Historical Catch Trends and Efficacy of Video Surveillance Monitoring of Catch Per Unit Effort at Recreational Fishing Piers in South Carolina

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HISTORICAL CATCH TRENDS AND EFFICACY OF VIDEO SURVEILLANCE MONITORING OF CATCH PER UNIT EFFORT AT RECREATIONAL FISHING PIERS IN SOUTH CAROLINA

by

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I would like to dedicate this work to my wife, Meghan, who shares my love for everything oceanic and has supported me throughout the course of this voyage.

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Abstract

In recent years, recreational anglers claim declining catch rates in the shore-based pier fishery in South Carolina. The study seeks to evaluate whether catch data supports angler testimony in this region, to examine the relationship of landings at piers in context of the regional level, and to test a method which would enhance the ability of managers to monitor landings of this under-studied fishery. Novel, non-standardized catch series extending back to 1973 were acquired from fishing piers and examined in an attempt to produce significant trends in measures of catch. King mackerel catch (*Scomberomorus cavalla*) was tested for correlation to data sets representative of population level data sets. A video survey method was compared to on-site surveys for its cost efficiency and efficacy of detecting catch per unit effort and species composition of catch at piers. Analysis of the historical catch records produced significant trends in measures of catch that are consistent with declining size and abundance. These results were suggestive of general trends in total population dynamics for king mackerel. The video survey method was found to produce total CPUE estimates that were not significantly different than those produced by an on-site observer, though species composition was not detectable. Enhancing the capability of managers to detect and monitor variability of CPUE at recreational piers will result in a better understanding of local fishing success, which can be indicative of population level dynamics.

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Introduction

Significance of Recreational Fisheries

The sustainability of the natural resources on which anglers rely must be ensured to maintain economic prosperity and quality of life for anglers and the functionality of ecosystems. Ninety percent of saltwater fishing takes place in state managed waters. The four most harvested fish by recreational anglers in the U.S. are regularly landed at onshore and nearshore sites within the state of South Carolina. Approximately 40% of fishing effort is conducted from shore-based sites on the Atlantic Coast (NOAA Economics of Fisheries Report 2011), though non-shore-based effort has increased in South Carolina between 1981 and 2009 from approximately 0.6 million recreational fishing boat trips to approximately 2.7 million trips.

The study site is situated in Horry County which relies heavily on tourism with 90% of the 15.2 million annual tourists visiting the beaches of the “Grand Strand” in Horry County (Myrtle Beach Chamber of Commerce Data and Statistics 2013). The recreational fishing industry is increasingly important, economically, ecologically and politically. According to a 2011 National Survey of Fishing (US Fish and Wildlife Service And Census Bureau 2011), 8.9 million saltwater anglers fished 99 million days, expending $961 per person in fishing related expenses.

Recreational fisheries managers have long considered recreational fishing on fish populations to be insignificant. Based on harvest ratios, the recreational fishing sector to total landings has been estimated up to 4% (Arlinghaus 2005) of US landings and up to

12% globally (Coleman 2004). Though, Coleman puts the U.S. number at 10% when forage fish are excluded and up to 38% in the South Atlantic for highly targeted recreational species. It should be noted though that harvest ratios of landings can be misleading when it comes to predicting the state of fisheries (Mutsert et al 2008, Arlinghaus 2005). Evidence for this is supported by Ihde et. al., (2011) who stated that in the US, the percentage of total catch contributed by the recreational fishing is increasing of 71% of marine species; due to not only a growth in the recreational sector but a decrease in the commercial sector. Recreational fisheries are not driven by the monetary value of the catch as are commercial fisheries. Thomas (2004) reports that enjoyment was the most important aspect of recreational fishing as reported by anglers.

This is not to say that recreational fisheries should be considered unimportant when it comes to impacts on the environment. Lewin et. al,. (2006) cite a multitude of possible recreational angling effects. These include effects directly to exploited species, on the associated ecosystems, and habitat disturbance.

Long Bay Pier Fisheries and Site Description

Long Bay is a shallow embayment (<12m) located between the outlet of the Cape Fear River at the headland of Cape Fear, North Carolina and the outlet of Winyah Bay in Georgetown, South Carolina. It experiences an average semidiurnal tidal range of 1.6m. The coast exhibits a typical sandy beach profile found along the South East U.S, broken up by barrier island complexes and marine dominated inlets. Bottom type is sandy with some hard bottom.

Pier fisheries have been shown to exhibit seasonal changes in relative abundance of fishes (dos Santos 1999). The piers in the study sites are found along beaches along the bay and are situated along the routes of several migratory fish species. Recreational pier fishers have learned the migration timing of these fishes and the effort and gear types vary accordingly. An earlier pier survey conducted by the author in 2007 (poster presented at ERF 2007) identified peaks in effort occur the in the months of July and October. The peak in July is more reflective of high turnout of vacationers than it is due to high fishing success; July actually produces the lowest CPUE. The first real fishing success peak occurs in May when several target species are most abundant during their seasonal migrations. The October peak is truly reflective of fishing success since the vacation season has passed. Many out-of-town visitors to the pier have come to the area specifically to target the returning migrant species that were present in the spring (Hammond and Cupka 1977).

Fishing tournaments are a frequent occurrence in the recreational pier fishery, ranging from those organized by a single pier fishing club to a regional tournament involving several piers. Tournaments can run for a weekend (common for king mackerel), or up to a month as part of a regional tournament that runs from April to October. This tournament targets two species per month when they are at highest abundance. The latter tournament was originally managed by the Myrtle Beach Chamber of Commerce, though control now lies with an association of pier representatives. Records of tournament entries are maintained by individual piers as is necessary for official entry.

Study location

Recreational fishing piers are unique platforms for angling. Piers in Long Bay are privately owned businesses that charge daily admission. Fishing pass sales records show how intense effort can be at the locations, with a record maximum of three-hundred passes sold in a single day at a single pier. According to South Carolina Department of Natural Resource Records (personal communication with SCDNR Statistics, November 2007), peak pass sales ranged between eighteen and twenty-nine thousand per year during a fourteen-year period between 1992 and 2005 for four popular fishing piers that consistently reported. The popularity of piers as fishing platforms is driven by their easy accessibility low cost, high capacity, and access to amenities (tackle shops, restaurant and restroom facilities). Most importantly, the overhanging pier and pilings act as vertical structure and shade that can attract fish (Verweij 2006). Piers also allow fishers access from the surf zone out to deeper waters otherwise only accessible by boat. The majority of effort is employed via bottom rigs baited with shrimp (Hammond and Cupka 1977) which attract an array of species and are often deployed with no particular target species in mind. The diversity of angling tactics at piers provides 'sampling' from the top to bottom of the water column and from surf to near shore. As a result, the total catch composition at the end of a day of pier fishing is to a certain extent unbiased. Enhancing the capacity of fishery scientists to collect data will lead to not only a better grasp of the to population dynamics, but also to facilitate ecological and biologically relevant studies (e.g. catch rates versus environmental variation).

Figure 1 maps the locations of recreational fishing piers in Long Bay, SC. Piers occur at population centers along the coast forming what should researchers and managers should think of as sampling stations that occur along a latitudinal gradient. The potential as piers for data gathering platforms has already been realized by the physical and atmospheric sciences, with continuously operating weather and water quality stations deployed and maintained by various agencies. This potential should enhance the allure of piers as biological observatories as the physical measurements are already available.

The presence of physical data alongside CPUE data can be a useful tool for understanding the effects of the environment of fish presence and survivorship, among other phenomena. For instance Stoner et. al., (2004), discusses factors such as how density and size of fishes in the fishing area may affect fish density estimates when based on CPUE. The fish habitat within the Long Bay pier fishery is subject to the effects of ever-increasing human development and the resulting pollutants that are carried by modified watersheds meant to purge an ever-increasing percentage of impervious surfaces of storm water. Hypoxia-induced distributional changes of fish were observed in summer 2004 (Sanger et. al, 2010) and again in fall 2012 (see references to follow link to video documentation of this event, Glover 2012) in Long Bay, as bottom-dwelling flounders were concentrated into remaining oxygen-rich water along the coast and coincidentally beneath fishing piers. The combination of high fish density at locations of high fishing effort leads to what is locally known as a “flounder jubilee,” as CPUE is only contained by creel limits. The jubilee in 2004 was the first sign to researchers that a hypoxic event was underway, and may have gone unnoticed otherwise. Improved data collection from fishing piers will result in higher resolution CPUE data. This data can be used to infer abundance and temporal distribution, which would be required for assessing the effects of environmental degradation. Investigation of environmental variation as a driver of fishing success is outside of the scope of this particular study but such investigation will be made easier with an enhanced understanding of catch variability at these recreational fishing piers.

2007 Survey at Springmaid and Apache Characterization of Pier Fishery

Recreational pier fisheries have been under represented in the scientific literature pertaining to the subject, with only one study dating from 1973 (Hammond and Cupka 1977) describing the pier fishery. A comparable unpublished on-site CPUE survey (Johnson 2007) was conducted at Springmaid Pier and Apache Pier in Long Bay, SC between April and September 2007. Compositional comparisons between the 1973 and 2007 fishing seasons suggest differences in the numbers and composition of landings, including a shift in the identity of the three most landed species, a higher mean trophic level of total landing composition and lower CPUE in 2007. Though no trends can be confidently discerned from a compositional comparison of only two years, some of the results fall in line with reports by anglers who cite declines of some targeted species. For instance, anecdotal reports regarding king mackerel claim that landing declines are so severe that as a result a local king mackerel club completely disbanded in 2011, relating during a personal correspondence, “There are no fish for our club to catch.” This story has been repeated by numerous anglers and at numerous piers within the South Carolina portion of Long Bay. The testimony of the anglers was strengthened by privately-held landing logs of king mackerel at the piers. Reports from anglers combined with their historical data sets lead directly to some of the hypotheses explored within in this study.

Current Recreational Catch Monitoring Approach

It is acknowledged that the development of management techniques that preserve the functionality of marine ecosystems while maximizing yield by fisheries is vital to the health of marine populations and the anglers who rely on their productivity. To do this, Congress passed The Magnuson Fishery Conservation and Management Act of 1976. The National Oceanic and Atmospheric Administration (NOAA) Fisheries, state natural resources agencies, and regional fishery councils are charged with gathering the best available scientific data This process includes the input of industry stakeholders with the purpose of maximizing sustainable yield (MSY) while ensuring the sustainability of fish stocks. The current approach used by NOAA Fisheries relies on subsampling via the Marine Recreational Fisheries Statistics Survey (MRFSS). This methodology utilizes phone and dockside intercept surveys to estimate the number of trips anglers are taking and the number of fish they catch on those trips, allowing for a CPUE estimate.

An amendment, the Sustainable Fisheries Act of 1996, requires that fishery management plans (FMPs) be developed for highly migratory species. FMPs account for the life history strategies of species and tailor regulations to account for these strategies. The Southeast, Data Assessment, and Review (SEDAR) process is a multi-step method for examining stock assessments which includes data collectors, biologists, anglers, database managers, stock assessment biologists, council members and staff throughout each stage. The Marine Fisheries Advisory Council collect data secured from various sources such as NOAA Fisheries Marine Recreational Information Program (description found at countmyfish.org) and various fishery-independent data indicators of life history variability. This data is used to make decisions on a regular basis.

The Fish Stock Sustainability Index (FSSI) is a report card for the 230 recognized fish species important to recreational and commercial fisheries in the US. Species are assigned a score of up to 4 points based on the status of the fishery. Fisheries that are deemed overfished receive the lowest scores while healthy sustainable stocks receive higher scores. As of December 2012, the FSSI reported that the 230 US stocks achieved roughly two-thirds (616/920) of the possible points. As more stocks become targets of fishing or as bycatch of those fisheries, the will need to be added to the FSSI. Therefore the need for research to understand these species' ecology and biology will also increase. Managers will need to ensure that fish stocks reach the requirements of the FSSI but also be maintained at those levels, requiring regular monitoring and assessment. State agencies such as the South Carolina Department of Natural Resources (SCDNR), relying on the work of NOAA Fisheries, can then enforce regulations such as creel and size limits, which ensure the sustainability of fished species.

Most on-site recreational surveys target the charter, head boat and private boats returning to marina, with shore-based estimates often calculated with a high degree of error. However, roughly half of the effort is based on shore so better understanding of the shore-based effort is warranted. Daily fishing pass sales on local piers range anywhere from one to three hundred per day at a single pier, according to recent records (SCDNR fisheries statistics division personal communication 2007). The anglers can potentially provide needed fishery statistics. Definition of these fisheries is warranted since the composition of recreational fishery catch is different than adjacent commercial fisheries. It is likely not equal to the charter and head boat fishery either. Ihde et. al., (2011) showed that the increase in the proportion of recreationally-targeted species is higher than that of the commercial sector and suggests that traditional commercial management techniques may not apply to recreational fisheries. The MRFSS itself has been cited more than once for its inadequacy in correctly estimating fishery landings. NOAA Fisheries appears to be addressing these concerns with the implementation of the National Saltwater Angler Registry (NOAA)and reviewing the effectiveness of their phone and on-site survey methods. NOAA Fisheries cites new and alternative data sources as helpful to improve the overall data set. One such alternative method is discussed in the following section.

Video Surveillance of Fisheries

Recreational anglers provide a unique channel for fishery data acquisition as they are ‘sampling’ at high frequency and at their own expense. Fishing piers grant an exceptional opportunity for tapping this information, due to the high density and regular gathering of anglers. Pier anglers are attracted to these venues because they offer easy, land-based access to waters ranging from surf to nearshore. This allows for access to species that would otherwise only be reachable by boat and are filled with amenities. Most importantly, anglers know that piers attract schooling and solitary pelagic fishes from the bottom of to the top of the food chain (Grothues and Able 2010).

The development of video surveillance as a remote sensing tool is a powerful tool to gain insight into these fisheries. Video surveillance can provide data sets with a higher temporal resolution than traditional techniques would allow, and can be archived for future reference. Video surveillance has the potential to rule out uncertainty, resulting from inaccurate interview surveys.

