Length Range	Mean (SD)	N	Depth Range	Length Range	Mean (SD)
1	92	15.5 - 56.9	245 - 436	319 (33)	23	9.7 - 84.6	272 - 382	319 (36)
2	463	15.5 - 69.9	279 - 505	389 (38)	76	7.1 - 84.6	275 - 475	378 (45)
3	109	15.5 - 69.9	301- 610	429 (60)	63	16.4 - 84.6	275 - 576	414 (69)
4	19	21.6 - 69.9	351 - 623	442 (78)	8	31.9 - 76.3	409 - 591	487 (62)
5	3	37.3 - 38.1	480 - 595	522 (64)				
6	1	52.3	801					
7					1	34.1	362	
Total	*687*	*15.5 - 69.9*	*245 - 801*	*389 (56)*	*171*	*7.1 - 84.6*	*272 - 591*	*388 (66)*