There are numerous studies that investigate the use of Electronic Monitoring Systems (EMSs) in replacing, or augmenting the work of onboard fisheries observers of commercial fishing vessels in detecting catch composition, bycatch, and CPUE (Ames et. al., 2005, 2007; Bonney and McGauley 2008, Cahalan et. al., 2010). However, studies of recreational fisheries are nearly impossible due to the wide geographic range and low density of anglers. Recreational pier fisheries are the exception to this rule. The opportunity presents itself to assess the efficacy of video surveillance as a means of CPUE detection of landings in the fishery.

Objectives and Hypotheses

Anecdotal evidence raises questions about the magnitude and direction of CPUE trends for some highly targeted recreational species. Collecting testimony of anglers via survey is the primary method for assessing recreational fishing pressure. Chapter one will investigate the concern raised by fishers that total landings and weights are experiencing declines, with particular focus on species mentioned by fishers and using novel data sets generated by those fishers. **Hypothesis 1: Examination of privately-held historical pier landing logs will reveal declines in abundance and weight of recreationally important species. Specific attention is given to king mackerel which fishers claim to be the species undergoing the most noticeable decline in CPUE**.

Given the cited shortcomings of shore-based recreational CPUE reporting to fishery managers, and the declines of popularly targeted species asserted by anglers, a method for enhancing monitoring of recreational pier fishing is warranted. Chapter Two describes a video surveillance approach to remotely detect CPUE and species identity at recreational fishing piers. **Hypothesis 2: Video surveillance will produce an estimate of CPUE and species identity that is not significantly different from that produced by an on-site survey. Video surveillance is also hypothesized to be more cost-efficient than employing manned field surveys**

CHAPTER ONE Trends from Privately-Held Historical Log Books

Introduction

Fisheries encourage the removal of the largest fish in populations, especially in recreational fisheries where the goal of tournament fishing is to catch the largest fish possible. The removal of the largest fish in a population has been hypothesized to be an evolutionary pressure (Conover 2002, 2009) that can lead to effects including removal of individuals of the highest fitness potential (Sutter et, al,, 2012), faster maturation and smaller size at maturation (Roos 2006) and ecosystem structure change due to top-down trophic cascades leading to increase in prey abundance (Shackell et. al., 2009). Eikeset et. al., (2013) suggest that size reduction for smaller size fish would be compensated by the increase abundance of smaller-sized individuals. If fishing pressure has selected for smaller-sized individuals within populations, it is reasonable to hypothesize that the size of tournament-winning fish would decline during the course of the time series. To test for this for trends that would support the fishing pressure selection hypothesis the size of the largest fish landed for each species over time as recorded in privately-held recreational logbooks was analyzed.

Anecdotal reports by recreational pier fishers insist that the number of king mackerel landed at piers in Long Bay, SC has declined in recent years. In support of their claims, representative anglers at two of these piers provided fishing logs that listed the date, weight and the anglers who landed each fish for every fish landed per year. It is assumed herein that the overwhelming majority of landed fish would have been recorded since the fish is highly prized for its food value and as a target of several local fishing tournaments. The majority of king mackerel that come into range of the piers is of legally harvestable size (Godcharles and Murphy 1986) which reinforces the idea that all landings would have been recorded. In addition, it is rare for a single anglers to land more than a single fish in a single day (especially within the last decade) so maxing out of limits resulting in discard of any additional landings would not have resulted in un-reported fish; the fish would likely be recorded before discard. It is hypothesized that examination of these king mackerel landing estimates will provide evidence for landing decline, generating evidence for further evaluation of the fishery.

Methods

Two privately-held recreational landing logs were obtained from South Carolina recreational fishing piers at Long Bay. Fish were weighed at a calibrated weigh station located on each pier. The date, identity of the anglers, and the common name and weight of each fish were recorded on logs from both piers. Figure 1 maps the location of all fishing piers and the study sites along the coast of Long Bay.

Surfside Pier (1973-2012)

The first log was maintained by the management of Surfside Pier, Surfside Beach, South Carolina. The logs included thirty years of fishing records between the years of 1973 and 2012. Hurricane Hugo destroyed the pier in September of 1989 and the pier remained out of commission through 1990. Also records between 1993 and 1999 were missing. The log consisted of landings of nineteen species, though the intensity of record keeping seemed to vary from year to year and by species. For king mackerel which considered the pinnacle of the fishery, it is assumed that all individuals were recorded. The species whose numbers were not regularly reported would almost certainly have been reported when individuals were of large size, since those records would have been turned over to the Grand Strand Fishing Rodeo Tournament Committee (personal communication, through tournament website, Grand Strand Fishing Rodeo@Facebook.com, October 2013) for a chance to win prizes in local tournaments. Sixteen species were chosen for the analysis based on their regular inclusion in the records. For Surfside Pier, non-parametric Spearman's rank correlations were performed to identify trends in the weight of the tournament-winning (heaviest) fish for each reported species over time. Spearman's rank correlation results were listed and time series plots drawn with linear trendlines and R^2 values for those species that were significantly correlated in order to better visualize the strengths of the trends. Due to the likelihood of all landings being reported in all years, king mackerel were also analyzed along with the Springmaid Kingfish Club Data set, details of which are discussed in the following section.

Springmaid Pier Kingfish Club (1989-2011) and Surfside Pier king mackerel (1973-2012)

The second log was maintained by Springmaid Pier Kingfish Club (personal communication with club representative at Coastal KingClub@Facebook) and consisted of 20 years of landing logs between 1989 and 2011. The destruction of the pier by Hurricane Hugo resulted in no logs from fall 1989 through 1990. The 2004 and 2005 records were missing from the logs and only the number of king mackerel landed by year could be obtained for the years 2006-2011. The club disbanded after the 2011 fishing year claiming, "There are no fish for our club to catch". The club recorded all king mackerel and cobia landed on the pier during the time frame. The Springmaid Pier records were combined with the Surfside Pier records in the time series, since the Springmaid records occur during the data gap in the 90s from Surfside Pier. Visual inspection of the total number of landings appeared to related. The degree of similarity was tested with Spearman's rank correlation analysis.

The weight range of landings was reported for all reported individuals in the time series to indicate the size of fish vulnerable to the pier fishery. The number of fish per year or per season and total weight of fish per year was also recorded. The average weight of landings per year and per season was also calculated and tested against time since average weight of landings is often used as a gauge of population health. The total number of anglers who landed fish per year was counted to test whether the number of anglers landing fish has declined. This is not a measure of effort of course, as there is no tally of the number of anglers who fished but did not catch.

A major obstacle of the king mackerel data set is the lack of effort reporting which is used in a calculation of catch per unit effort, such as the number of anglers or hook-hours fished in a day. King mackerel are not continually present throughout the year within the study area due to seasonal migrations. For king mackerel there is clearly a fall and spring run so the tally of the number of fish per spring season and fall season was possible. Ninety days was chosen for the length of the spring season (May through June) and seventy-five days for fall (August 15th- October). Though landings occurred before or after the chosen temporal range, greater than 98% off landings occurred within this range and on all years. To get some measure of standardization, an index of landing abundance was calculated by dividing the number of fish landed during a season by the number of days in that season. For example, an index of landing abundance equal to 1 means that in the time frame of interest, on average one fish was landed per day. An index of king mackerel landing abundance was also calculated for fish per calendar year by adding the spring and fall seasons.

Temporal variations of king mackerel migration timing is presumed to explain the variation in the start and end days of king mackerel landings. To approximate the dates of arrival and departure to and from the fishery, the dates of first and last landing per year and per season were plotted for visual inspection and tested with Spearman’s rank correlation in an attempt to detect change during the time series. The date of first landing was subtracted from the date of last landing per year and per season to give the length of the season which was also tested for correlation with year to detect change in season length. Season length was tested against the landing index to test for a relationship.

This portion of the study seeks to determine whether angler testimony regarding declining populations can be supported by their self-collected data sets. If such support is found, this study will determine how the pier data relate to landings at the state and the population throughout its range. The results from the recreational pier logs were compared to state and national landing records maintained by the NMFS Marine Recreational Fishery Statistical Survey (MRFSS) and analyzed for king mackerel landing and effort trends.

Total weights by year and average weight by year were analyzed for significant trends using Spearman's rank correlation. The pier records were examined in the context of the state-wide and stock-wide catch estimates by the National Marine Fisheries Service in an attempt to show that landing trends at piers are reflective of regional and stock-wide trends.

It is acknowledged here that either the number of fish landed per hook-hour or at least fish landed per angler-hour would have been preferable effort measures since it is possible and likely probable that variations in these effort parameters could alter the number of fish landed per day. There is no way to know from the data set whether one or ten angler caught the one fish landed on a particular day. Given the data set, the number of fish landed/day is the lowest achievable unit of resolution possible. Another uncertainty that cannot be addressed in this study is how fishing effort may vary with fishing success. King mackerel for instance are known to come in runs lasting anywhere from a day to several consecutive days. So the question is: once one king mackerel is landed, does that angler spread the word which leads to an increase in effort? Does that increase in effort alter the number of fish landed? Is it probable that the two angler are more likely to catch two fish in a day than it is for one angler to catch two fish in a day. There is no accurate means to establish these as parameters so any effect of these is assumed to be constant throughout the time series.

Statistical Analysis

Spearman's rank correlation (Spearman 1904) is a non-parametric measure of the statistical dependence between two variables with +1 or -1 indicating a perfect correlation and occurs when one variable is an exact monotone of the other. Spearman's was chosen over Pearson correlation because: 1) it does not require normality which many of the data sets do not exhibit, 2) It is less sensitive to outliers which have been noted for some of the variables, and 3) it does not require the relationship to fit a linear function in order to report a perfect correlation since it fits a monotonic function instead. A monotone function is a function that preserves the given order between ordered sets. This is how a catch per year could be characterized, since the values will not be reordered from lowest to highest. Note that Pearson and Spearman's return very similar values when the data is elliptical in shape and has no outliers. In addition to Spearman's rank correlation, a linear trendline was drawn to test how well the data fits a linear function between the first and last data point and will be important for some variables. Relationships are considered significant when the significance value (p) was less than 0.05.

Results and Discussion

Surfside Pier (1973-2012)

Table 1 lists the results of Spearman's rank correlation coefficient aka Spearman's rho (r_s) and significance value for 19 species over time for Surfside Pier. All significantly correlated species (47% of those tested), only whiting produced a positive trendline. When species that did not produce significant rho's are included, only spot, tarpon (*Megalops atlanticus*) , pompano (*Trachinotus carolinus*), and little tunny (21% of those tested) produced positive trendlines. Black drum (*Pogonis chromis*) were highly ($p<.000$) correlated (Figure 2h). The R^2 for the trendline is 0.75. Jack crevalle was significantly correlated. Jack crevalle are not frequent visitors to the pier so all landings would have been recorded. Spearman's rank indicates that Red drum (*Sciaenops ocellatus*) was significantly negatively correlated with time (Figure 2e) but this relationship should be considered carefully. Management of this species relies on slot sizes, which would decrease the size of tournament-winning fish for later years since fish must be in the slot limit to be kept. Therefore landings exceeding the max slot size would probably not have been weighed in later years since the scale is far away and would increase the mortality rate of the release. Also anglers would be concerned about possessing the fish for too long in fear of a ticket. Spearman's rank analysis of sheepshead (*Archosargus probatocephalus*) were highly negatively correlated ($p<.01$) with time (Figure 2d). Spadefish (*Chaetodipterus faber*) were significantly correlated (Figure 2b), although the data is highly skewed (skew greater than +1) to the right with

10 of the 12 records occurring after 2003 and the other two from 1973 and 1974, so this result is not conclusive. Spearman's rank says weakfish (*Cynoscion regalis*) were significantly negatively correlated (Fig 2c) although records were highly skewed to the right. Whitings (*Menticirrhus sp*.) were significantly positively correlated (Figure 2a). Cobia (*Rachycentron canadum)* were not significantly correlated (Figure 2i) but it should be noted that only one of the sixteen reported landing of a cobia occurred between 2000 and 2012. Croaker (*Micropogonias undulates*) was not significantly correlated and reports were highly skewed (skewness>+1) to later years. The skewness of the reports could be indicative of anglers turning to croaker when more exciting prospects have declined, i.e., an example of fishing down the food chain. If there is truly a decline in landings, the level of croaker as bycatch in the shrimp trawl fishery should be addressed as they are reported regularly in discard records (Whitaker et. al., 1989, 2005). A 1973 fishing survey (Cupka 1976) reports these fish as one of the top three fish landed by number at piers in the area, which is not the case in a survey with similar objectives conducted by the author in 2007 (poster presentation at ERF Conference 2007). Flounder (*Pleuronectidae*) landings are complicated in that the fishery catches at least two species of flounder which are not distinguished in the landings logs. If the species were distinguishable, a significant trend may have been demonstrated. Even though not distinguished here it is likely that summer flounder (*Paralichthys dentata*) comprised nearly all landings based on the results of the surveys cited above. Pompano was not significantly correlated with time by Spearman's though the trend does seem to be positive. The R^2 is very low, however, so not much can be said from it, even if the

relationship is true. Spanish mackerel (*Scomberomorus maculata*) were not correlated significantly by Spearman's and weights of landed fish appear stable. No significant relationship was observed for spot which is not unexpected, since spot would hardly be considered a prize fish. Consequently, it was only reported for six years during the time series. There was no correlation for tarpon, which is a southerly species and is rarely landed in the pier fishery. There was no significant correlation for spotted seatrout (*Cynoscion nebulosus)* even after the removal of an outlier in 2009. The data for seatrout is highly skewed right and may deserve more attention. Fishers claim that landings of seatrout have declined. The graph does seem to have a downward trend but the statistics of the study do not support this contention. Bluefish (*Pomatomus saltatrix)*, pompano, spanish mackerel were not significantly correlated though all rank highly in landing abundance at piers. These results may be biased towards higher catches of these species in later years associated with an increase in a jigging technique that is highly effective at catching these species. Amberjack *(Seriola dumerili)*, little tunny, and tarpon were not significantly correlated and were rarely recorded, as they are atypical of the shoreline habitat in Long Bay.

For species that are infrequent visitors of the pier fishery, there is likely value at looking at the landing record distribution by time. Figure 3 plots tarpon, amberjack, little tunny (*Euthynnus alletteratus*), jack crevalle (*Caranx hippos*) and cobia in an attempt to identify patterns in their temporal distribution, which may be indicative of phenomena such as longitudinal or latitudinal water mass shifts. These water mass movements could carry or drive these fish within reach of the pier fishery. A particularly striking grouping is seen with amberjack in the early 1980's, which also seems to coincide with a grouping of jack crevalle and cobia landings. The coincidence of landings of three species suggests a physical phenomenon that affected each of these species in way that caused them to move in the near shore environment. This is a case of recreational pier landings producing added value in terms of hypothesis generation regarding fisheries oceanography. Historical environmental records do exist for this region and an investigation of the influence of environmental change on variation of landing frequency and intensity is warranted.

King mackerel were highly ($p<.01$) significantly correlated with time. Additionally, when only the 2000-2011 period was tested (no king was landed in 2012) the R^2 increased from .27 to .64, and the trendline steepness increases from -0.14 to -0.67 (Figure 2g). This time period is consistent with the start of anecdotal reports of landing declines by fisher, and would be consistent with a struggling fishery population or avoidance of the fishing area due to some environmental repellent. Environmental signals that may influence king landings may include temperature or oxygen concentration anomalies associated with upwelling events. Hypoxic events have been documented to be the cause of the summer flounder fishery anomalies in the area on at least two occasions within the last decade (Sanger et. al., 2010).

Springmaid Pier Kingfish Club (1989-2011) and Surfside Pier king mackerel (1973-2012)

Figure 4 is a visual depiction of the weight of all landings of king mackerel by date during the time series of interest. The Springmaid landings look as though they are in line with the Surfside data, thereby bridging the gap left by the missing Surfside records and indicating that the piers exhibit similar annual variation in landings.

Figure 5 graphs the day of the year king mackerel were landed during the time series. Especially in the early years of Surfside records, a clear Spring and Fall run can be distinguished. The length and numbers of fish within these seasons varies throughout the time series. The intensity of angler effort likely modulates with the beginnings and endings of these runs. However, the tackle that targets king mackerel is present throughout the summer season as evidenced by landings of large bluefish which are caught on identical tackle. Figure 6 is a graph of the total landings by year. Spearman's rho was -.707 for total number of landings by year for Surfside Pier. The number of fish landed at Springmaid was compared to the number landed at Surfside. That comparison was analyzed using Spearman's rank correlation to test the justification for using Springmaid Pier to fill in the gaps in the Surfside data. Spearman's rank correlation validated the relationship with an r_s of .774 and p<.05 for 10 years between 2000 and 2011, in which the total number of Mackerel landed was reported for both data sets. The R^2 of the linear trendline for this relationship was increased to .56 from .23 when the outlier at data point 19,46 was removed from the data set (Figure 7). If this relationship is true for two piers that are miles apart, it is reasonable to assume that many or all of the piers in the area experience similar temporal variation in landing success. This suggests the notion of a population-wide spatial and/or temporal variability that is experienced across the region, rather than the variability as a product of random chance as fish move around Long Bay. The 1980s held the highest average number of annual landings (107/year). The average number of landings in the 1980s was ninety percent higher than it was in the 2000s (11/year). Analysis of this fishery using this average catch by decade produces a result roughly in line with the definition of a stock collapse as argued by Worm et. al., (2006). They consider a stock collapsed when the catch level within a given year fell to ten percent of the previous maximum year recorded. Showing a decline in catch between average catch over decades instead of using only the maximum and minimum years provide a more convincing measure. The Worm et. al, definition has been argued as an inadequate definition of stock collapse since it exaggerates the magnitude (Wilberg and Miller 2007) and rate (Jaenike 2007) of stock collapse.

Figure 8 demonstrates the length and weight of fish that are vulnerable to the fishery (range=0.9-23kg, average=5.4kg) at Springmaid and Surfside Pier. This information is not useful to determine year classes with much certainty, since sex information is not present. This information would influence the results, since king mackerel exhibit sexual dimorphism, with females growing faster after age two and reaching a larger maximum size as found by Devries and Grimes (1997). The length estimate was calculated from a length-weight relationship determined by a study of unsexed fish. The weight of each king mackerel was reported for every fish landed.

The average weight of landings by year was calculated in order to discern any trends in the average size of individuals making up the population (Figure 9). There is an increase through the early 2000s with a max in 2006, followed by a decline well below the lowest measure on record from before 2006. It should be noted that the sample size is lower for the time span of decline, with as few as just one fish landed used in the average calculation. The variation in sample size between years, however, does match what would be expected with a failing population.   This effect may be traced to overfishing, where the largest fish are targeted and removed first.

Season length (not to be confused with the definition of “season” in the index of landing abundance calculation) is defined here as the number of days from the day of first catch to the day of last catch of king mackerel. There is a spring run and fall run, which is why the days in between the last fish caught in the spring and the first in the fall are not included. The total length of season adequately predicted the number of fish landed in a season (Figure 11) according to Spearman’s rank (r_s =.703, p<.000). So, more fish are landed when they are within reach of the fishery for a longer time span.

It can be determined from above that the length of a season varies, so the starting and end dates of each season were examined for variation over the time series. This examination should identify trends such as earlier or later arrival and departure times (Figure 12). The days of the year for first and last landed fish of the spring and fall seasons were plotted over the time series for Surfside and Springmaid (trend lines and Spearman’s rank correlation represent Surfside only). The maximum variability occurred for all measures in the 2000s compared to the previous decades (70’s, 80’s and 90’s). The change was less pronounced in the fall season, with the most dramatic change in the day of year for the first Mackerel landed in the spring season, i.e. first fish of the year. This produced a positive linear trend line which could indicate an arrival date of fishes towards later in the year. First-day a fish was landed by year was the only one of the four start/end day of year measures in the figure to be significantly correlated by Spearman's rank (r_s=0.366, P<.05). This may be indicative of the importance of environmental parameters e.g. wintertime water temperature as a driver of fish migration timing This does not explain the increase in variation over time unless climatic parameters have become increasingly varied over time, which is a possibility. The lines of best fit for Surfside season data converge at some future point, suggesting a decline in season length (day of first landing of season minus day of last landing of season). The lines of the scatter graph with in a season overlap at some points indicating a season length of one day; absence of lines indicated that no king mackerel landings were reported, as there were zero fish reported in the fall of 2009 through 2011 and the spring and fall of 2012. Spearman's rank correlation of the length of season by year was significant for both the spring (r_s =-.472, P<.01) and fall season (r_s =-.525, P<.01).

Since it was determined that king mackerel exhibit two distinct runs, the number of fish landed per year was divided into the number of fish landed in the spring and fall season (Figure 13). This was done in order to determination how the number of landings varied by year, and the variance between the two seasons within a year. The number of fish landed within a defined season (number of days as described in methods, which is different than the length of season used in the calculations from the preceding paragraph) was used to generate an index of landing abundance within that season. The resulting index is the number of recorded king mackerel landings per day. This index also demonstrates the disparity between fall and spring. Spring versus fall Index of abundance was significantly correlated by Spearman's rank (r_s =.672, P<.001), suggesting that the success of the spring run can be a predictor of the number of fish in fall run. The all abundance was a significantly better predictor of the following spring abundance (r_s =.621, P<.001) with the linear trendline R^2 increasing to .27 from .076 for the spring versus fall of the same calendar year after removing an outlier (Figure 13). The R^2 value is still rather low but could suggest that success of the fall run is a better predictor of the success of following spring run than is the spring rung of the following fall run. This makes sense as there is less fishing during winter months, therefore less reduction in population size due to fishing mortality than there would be in the summer.

The number of landings per year is significantly correlated for at least two piers separated by several miles, suggesting that the region experiences similar variability. The next step is to discover the relationship between landings in the study site and broader scale estimates of king mackerel landings. To determine this, pier landings were tested against the estimated number of landings for the state of South Carolina and against the number of estimated landings in the South Atlantic. Surfside Landings were significantly correlated (p<.05) with South Carolina estimates (Figure 15), but not with the South Atlantic estimates. This indicates regional variability of landings on the population-wide scale, due possibly to a spatial shift of the center of mass or range modulation of the mackerel population.

MRIP estimates of the South Atlantic population of king mackerel (Figure 16) show an initially steady, and then increasing landing estimate, reaching a maximum in 2007. The 2007 level was nearly fifty percent higher than the next highest landing estimate on record. In 2012 the landings of the South Atlantic stock, dropped to its lowest level on record with just 176,000 fish. This level represents 41% of the total catch in 1989, the lowest year on record preceding the 2007-2012 trend. 2010-2012 reported rapidly decreasing catch totals, all of which were below the level of each preceding year. The preliminary estimate as of Nov 2013 for calendar year 2013 was 95,000 fish. A linear trendline drawn between the peak in 2007 and the 2012 produces a negative slope with R^2=0.8867. The standard error indicated by the figure increases during the time series as the number of samples declines. This may be caused by decreased sampling resolution due to budget funding issues. Standard errors of similar size occurred during the 1980s but were not associated with low estimates of total catch and did not exhibit any sort of trend during those years, unlike seen during 2007-2012.

Approximately 0.5 to 2.6% (SEDAR16) of Atlantic effort targeted king mackerel (Ortiz 2008), so CPUE was calculated using that assumption but does not explicitly reflect vessels only targeting king mackerel. Landings evidently experienced a steady rise following the implementation of regulations designed to rebuild the fishery. According to NOAA Fisheries, the stock is generally not considered overfished. However, if the number of fish landed per angler trip is plotted, the story during this period may be considered in a different light. While catch has been steady or increasing since the implementation of regulations designed to sustain the fishery, the CPUE has been steadily declining (Figure 17). Note that the 2007-2012 CPUE estimate was based on the average CPUE of the previous 10 years (which varied +/- 0.1%). King mackerel CPUE experiences a peak in 2007 that corresponds to the peak in landings, before mirroring the landing estimate decline.

According to the MRIP survey, the estimated number of landings for southeastern states experienced the most recent peak between the years of 2007 and 2009 (Figure 18). The shore-based landing estimates exhibit similar declines. However these data sets have standard errors regularly exceeding 50% for North and South Carolina, and 30-40% for Florida. The proportional standard error of an estimate as a percentage of the estimate is calculated as a measure of precision. Estimates with proportional standard errors 50% and higher are considered “highly imprecise” according to MRIP.

The decline in landings appears to occur nearly simultaneously for both the Gulf of Mexico and South Atlantic populations (Figure 19), though the decline was to a greater extent for the Atlantic population. Southern U.S. king mackerel are managed as two distinct but overlapping populations based on otolith shape (Patterson et. al, 2008) and DNA evidence (Broughton 2002). NMFS landing estimates of the South Atlantic stock and the Gulf of Mexico stock were roughly equal and significantly correlated to one another, exhibiting similar annual patterns. The Gulf experienced its maximum landings during the time series (1980-2012) in 2005, with the South Atlantic maximum following in 2007 at 1.1 million fish. One must hypothesize that the cause of these declines may be related to environmental changes, rather than a result of fishing. Since each population is demonstrating similar trends under different management, one must hypothesize that the cause of these declines is likely environmental. These declines do not appear to be the result of overfishing. There is sufficient evidence to support the claims by fishers that recreational landings of king mackerel are declining. It cannot be determined from above however, whether the decline in landings is related to overfishing or to environmental conditions that repel king mackerel from known fishing grounds.

As of 2006 the Gulf Stock was rebuilt based on the analysis of SEDAR process. Indicators of stock health were not sufficiently positive so did not warrant any changes in management of the Atlantic Stock. Spawning stock biomass was also reported to be in decline as of the SEDAR16 report, though stable landings during the time period since the previous report likely mitigated that concern to some extent.

If overfishing is occurring in the Atlantic king mackerel population, then why was it not predicted? One possible factor that would mask a declining stock was recognized by Ricker (1973), who discusses how CPUE is higher for a new fishery before MSY is established. Once MSY is reached the CPUE drops. It is unlikely that this scenario is the case since the fishery had been well established and declared stable—unless this process could be cyclical, with periods of rebuilding followed by MSY, followed by overfishing and back to rebuilding. MSY is a theoretically sound idea, however the lack of continuous updated data and long time between fishery management decisions causes the method to be insensitive to real time population dynamics. Larkin (1977) outlines many of the shortcomings of MSY, going as far as to say, “it is a pity that now, just when he concept of maximum sustainable yield has reached a worldwide distribution and is on the verge of worldwide application, it must be abandoned.” Maximum sustainable yield was not abandoned, however, and remains a standard calculation (now supplemented with Optimum Sustainable Yield) for many fishery assessments. The effectiveness of the strategy is dependent on the frequency and accuracy of the population estimates, however, which are often lacking.

Maunder et. al., (2006) cover reasons why CPUE is an ineffective proxy for abundance in general. Still, CPUE is often the only regularly collected data that can indicate population abundance. An assumption of CPUE in management is that stability of CPUE is reflective of the stability of the population. Harley et. al., (2001) state problems with CPUE including instances where CPUE remained high while population abundance declined. Walters and Hilbourn (1976) emphasize the need for more adaptive fishery techniques. If the king mackerel fishery data was available to managers on a real-time basis such a decline may have been avoided. Management is headed towards increasingly finer data resolution however.

Fishery-independent estimates of abundance and life history are very informative when it comes to understanding the state and direction of a fished population. The most recent king mackerel assessment (SEDAR16) identified that spawning Atlantic stock biomass was decreasing during the period of high landings. A three-year lag in age of first reproduction for year classes in the early 2000s would result in reduced numbers of juveniles in the late 2000s. Therefore, it is possible that the removal of spawning individuals in the early 2000s could have resulted in the declining landings seen after 2007, due to declining population size. SEDAR16 reported that the South Atlantic Stock was slightly above the MFMT (Maximum Fishing Mortality Threshold) and that it was not clear if the population was experiencing overfishing. SEDAR estimates of total population of 1+ year fish suggested between 1980 and 2006 suggest a downward trend of the Atlantic stock. According to the fourth quarter 2012 FSSI, both populations of king mackerel remain at the maximum 4 point level.

Minimum size limit was raised from 20" to 24" in 1999 and has remained so since, with the recreational quota at approximately 2/3 of the 10.2 tons of total allowable catch (SEDAR16 2009). As of 2006, neither sector has reached their quota since 1998 with fishing harvest levels remaining between 55 and 85 percent of the total allowable harvest.

The percentage of fish that are released has steadily grown from nearly 0% to a max of 40% in 2005. This growth is likely the result of the recreational sport fishery's encouragement of catch and release to help ensure sustainability of catch. The North Carolina Department of Natural Resources, for instance, encourages catch and release by offering citations for fish over 45 inches (114.3cm) that are released alive (Division of Marine Fisheries. 2013).

Landings levels were high at the last fishery assessment report in 2009 but have significantly declined since them. The next scheduled Data, Assessment, and Review (SEDAR38) for king mackerel occurs in 2013 and should shed more light on the situation.

Conclusion

Recreational pier fishing records were found to produce trends in composition, numbers, and sizes of landings. Those trends indicate changes in spatial occupancy, or changes in the population dynamics of the species in question. For king mackerel it is all probably that all landings were recorded. The apparent decline in landings of king mackerel is theorized to be a result of declines in abundance at the population scale. When compared to standardized CPUE records of king mackerel at the regional and population level, it is likely that the declines in landings seen at piers are in fact reflective of a population-wide trend of declining abundance. This study is by no means a comprehensive review of the state of any of the fisheries addressed above, but meaningful insight can be drawn from the non-CPUE privately-held recreational pier fishing landing logs. The logs are limited in their ability due to the lack of effort measure, though the results from the king mackerel data sets are convincing enough to warrant further investigation. Accordingly, the king mackerel data set has been submitted to the Southeast Data, Assessment and Review 38 committee, and is the only recreational data set depicting the actual number and weights of landings in this fishery.

CHAPTER TWO Evaluation of the Efficacy of Camera Surveillance to Detect Catch per Unit Effort at a Recreational Fishing Pier

Introduction

Giving fishery scientists the ability to better monitor recreational fishery landings will lead to better understanding of fishery and ecosystem dynamics. Video surveillance precludes the error associated with interview surveys. Steffe (2010) says surveyed anglers were shown to be unbiased when reporting effort to surveyors, while Thompson (1991), reports that overestimates by angler of expenditures and fishing effort should be considered the results of the "avidity bias."

The development of remote sensing techniques for video surveillance of recreational fishery ca be a powerful measuring tool for these fisheries. Video surveillance results in the generation of data sets with high temporal resolution and the video can be preserved for future reference.

A video surveillance system was implemented to monitor recreational fish landings on Apache Pier, Myrtle Beach, SC. This method allowed for continuous monitoring of fish landings and quantification of fishing effort. The recorded video was transferred to hard copy, stored for analysis and compared with surveys conducted through on-site observation. The continuous footage allowed for a cost-benefit analysis. The time and effort spent watching video and recording data was reduced to the smallest possible sub-sample, without compromising the resolution of data needed to provide an accurate estimation of fish landings. The practicality of cameras as a monitoring tool was considered in regards to costs of equipment, maintenance, and data analysis, were compared to the cost of an on-site observer. Cameras were placed in positions that achieved the goals of quantifying angler effort as well as numbers and composition of fish landings. The degree to which CPUE could be detected was evaluated in order to determine plausibility of the method for possible adoption by fishery researchers and managers.

Methods

The JPEG2000 Dual Codec surveillance package was purchased from an online security surveillance dealer. The equipment was purchased as a package deal for cost efficiency and ease of application. Since this equipment was designed for use by the public, the installation and operation of the hardware and software was fairly quick and simple. Wired cameras, though more difficult to install, were chosen over comparably-priced wireless cameras which offered lower image resolution. On a pricing scale of surveillance units, the package was low to moderately priced, though it met the needs of the study while maximizing allocation of the allotted funds. The surveillance camera included four 420-line resolution all-weather cameras with 150-foot range infrared LED night vision capability. Each camera came with 100ft leads, power sources and adjustable fixed mounts. The video was recorded to a 4-channel digital video recorder (DVR) capable of storing 250GB (~96hrs) of data which was removable via DVD Burner, USB drive or through its Ethernet capability. The package also included a 15" video monitor. The software on the DVR allowed for split-screen viewing of all four camera views on the monitor, as well as a remote to control all monitor and DVR functions. A surge protector and pre-existing on-site lightning rod were used to protect the hardware, which was all housed inconspicuously in a purpose-built plywood box in a pier shelter.

Cameras were placed at locations along the pier that captured fields of view of varying distances and angles. Distances along the field of view were measured, allowing for distance-detection attenuation calculations. While cameras recorded fishing, an on-site observer simultaneously watched the camera angle of interest. The observer recorded the number, species, time and location of each fish caught within the field of view during the study period. The numbers of anglers, observers and fishing rods were recorded. At the end of each study day, the recorded video was transferred from hard drive to digital video disc for later analysis. The analyzer recorded watched the video and recorded the same data as would be recorded by the on-site survey. The data from the on-site survey was compared to the data from the video.

Catch Confirmation: Deck Camera (7-60m)

A camera was placed about 2.5 meters above the pier deck and aimed down its length. The south side of the pier was chosen as the mounting location, since it was identified that the majority of anglers fished the one side during the spring and summer. Anglers were captured in the field of view which spanned approximately 7-60m. The camera angle was directed slightly behind most of the anglers on the south side and farther behind of fishers on the north side (Appendix 1). Anglers, spectators and structures were obstructions in the camera field of view. Fish came into the field of view as they were brought over the rail and onto the pier. This field of view was intended to determine the farthest distance in which fish presence and species could be accurately quantified, while exploring the degree to which obstacles cause underestimation of the actual catch since they obstruct the line of sight. The distance between the camera and each fish landed was recorded in order to establish an decline in detection ability of landings with increasing distance from the camera.

Catch Confirmation: Rail Camera (+7m)

The rail camera angle tested the ability of the camera to quantify the number of fish recorded over an unobstructed field of view. The camera was mounted on the rail of the pier, and angled down its length. This angle allowed for the observation of fishes as they were brought from water to pier, and eliminated the view obstruction of people and structures between camera and fish. During recording, an on-site observer recorded the total number of fish that could be seen from the camera position. Due to the point of view at this observation position, it was not always possible to see the exact location of each fish caught as was possible with the deck camera. As a result of this, the field of view was sub-divided into three sections (near, medium, and far) that noted the approximate position of each fish caught based on markers identified along the pier rail. The ability of the observer to see fishes was constrained by the long distance spanned by the field of view from the observation position. Therefore, it was not possible to identify all species. Unidentifiable fishes were recorded as “unknown species.” The number of fishers and fishing rods that could be seen from the observation point were recorded for each section. The number of fishes, anglers, and fishing rods counted during video playback were compared to the number of fishes, anglers, and fishing rods counted during on-site survey, in order to calculate confirmation percentages for subdivision of the field of view.

Catch Confirmation: Night Vision Camera (<15m)

The surveillance equipment allowed for dusk to dawn video monitoring since the cameras were equipped with infrared night vision. The ability of this night vision camera to detect landings was tested since night time fishing effort can be as intense as the effort on some days (Johnson unpublished data 2008). An on-site observer recorded actual catch for comparison with video evidence in order to establish a catch confirmation percentage.

Species Identification

All Camera angles were investigated for their ability to determine the identity of captured species. The ability of the cameras to detect species identity was tested during the video playback by dividing the number of fish of each species counted during video surveys by the number of fish of each species counted by the on-site surveys resulting in a percent identity confirmation.

Fishing Effort Detection

The numbers of people, fishers, and fishing rods were recorded at the beginning and end of each 15 minute interval; those values were averaged and assigned to each of the landing entries within each 15-minute interval. Ideally these data points would have been counted at the time of each landing entry, but an accurate count was difficult since events often occurred up to four times a minute. The averaging was done in an attempt to establish a coarse measure of the variability of people, anglers and rods that occurred between 15-minute intervals. The recording of fishes, anglers and rods, when paired with the number of fish landed within a time interval allows for the determination of catch per unit effort in the units of number of fish landed per angler-hours or number fish landed per angler hours.

Catch per Unit Effort

Catch per unit effort (CPUE) was calculated using the catch and effort confirmation data from video and compared to calculation from manned surveys. CPUE was calculated as the number of landings per angler, and the number of landings per fishing rod. The number of landings per hook hour would have produced the finest effort resolution, but hooks were not distinguishable at distance by on-site or video observer. Though hooks were not discernable video, the on-site observer recorded that the number of hooks on a rod ranged between one and seven depending on the angling method. The majority of anglers targeting bottom fish used a two-hook bottom rig, while the majority of anglers targeting mid-water fishes used jigging rigs with five to seven hooks.

Reducing Video Observer Effort

The use of video technology could reduce the time and effort spent observing and analyzing landing data during playback. The number of fish counted during a given percentage of a video segment was recorded and then multiplied by the appropriate value in order to provide an estimate of the number of catch within the whole segment. For instance, the number of fishes counted during a segment that comprised 10% of the total video was multiplied by ten to provide an estimate of the actual number of catch during the total video. This method was repeated segments that comprised20, 30, 40, 50, 60, 70, 80 and 90% segments.

Cost comparison of Remote Versus On-Site Observation

The cost of a travelling on-site observer was compared with the cost of a video surveillance system and stationary remote analyzer. This comparison assumes an equal hourly compensation for both observers. The cost of an on-site observer was calculated using the standard compensation rate 35 cents a mile and the 30 mile round trip distance to the study site. The onsite observer traveled to the pier to produce his one-hour survey while the video observer did not. The comparison assumes that each observer produces data from one-hour of fishing, but note the video observer cut the time spent watching video by half by increasing playback speed to 2x.

Results and Discussion

Catch Confirmation

Figure 20 is a graphical representation of the number of fish landed per minute during an afternoon of fishing and illustrates how landings occur with time. The total number of fish recorded by video was divided by the number of fish counted during the on-site surveys, resulting in a confirmation percentage that is a function of distance from the camera (Figure 21). An unexpected low confirmation percentage at the closest distance is the result of fish being carried above or around the field of view of the camera angles using four meter long fishing rods, even though anglers were clearly visible while the fish were being landed. No distance resulted in 100% confirmation accuracy and accuracy dropped below 60% at 25 meters. No landings were confirmed past 50 meters.

The average number of fish during 54, 15-minute sampling intervals recorded over five observation days was calculated to determine confirmation percentage of landings. As would be expected, the zones closest to the camera were the most effective. Confirmation percentages varied between 0 and 71% for the differing camera angles (Figure 21). By only including landings from the south side of the pier from the deck camera video, confirmation accuracy was increased from 35 (SD=19.5%) to 71 (SD=18.5%). Anglers on the north side were less visible as the camera was positioned to capture landings on the south side of the pier, so the overall estimate was only 9.4% (SD=14%) confirmed. The rail camera produced a 64% confirmation percentage. The infrared camera was ineffective as it was unable to discern fishes from anglers, probably due to the lack of shimmer of fish experience in daytime footage. Out of twelve landings witnessed by the on-site observer, none were confirmed during video playback.

Species Identification

Twenty-two species were observed during the on-site landing surveys conducted at Apache Pier between April 20, 2009 and May 11, 2009. Seventy-nine percent of landings were either bluefish (35%), Spanish mackerel (19%), or whiting (25%), while the other 19 species (21%) each made up 0-4% of total landings. This catch composition reflects the typical catch composition of the season. The on-site surveyor identified greater than 98% of landings to species level during the on-site surveys. In cases where the subjects were too far away from the observer, when fish were thrown back too quickly, and when the view of the fish was blocked by the handler during observation, the species of fish could not be identified by the observer.

The ability of the cameras to capture species identity was tested by dividing the number of fish counted during video playback by the number of fish counted during the same time of the on-site observer. The ability of cameras to detect species was found to be limited. The deck camera less than 1% and the rail camera less than 2% of those confirmed at the species level even when including landings in the zone closest to the camera. The exceptions were distinctly shaped animals such as Rays (7 identifications), crabs (1 identification), the Cannonball jellyfish (1 identification), and the Spadefish (1 identification). All of these were the only subjects identified with confidence during the video playback, and all were identified in the positions closest to the camera. A camera placed above a cleaning table provided the highest accuracy of species identification, with 100% of species larger than six inches. With the exception of the cleaning table camera, these results conform to a commercial study which also showed low species identification confirmation percentages (Ames 2005).

Fishing Effort Evaluation

The number of people and anglers were detected 70 and 80 percent, of the time while the number of fishing rods only 54 percent (SD=10.2) of the time. When using the infrared night vision camera, fishing rod confirmation percentage increased with the aid of extra pier lighting. Light colored fishing rods had a higher confirmation percentage since they reflected more light. Note that even though fishing rod confirmation was lower than the confirmation percentage of anglers, it can be assumed that each fisherman has at least one rod and no more than two due to a limit imposed by the pier operator. The infrared camera detected rods and people but since no fish were confirmed its inclusion in a catch per unit effort calculation would equal zero so would be inaccurate.

The confirmation percentage of video to on-site was greater than 100% for fishing rods for two of the five observation hours recorded during the rail camera study. This indicates that video footage was unable to correctly determine the position and number of anglers and fishing rods in the field of view, or the observer had missed detection of certain rods. The latter is less likely.

The highest catch confirmation percentage was 71%. To understand why rod confirmation is not higher, the relationships between rods, spectators and anglers were evaluated. Anglers and spectators act as obstacles to the line of sight between camera and fish. One would predict that the catch confirmation percentage accuracy would decrease as the number of people standing in the line of sight increases. This relationship was analyzed by plotting the average number (during 54, 15 minute observation intervals) of people at increasing distances versus the confirmation percentage of fish caught at the coinciding distance. The predicted negative relationship was not confirmed. The resulting relationship is not significant according to a low R^2 value and Spearman's rank r_s=.2, P=.491). A line of best fit was positive, though the highest catch confirmation occurred during a low total people on pier count. Given more data points and increased variety of landed fish species, there may be a correlation between density of people and confirmation accuracy. This lack could be real, however, and may be explained by the large abundance of Spanish mackerel and bluefish landed combined with the high turnout of anglers targeting these fish on certain dates. The long lengths and shimmer of these fish, combined with the long length of time during which these fish remained in the field of view (due to the fishing style), may have been responsible for the high confirmation percentage during the corresponding observation hours. These species made up the majority of catch during some observation hours, giving weight to the resulting relationship.

Confirmation accuracy of anglers ranged from 52-100% (avg=75.3%, stdev=13.99%). The number of obstacles increased with increasing distance from the camera. The significant negative relationship (r_s =-.560, P=.040) is most likely due to the high densities of anglers and people in the foreground blocking the view of anglers in the back.

Confirmation accuracy of rods ranged from 25-46% (avg=31.9, stdev=6.7). Rods are hard to see in general due to their thin profile and lack of contrast with the background. The significant positive relationship (r_s =.301, P=.296) is opposite of what was expected but may be explained by high number of jigging rods present during observation hours. These rods are more visible than to bottom-rigged poles, are more visible since they have a larger diameter and length and are constantly being worked up and down which making confirmation easier during video playback.

All people (spectators plus anglers) confirmation percentage ranged from 54-85% (avg=69.7%, stdev=11.27%). The ability to count the number of people on the pier is reduced with increasing numbers of people on the pier. The significant negative relationship (r_s rs=-0.640, p=0.0016) is most likely due to the high densities of people. Spectators and anglers in the foreground block the view of those in the distance.

The density of anglers and the number of fishes landed was much higher on the south side of the pier than on the north side during the study. During nine observation hours, the on-site observer recorded 17 fish on the north side versus 308 on the south side. Experienced pier anglers believe that fish can be landed in higher numbers on the south side of the pier in the spring and on the north side of the pier in the fall. Anglers hypothesize that this is due to the general direction along the coast in which fish are travelling during their seasonal migrations; moving to the north in the spring and to the south in the fall.

Catch per Unit Effort

The number of fish caught per rod per observation period as recorded by the on-site observer during the deck camera study was used for the on-site measure of catch per unit effort. The numbers of fish landed on he recorded number of rods during fifty-four, fifteen minute segments were averaged to give a catch per unit effort for north and south anglers. The average catch per unit effort was calculated to be higher on the south side of the pier than on the north. The data range for the north was 0-1.1 fish per rod hour and .66-5.4 fish per rod hour for the south. The south side CPUE was higher though more variable. It should be noted that since the experienced anglers believe that catch is higher on the south. The success rate on that side should also be higher, which would increase the CPUE on that side. The CPUE on the south side was never zero, however, so that alone makes it a better position for camera monitoring. If the migration direction theory is correct, then the camera should be moved to the north side during the fall. The observer witness evidence that supports this theory. During the study (during spring) Menhaden schools were observed on almost all instances to approach from the south and then travel around the pier instead of under.

The calculation of catch per unit effort (CPUE) of landings during the on-site surveys was compared to that calculated from the video surveys. CPUE is defined in this case as any and all species coming onto the pier per rod per 15 minute time interval.

This beginning and ending numbers were usually not very different within a 15-minute time period. Metrics for an eight hour time period were recorded by an onsite observer and compared to video playback. The result was 54, 15-minute intervals, for each of these, CPUE was calculated for each and then averaged. 71% of the confirmed catch occurred in zone 1 (south side closest to camera) for all dates. When only considering the south near camera angle, confirmation estimates of average catch and average rod number increases (27.9%-->41.7% and 54.4%-->75.7%). Since catch and effort estimates were highest for south near camera angle, CPUE was determined for only south near camera angle.

Video estimates of CPUE were generally higher than CPUE calculated from data collected during the on-site survey. When only thinking of catch, one may expect an underestimation of CPUE but since effort is also underestimated the video playback CPUE estimate were overestimated. This is because observer watching video estimate on average under estimates effort less than he or she underestimates catch. This is especially true when considering fishing rods which are more underestimated than are anglers. CPUE was calculated twice, once using the number of fishing rods as the effort term and once using the number of anglers as the effort term. Data sets of CPUE were highly skewed (>+1) so the data were square root transformed to satisfy normality, which is required for detection of significant difference via student t-test.

The ability of video to adequately detect CPUE depended on the effort term used. T-test analysis of video CPUE compared to on-site CPUE when using number of fishing rods as the effort term was found to be significantly different (p=.02996, Figure 22a). Figure 22b. illustrates that the video estimate of CPUE is not significantly different (p=.8998) than the CPUE calculated during the on-site survey when the number of anglers was used as the effort term.

It would be inappropriate for an observer to estimate catch based on an observation of any one 15 minute interval. For example, during 15th interval CPUE when calculated with fish/rod hour is overestimated by approximately 230%. An average of all intervals provides a more accurate estimate. A Non-parametric Runs Test for Serial Randomness (Zar 1984) of catch by minute (Figure 23) confirms (p<.0001) that catch is not random in time. There are in fact '*runs*' of fish hooking events.

Note one minute intervals of CPUE (Figure 23) were possible to estimate, since the survey recorded the exact minute that fishes were caught. However, the number of fishing rods were only recorded every 15 minutes. Then the number at the beginning and the end of the 15 minute interval was averaged in an attempt to capture the variability of the number of rods due to the departure and arrival of anglers.

Reducing Observer Effort

Video Playback Effort Reduction

The time spent reviewing footage can be reduced by increasing the playback speed (Figure 24). The deviation from the theoretical curve (broken line) of increasing playback speed can be explained by the need to pause or rewind the video, especially when landings occur in quick succession. Observation periods with higher number of landings will take longer to review, since the observer will have to pause the footage more often. Increasing playback speed results in loss of count accuracy. However, Figure 25 shows that this loss is minimal; at a playback speed of 8x, the estimate is still above 85% accuracy. It is up to managers to decide what threshold of underestimation is acceptable, while acknowledging probable underestimation.

Figure 26 illustrates how reducing the portion of video watched results in decreasing accuracy of estimated landings during the entire video segment. Each data point represents one of five estimations for that particular segment length viewed. Segment percentages with less than five data points visible are due to repeat estimate values, therefore there is overlapping of points. One hour of observation on 05/06/2009, watching eighty percent of the video resulted in an estimate that is approximately ninety percent accurate, fifty percent watched resulted in an estimate that is approximately eighty-five percent accurate. It is up to managers to decide how accurate the estimate needs to be. It was also found in this study that the five estimate values for any one segment length watched when averaged, resulted in a reasonable estimate of the actual number of landings. So an alternative method to reduce the time spent watching video, would be to watch five 10% (6 minutes) segments and then average those values. The time spent watching video would be 0.5 hours or half the length of the video.

Cost comparison of Remote vs. On-Site Observation

The validity of cameras as a monitoring tool was considered, in regards to cost of equipment, maintenance, and data analysis, as compared to the cost of employment of on-site observer. This study assumes a complete equipment replacement every three years (step up seen in line of Fig 27). Such replacement may be unnecessary. Figure 27 illustrates the comparison of estimates that the cost of video surveillance would be roughly half that of employing an on-site observer. The value provided by video surveillance would be further enhanced if the sampling interval and the video playback speed were increased and equipment replacement rate decreased.

More expensive packages would enhance the ability of cameras to detect landings. There are companies that offer high definition, motorized mount cameras, and remote operation capability and technical support; their services will be attained at a premium, but may be worth investigation if found to be cost efficient.

Subsampling by the short range deck camera for species identity when combined simultaneously with the longer range rail or pier camera could allow for identification of species and more accurate quantification of CPUE. If set up correctly, the deck camera or rail camera has the potential to capture both long range and short range landings, eliminating the need for a separate short range camera for species detection. This may be complicated, however, by anglers closest to the camera maneuvering their catch outside the field of the view. This opposite phenomenon was noticed during the rail camera study. Fishes were seen while anglers remained off camera.

This method raises the question; does the presence of the cameras affect the behavior of the angler? While surveillance is being employed in commercial industry with success, it is also mandatory so more likely ignored in that setting. One would hypothesize that the cameras, may deter anglers from fishing within the surveillance area. There was no formal survey was conducted regarding participant approval, it should be noted that there were no complaints to the surveyor, and many anglers were eager to have their pictures taken holding their catch. Miller et. al., (2010) illustrated that recreational anglers are very willing to make to contributions to aid management. Going so far as to request harvest levels below those levels set by managers. Throughout the study, anglers and spectators inquired as to the purpose of the cameras. The pier management, staff and patrons were all enthusiastic about the study and were always willing to participate. At no time did anglers express to the surveyor objection to the study and many asked what they could do to further its objectives. Management and anglers were especially interested in making the video feed available to the public via a live web feed. One gentleman even offered services in the form of internet cable installation and offered to donate the necessary materials. There may be creative ways or checks to increase the ability of a video surveillance system to assess identity. Creating a camera continuum along the pier length, or creating a voluntary or paid angler participation scheme in which a sub sample of anglers relate their catch composition are examples.

One point to keep in mind is the appropriateness of considering CPUE data as an indicator of stock health. For instance Stoner et. al., (2004), discusses factors such as how density and size of fishes in the fishing area may affect fish density estimates when based on CPUE. Maunder et. al., (2006) says that CPUE varies over a species geographic range. This video surveillance study comes nowhere close to sampling such a range. The study does, however, assert that at a certain time and location the CPUE was ‘x’ value. Recreational pier fishing is largely unbiased in that the fishing is passive since piers are stationary and more similar to fishery independent data in that angling success is only possible when fish are in the angling area, versus other forms of fishing where anglers can increase success by following the movements of fish. This may serve as an important feature of an experimental design that could measure the effect of environmental conditions on fish presence.

The report above provides a general model for a video monitoring program could be developed. Given the apparent potential of the system, further investigation is required to refine it, ultimately providing an even more accurate estimation of fishes landed on the pier. The video surveillance method will be especially effective in monitoring relative composition of day to day landings rather than total landings due to various issues. The following section describes some of these dilemmas and briefly suggests possible remedies that will increase the ability of managers to estimate total landings from a sub-sample of anglers.

A drawback of the camera monitoring system in its current form is that the extreme length of recreational fishing piers limits the portion of the pier that can be observed by a centralized surveillance unit. Most species can be caught at all locations along the pier, though it is likely that variation of species abundance and composition is correlated to increasing distance from the shore and with increasing water depth. For instance, it is likely that landings from the landward end of the pier are more representative of benthic and surf zone-associated species, while the landings from the seaward end of the pier are more representative of open water dwellers. This notion is supported by the distribution of fishing styles on the pier since almost all surface and water column rigging takes place on the most seaward third of the pier, while bottom rigging is probably evenly distributed along the pier. Characterization of this variability could be accomplished through verification by on-site observer or through installation of cameras over multiple cleaning tables. The resulting knowledge may be essential for a proper scaled estimate of landings, in which one portion of the pier is monitored and the total number of landings throughout the pier is estimated.

Conclusion

Video surveillance at recreational fishing piers provides an alternative source for fishery data acquisition by providing useful effort and catch frequency data at a virtually unlimited temporal resolution. Both catch and effort was underestimated, however, the resulting calculation of CPUE was not significantly different than that of the CPUE calculated from that of on-site surveys, though depended on the chosen effort term. The main limitation of this method is the inability of video footage to detect species identity and is due to the long distance between fish and camera.

The correct application of the data requires more study and will be the ultimate responsibility of the managing agency since CPUE data can have various interpretations. The study illustrates the potential for innovative monitoring methods that are cost efficient and effective. These methods encourage fishing community awareness of management activity. This method gives managers a continuous presence at locations where they previously had little, while creating a sense of connection to management for anglers. The study author hopes that this study will serve as inspiration for continuing research on this subject. Fine-tuning of camera confirmation capabilities should be undertaken immediately.

Works Cited

Ames, R. T. 2005. The efficacy of electronic monitoring systems: a case study on the applicability of video technology for longline fisheries management. International Pacific Halibut Commission Scientific Report 80.

Ames, R. T., G. H. Williams, G.H., Fitzgerald, S.M. 2005. Using digital video monitoring systems in fisheries: application for monitoring compliance of seabird avoidance devices and seabird mortality in Pacific halibut longline fisheries. NOAA Technical Memorandum NMFS-AFSC-152.

Ames, R.T., Leaman, B.M., Ames, K.L. 2007. Evaluation of video technology for monitoring of multispecies longline catches. North American Journal of Fisheries Management 27:955-964.

Arlinghaus, R., Cook, S.J. 2005. Letters: Global impact of recreational fisheries. Science 307:1561-1563.

Bonney, J., McGauley, K. 2008. Testing the use of electronic monitoring to quantify at-sea halibut discards in the central Gulf of Alaska rockfish fishery. EFP 07-02 Final Report.

Broughton, R.E., Stewart, L.B., Gold, J.R. 2002. Microsatellite variation suggests substantial gene flow between king mackerel (*Scomberomorus cavalla*) in the western Atlantic Ocean and Gulf of Mexico. Fisheries Research. Volume 54:305-316.

Cahalan, J.A., Leaman, B., Williams, G.H., Mason, B.H., Karp, W.A. 2010. Bycatch characterization in the Pacific halibut fishery: A field test of electronic monitoring technology. NOAA Technical Memorandum NMFS-AFSC-213.

Coleman, F.C, Figueira, Will F., Uleand, J.S., Crowder, L.B. 2004. The Impact of Unites States Recreational Fisheries on Marine Fish Populations. Science 305:1958-1960.

Conover, D.O., Munch, S. B. 2002. Sustaining fisheries yields over evolutionary time scales. Science 297:94-96.

Conover, D. O., Munch, S. B., Arnott, S.A. 2009. Reversal of evolutionary downsizing caused by selective harvest of large fish. Proceedings of the Royal Society of Biological Sciences 276:2015-2020.

Devries, D.A., Grimes, C.B. 1997. Spatial and temporal variation in age and growth of king mackerel, *Scomberomorus cavalla*, 1977-1992. Fishery Bulletin 95:694-708.

dos Santos L.D., Braun, A.S., Fontoura, N.F. 1999. Relative seasonal fish abundance caught by recreational fishery on Cidreira Pier, southern Brazil. Journal of Applied Ichthyology 15:149-151.

Eikeset, A.M., Richter, A., Dunlop, E.S., Dieckmann, U., Stenseth, N.C. 2013. Economic repercussions of fisheries-induced evolution. Proceedings of the National Academy of Science 110:12259-12264.

Glover, E. 2012. Surfside Beach, S.C. Pier Fishing for Flounder. www.youtube.com. YouTube, 31 October 2012. Accessed January 2013.

Godcharles, M. F., Murphy, M.D. 1986. Species profiles: Life history and environmental requirements of coastal fishes and invertebrates (South Florida): King mackerel and spanish mackerel. [*Scomberomorus cavalla; Scomberomorus maculatus*]. Florida Department of Natural Resources. Technical report TR-EL-82-4/82-11-58.

Grothues, T.M., Able, K. W. 2010. Association of adult fishes with piers in the lower Hudson River: hydroacoustic surveys for an undersampled resource. Final Report to the Hudson River Foundation. Grant#003/07A. Accessible at http://www.hu dsonriver.org/ls/reports/Grothues_003_07A_final_report.pdf.

Hammond, D.L., Cupka, D.M., 1977. An economic and biological evaluation of the South Carolina pier fishery. SC Department of Natural Resource Marine Resources Division. Technical Report #20. Accessible at <http://www.gpo.gov/fdsys /pkg/CZIC-sh222-s6-h3-1977/html/CZIC-sh222-s6-h3-1977.htm sh222-s6-h3-1977/html/CZIC-sh222-s6-h3-1977.htm>.

Harley, S.J, Myers, R.A., Dunn, A. 2001. Is Catch per Unit Effort Proportional to Abundance? Canadian Journal of Fish Aquatic Science 58:1760–1772.

Ihde, T. F., Wilberg, M. J., Loewensteiner, D.A., Secor, D.H., Miller, T.J., 2011. The increasing importance of marine recreational fishing in the US: Challenges for management. Fisheries Research 108:268-272.

Jaenike, J. 2007. Comment on “Impacts of biodiversity loss on ocean ecosystem services.” Science 316:1285.

Johnson, C.C. 2007. 2007-2008 Recreational pier fishing survey versus environmental variation. Poster presentation at ERF 2007, Providence Road Island.

Johnson, C. C. 2013. Comparison of 1973 and 2007 pier fishery surveys in South Carolina. Poster presentation at 2013 American Fisheries Society meeting, Tidewater Chapter. Solomons, Maryland.

Larkin, P.A. 1977. An epitaph for the concept of maximum sustained yield. Transactions of the American Fisheries Society 106:1–11.

Lewin, W-C. Arlinghaus, R., Mehner, T. 2006. Documented and Potential Biological Impacts of Recreational Fishing: Insights for Management and Conservation. Reviews in Fisheries Science 14:305-367.

Marine Recreational Fisheries of the United States; National Saltwater Angler Registry Program. Federal Register /Vol. 73, No. 250 /Tuesday, December 30, 2008 /Rules and Regulations. Accessible at <http://www.nmfs.noaa.gov/msa2007/ docs/registry_final_rule.pdf>. Accessed May 2013.

Maunder, M.N., Sibert, J.R., Fonteneu, A., Hampton, J., Kleiber, P., Harle, S.J. 2006. Interpreting catch per unit effort data to assess the status of individual stocks and communities. ICES Journal of Marine Science 63:1373-1385.

Miller, T. J., Blair, J., Ihde, T.F., Jones, T.M, Secor,D.H., Wilberg, M.J. 2010. FishSmart: an innovative role for science in stakeholder-centered approaches to fisheries management. Fisheries 35:242-433.

MRFSS Marine Recreational Fishery Statistics Survey MRFSS. Accessed 2012. Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division. Accessible at <http://www.st.nmfs.noaa.gov/st1/recreational/queries/>.

Mutsert, K. Cownan Jr, J.H. Essington, T.E., Hilbourn, R. 2008. Reanalysis of Gulf of Mexico fisheries data: landings can be misleading in assessments of fisheries and fisheries ecosystems. Proceedings of the National Academy of Sciences 105:2740-2744.

Myrtle Beach Chamber of Commerce. Myrtle Beach Area Data and Statistics. Accessed December 2013. Accessible at <http://www.myrtlebeachareachamber.com/ research/data_and _statistics.html>.

National Marine Fisheries Stock Sustainability Index. Accessed April 2012. Accessible at <http://www.nmfs.noaa.gov/sfa\/statusoffisheries/2012/first/ Q1%202012%20FSSI%20 Summary%20Changes.pdf>.

NOAA Fisheries Office of Science and Technology. Accessed November 2013. Outreach Presentation: 2013 MRIP update. Available at <http://www.st.nmfs.noaa.gov/r ecreational-fisheries/index>.

Ortiz, M. 2008. Standardized catch rates of king mackerel, *Scomberomorus cavalla* from the Marine Recreational Fisheries Statistics Survey MRFSS. SEDAR16-DW-14. Accessible at <http://www.sefsc.noaa.gov/sedar/download/S16_DW_14. pdf?id=DOCUMENT>.

Patterson III, W.F., Shipp, R.L., Clardy, T.R. Zhongxing, C. 2008. SEDAR16. Discrimination among U.S. South Atlantic and Gulf of Mexico king mackerel stocks with otolith shape analysis ad otolith microchemistry. SEDAR16-DW-30. Accessible at <http://www.sefsc.noaa.gov/sedar/download/S16_DW_30.pdf?id =DOCUMENT>.

Ricker, W.E. 1973. Two mechanisms that make it impossible to maintain peak period yields from stocks of Pacific salmon and other fishes. Journal of Fisheries Research Board Canada 30:1275-1286.

Roos, A.M. 2006. Evolutionary regime shifts in age and size at maturation of exploited fish stocks. Proceedings of the Royal Society. Biological Sciences. 273:1873-1880.

Sanger, D., DeVoe, R., Hernandez, D. 2010. Long Bay hypoxia study: A collaborative and multidisciplinary approach. In: Shifting Shorelines: Adapting to the Future,The 22nd International Conference of The Coastal Society , June 13-16, 2010 , Wilmington, North Carolina.

Sanger, D., Hernandez, D., Libes, S., Voulgaris, G., Davis, B., Smith, B.E., , Shuford, R., Porter, D., Koepfler, E., Bennet, J. 2010. A case history of the science and management collaboration in understanding hypoxia events in Long Bay, USA. Environmental Management 45:340-350.

NOAA Southeast Fisheries Science Center . 2008. SEDAR (Southeast Data Assessment, and Review). 2008. SEDAR 16 Complete Stock Assessment Report: South Atlantic and Gulf of Mexico King Mackerel. NOAA Southeast Fisheries Science Center. Accessible at <http://www.sefsc.noaa.gov /sedar/download/SEDAR16_final_SAR.pdf?id=DOCUMENT>.

Shackell, N.L., Frank, K.T., Fisher, J.A.D., Petrie, B., Leggett, W.C. 2009. Decline in top predator body size and changing climate alter trophic structure in an oceanic ecosystem. Proceedings of the Natural Academy of Sciences 277:1353-1360.

Spearman, C. 1904. The proof and measurement of association between two things. American Journal of Psychology 15:72-101.

Steffe, A.S., Murphy, J. J. 2010. The importance of validating the duration of fishing trips: Are harvest rates from on-site recreational fishing surveys unbiased? North American Journal Fisheries Management 30:506-510.

Stoner, A.W., Ottmar, M.L. 2004. Fish density and size alter Pacific halibut feeding: implications for stock assessment. Journal of Fish Biology 64:1712-1724.

Sutter, D.A, Suski, C.D., Phillip, D.P., Klefoth, T., Wahl, D.H., Kersten, P., Cooke, S.J. Arlinghaus, R. 2012. Recreational fishing selectively captures individuals with the highest fitness potential. Proceedings of the National Academy of Science 109:20960-20965.

Thomas, A.B. 2004. The social benefits of saltwater recreational fishing. Proceedings of the 2003 Northeastern Recreation Research Symposium. USDA Forest Service 152-156.

Thompson, C. J. 1991. Effects of the avidity bias on survey estimates of fishing effort and economic value. Final report to the Hudson River Foundation American Fisheries Society Symposium. 12:356-366.

U.S. Fish and Wildlife Service and U.S. Census Bureau. 2013. 2011 National survey of fishing, hunting, and wildlife-associated recreation. U.S. Fish and Wildlife Service and U.S. Census Bureau. Accessible at <http://www.census.gov/prod/2012pubs /fhw11-nat.pdf)>.

Verweij, M.C. 2006. Structure, food and shade attract juvenile coral reef fish to mangrove and seagrass habitats: a field experiment. Marine Ecology Progress Series 306:257-268.

Walters, C.J., Hilborn, R. 1976. Adaptive control of fishing systems. Journal of the Fisheries Research Board of Canada 33:145-159.

Whitaker, J.D. 2005. Atlantic croaker. In: Comprehensive wildlife conservation strategy. South Carolina Department of Natural Resources, Columbia, SC. Accessible at <http://www.dnr.sc.gov/cwcs/pdf/Croaker.pdf>.

Whitaker, J.D., DeLancey, L.B., Jenkins, J.E. 1989. A study of the experimental closure of South Carolina's sounds and bays to commercial trawling. South Carolina Marine Resources Division. South Carolina Marine Resources Center Technical Report No. 72.

Wilberg, M.J., Miller, T.J. 2007. Comment on "Impacts of biodiversity loss on ocean ecosystem services". Science 316:1285.

Worm, B., Barbier, E.B., Beaumont, N., Duffy, E.J., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H. K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R. 2006. Impacts of Biodiversity Loss on Ocean Ecosystem Services. Science. Volume 314:787-790.

Zar, J.H. 1984. Non parametric runs test for serial randomness. Biostatistical Analysis. 2nd Edition. Prentice Hall (Englewood Cliffs, NJ).

Tables and Figures

Species	r_s	DF	P	Mean	Std Dev.	N	R^2
Amberjack (*Seriola dumerili*)	0.300	5	0.683	25.555	3.144	5	.0803
Black drum (*Pogonis chromis*)	-0.863	18	0.000	3.390	1.604	18	.7453
Bluefish (*Pomatomus saltatrix)*	-0.270	27	0.173	4.534	0.916	27	.1045
Cobia (*Rachycentron canadum*)	-0.318	16	0.231	15.959	6.361	16	.1046
Atlantic croaker (*Micropogonias undulates*)	-0.069	13	0.826	0.550	0.395	13	.1718
Flounder (Pleuronectidae)	-0.304	26	0.131	2.514	0.858	26	.0651
Jack crevalle (*Caranx hippos*)	-0.119	8	0.785	9.317	4.868	8	.1144
King mackerel 2000-2012 (*Scomberomorus cavalla*)	-0.825	12	0.002	11.146	2.998	12	.6488
King mackerel 1973-2012	-0.510	31	0.004	13.482	3.463	31	.2675
Little tunny (*Euthynnus alletteratus*)	0.189	8	0.655	6.269	1.503	8	.0117
Florida pompano (*Trachinotus carolinus*)	0.203	18	0.417	1.252	0.269	18	.078

Red drum (*Sciaenops ocellatus*)	-0.519	22	0.014	3.558	3.060	22	.1368
Sheepshead (*Archosargus probatocephalus*)	-0.565	28	0.002	3.558	1.167	28	.3085
Atlantic spadefish (*Chaetodipterus faber*)	-0.657	12	0.023	1.423	1.301	12	.498
Spanish mackerel (*Scomberomorus maculata*)	-0.110	23	0.616	3.290	0.606	23	.1756
Spot (*Leiostomus xanthurus*)	-0.165	8	0.698	0.287	0.061	8	.0288
Weakfish aka Summer trout (*Cynoscion regalis*)	-0.632	15	0.013	1.527	0.893	15	.5771
Atlantic tarpon (*Megalops atlanticus*)	0.009	8	1.000	17.095	15.833	8	.0616
Whiting (*Menticirrhus sp.*)	0.552	18	0.019	0.788	0.134	18	.2699
Spotted seatrout aka Winter trout (*Cynoscion nebulosus*)	-0.231	14	0.426	0.287	0.061	8	.0524

Table 1. Results of Spearman Rank correlation of recorded landings of the largest individual by weight for each species and year between 1973 and 2012. For king mackerel, the period between 2000 and 2012 was tested separately since it coincides with the beginning of angler concerns regarding landing declines.

Figure 1. Map of the study area. Locations of fishing piers in Long Bay, SC with blowouts of study sites (marked by stars) at Springmaid Pier, Surfside Pier, and Apache Pier.

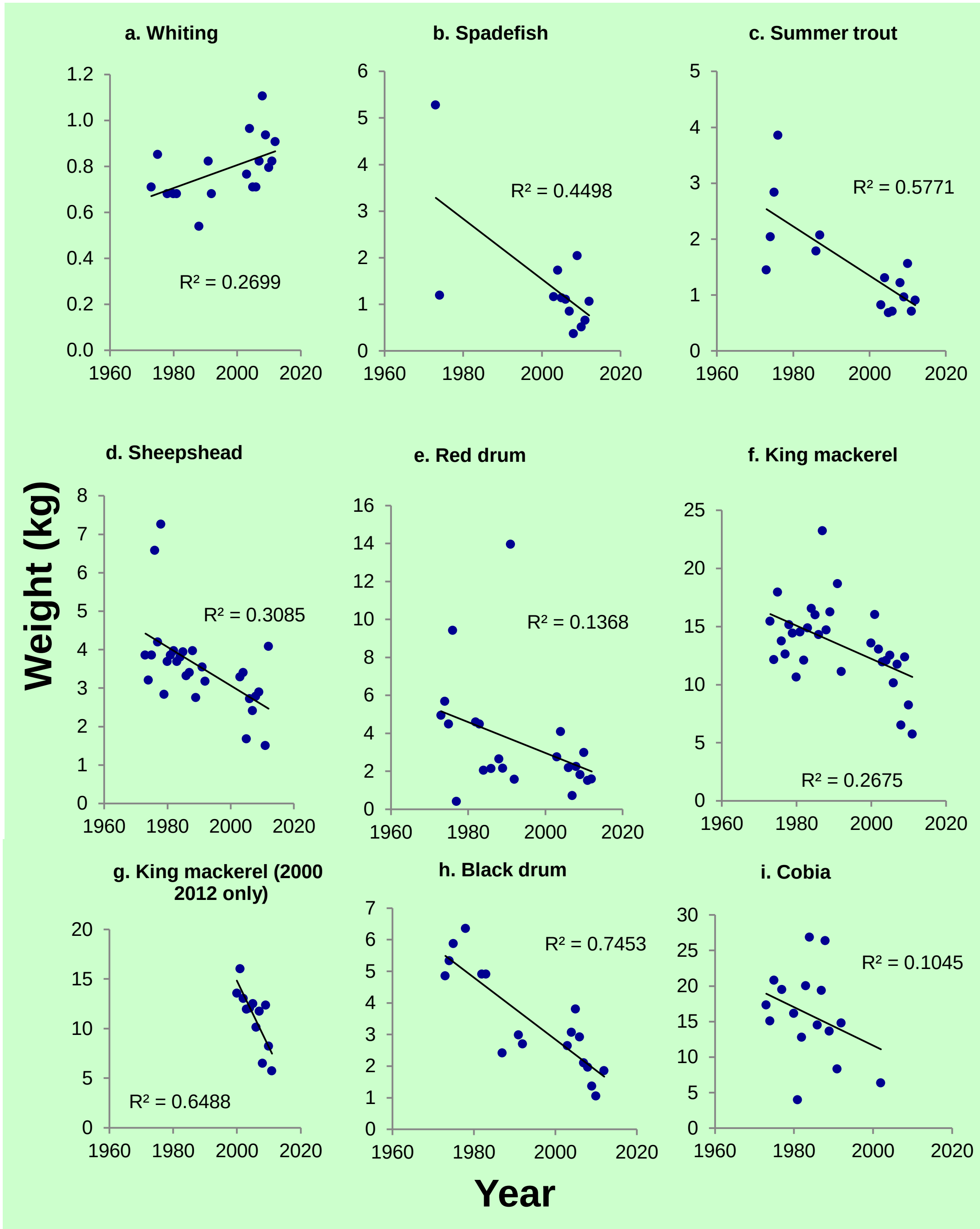


Figure 2a-2i. Largest landing entry weight by year with R^2 for significantly (Spearman Rank p<.05) correlated species

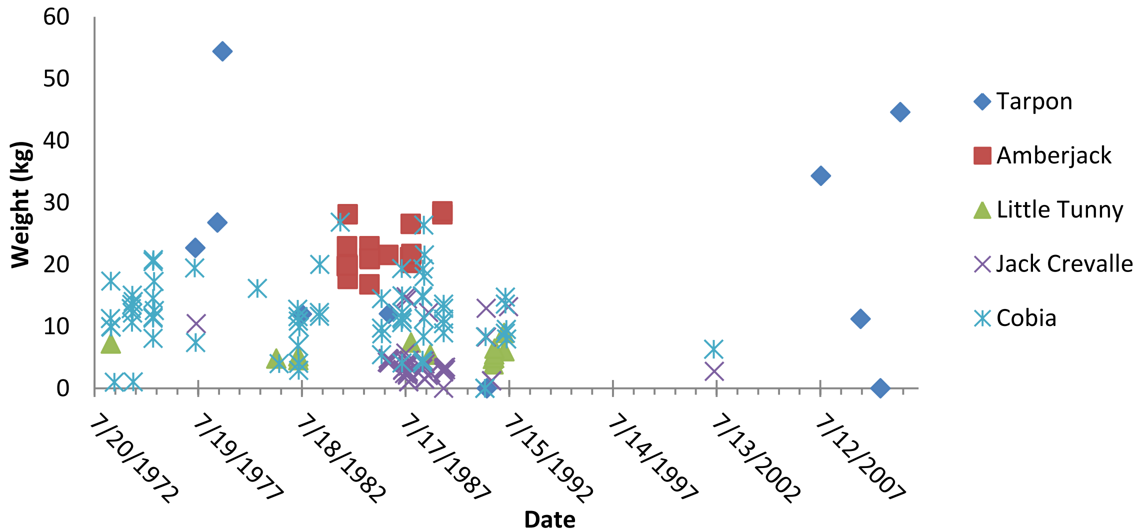


Figure 3. Infrequent 'trophy' species by weight and date at Surfside Pier. Note that, points where y=0 indicate that a fish was landed but the weight was not recorded.

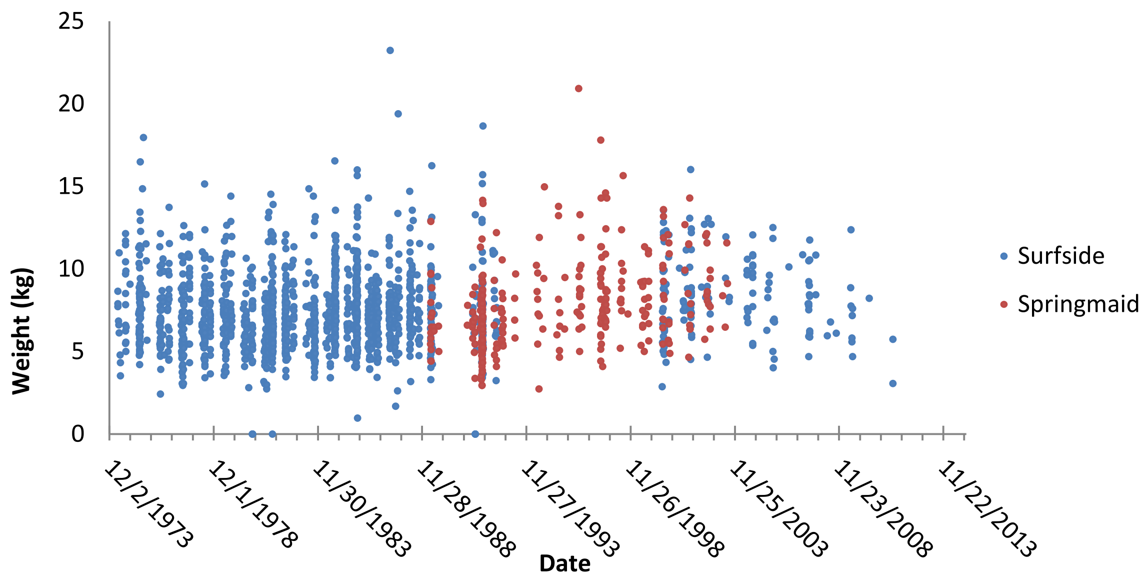


Figure 4. All recorded King mackerel landings at Surfside and Springmaid piers. Note that points where y=0 indicate that a fish was landed but the weight was not recorded.

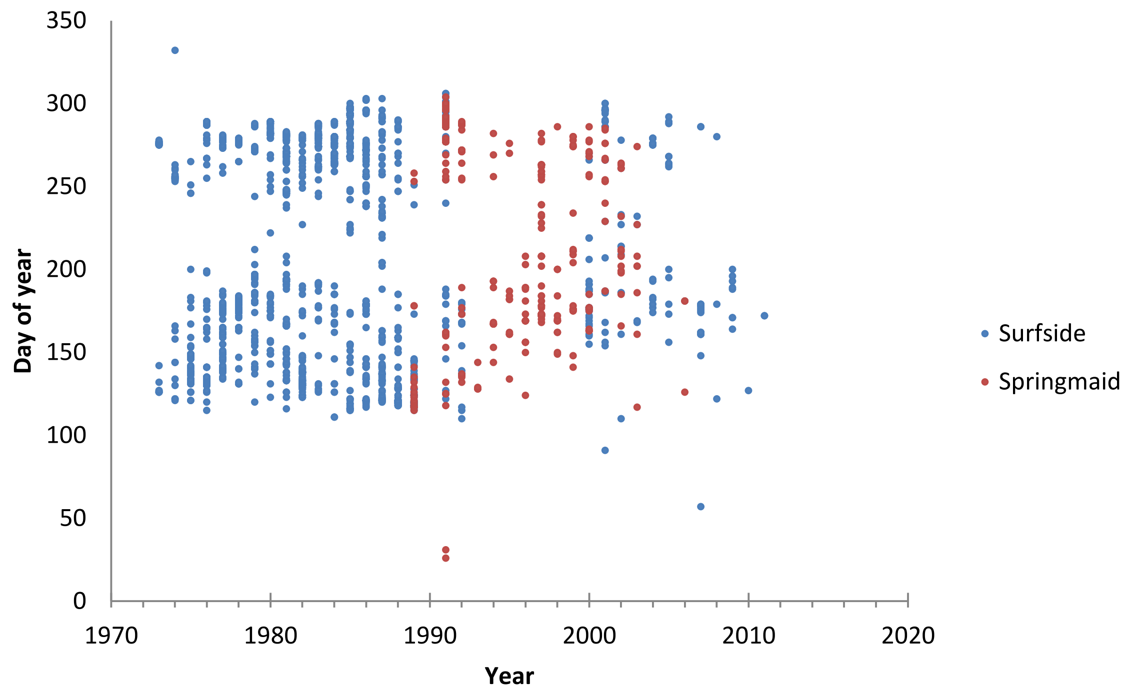


Figure 5. Day of year the year of all King Mackerel landings by year for Surfside and Springmaid.

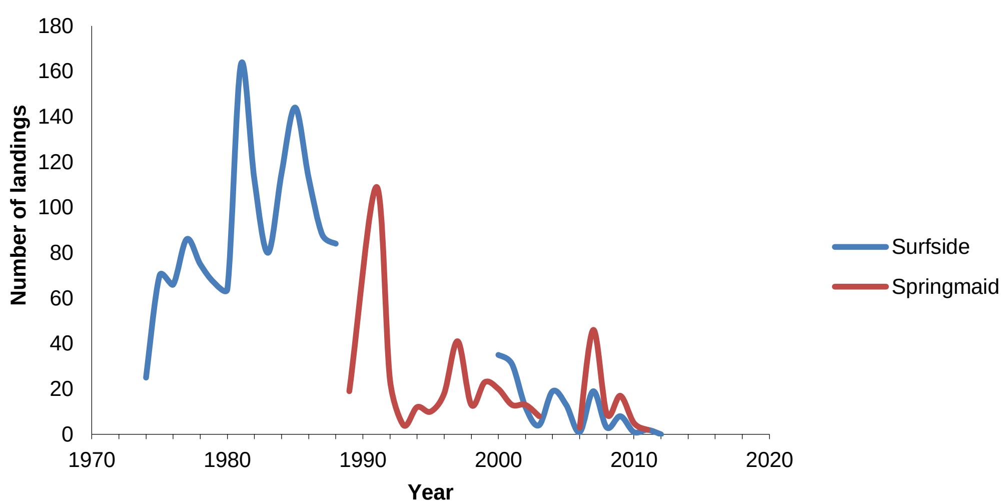


Figure 6. Number of King mackerel landings per year at Surfside and Springmaid Pier.

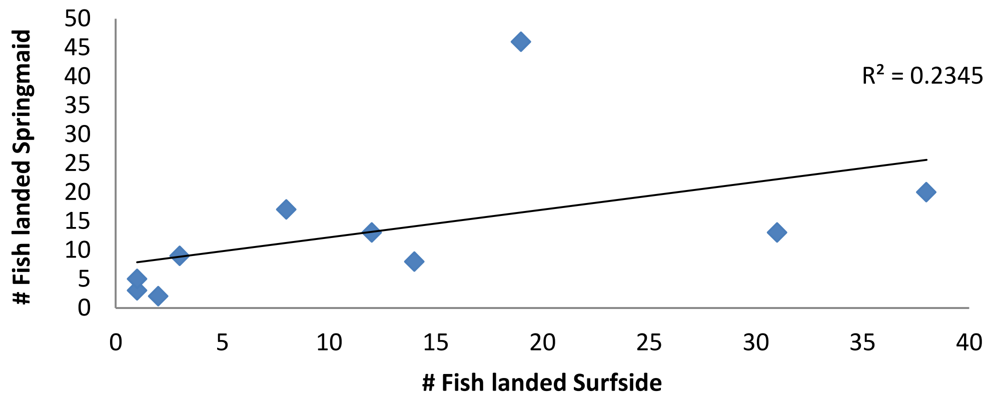


Figure 7. The number of King mackerel landed by year: Springmaid versus Surfside Pier.

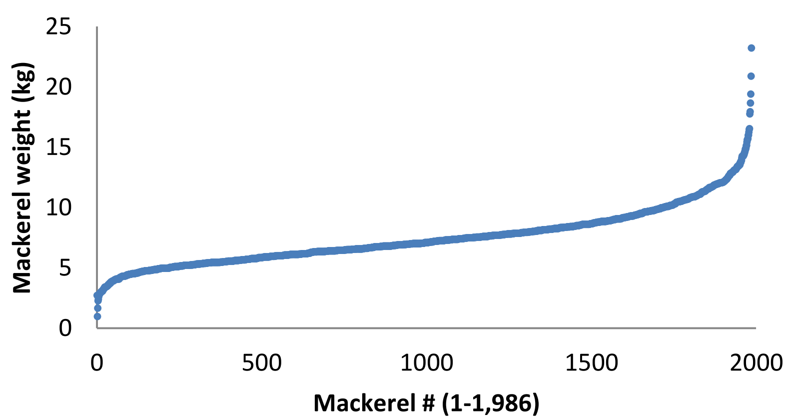


Figure 8. Weight of all King mackerel landed (n=1986) all years at Springmaid and Surfside Pier. It is possible that anglers confused juvenile king mackerel with spanish mackerel.

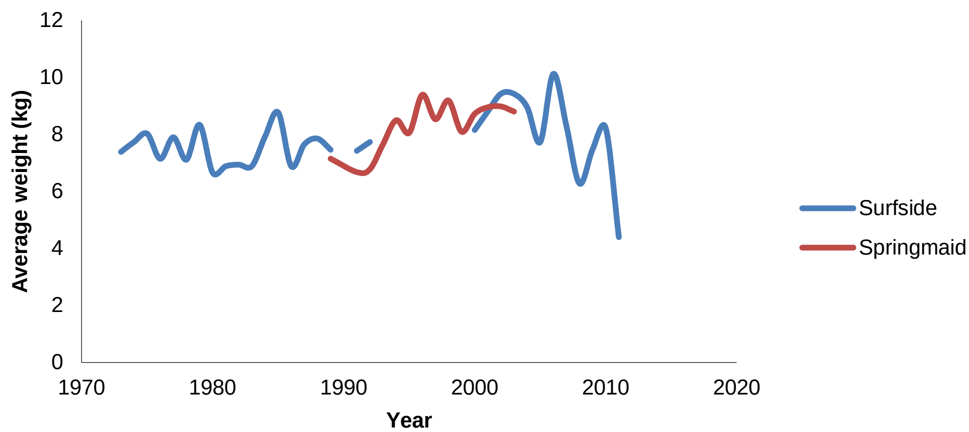


Figure 9. The average weight of king mackerel landed per year at Surfside Pier and Springmaid Pier.

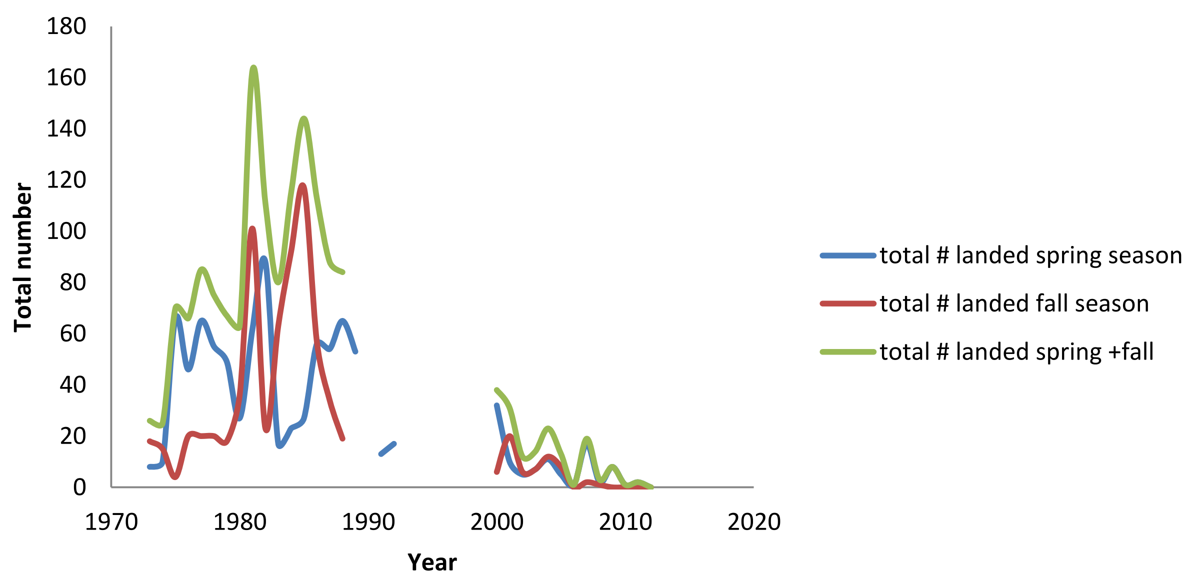


Figure 10. The total number of King mackerel landed by fishing season and calendar year.

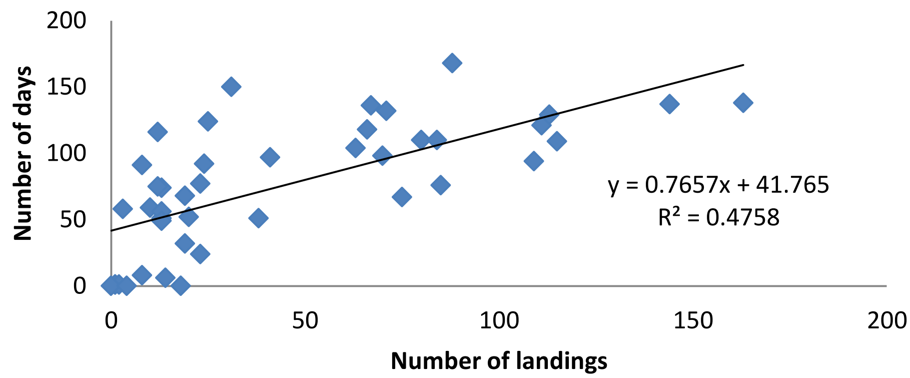


Figure 11. Length of fishing season versus the number of landings for Surfside and Springmaid Pier.

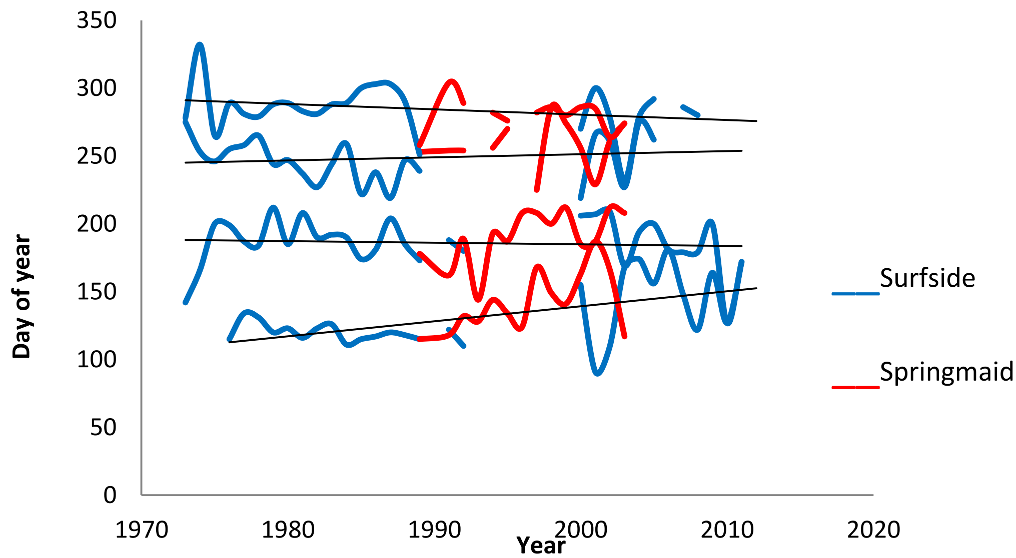


Figure 12. Day of year of first and last landing of season by year. Note: Trendline only fits Surfside data though Springmaid data may be thought of as a measure of interpolation since Springmaid and Surfside landings were significantly correlated

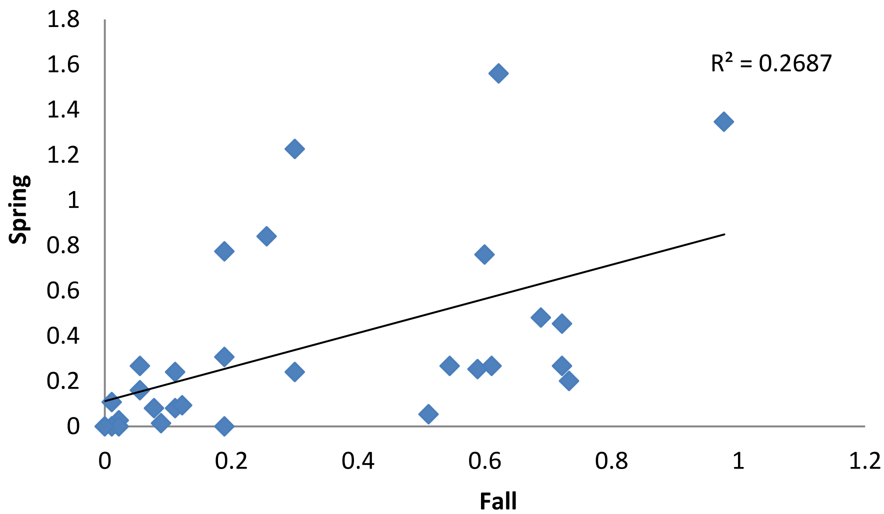


Figure 13. Landing abundance index for Spring versus Fall Landings at Surfside Pier.

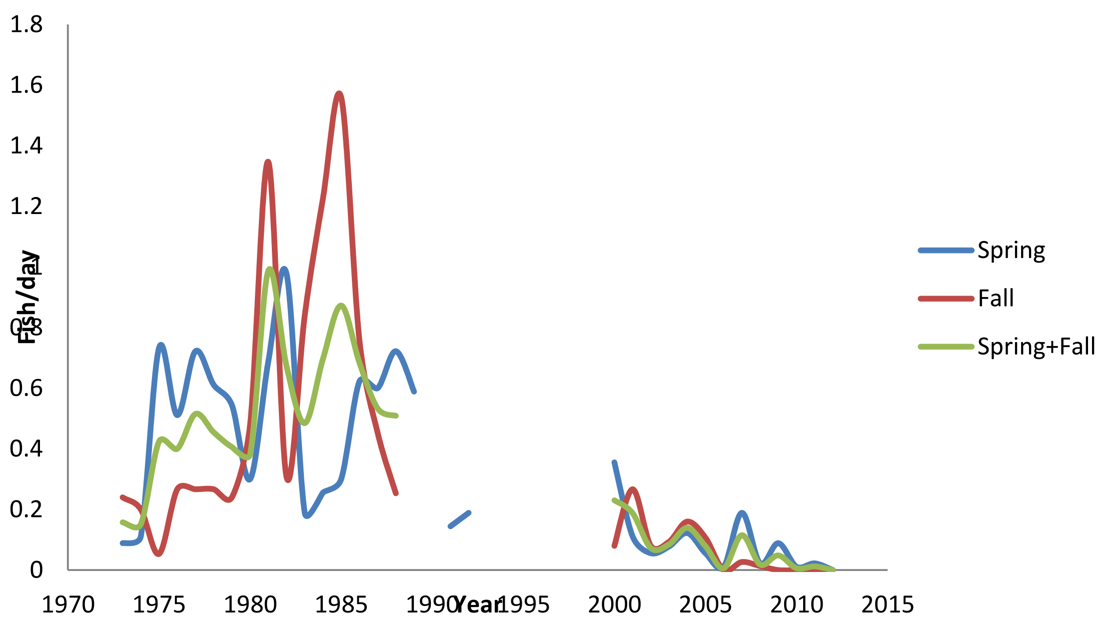


Figure 14. Index of landing abundance for Surfside Pier by year and fishing season.

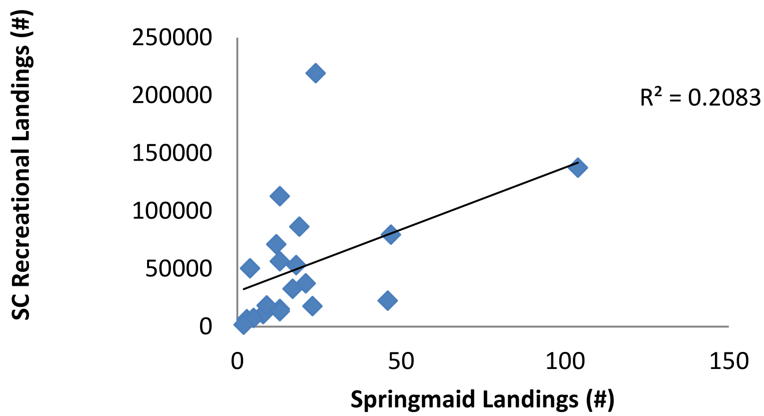


Figure 15. Total number of King mackerel landings: Springmaid Pier versus MRFSS South Carolina recreational landings.

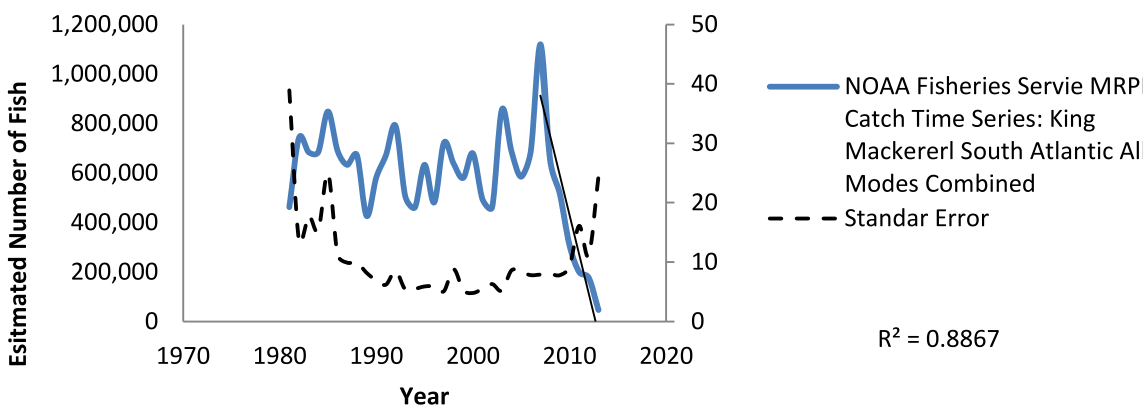


Figure 16. MRIP South Atlantic total King mackerel catch (catch + discards).

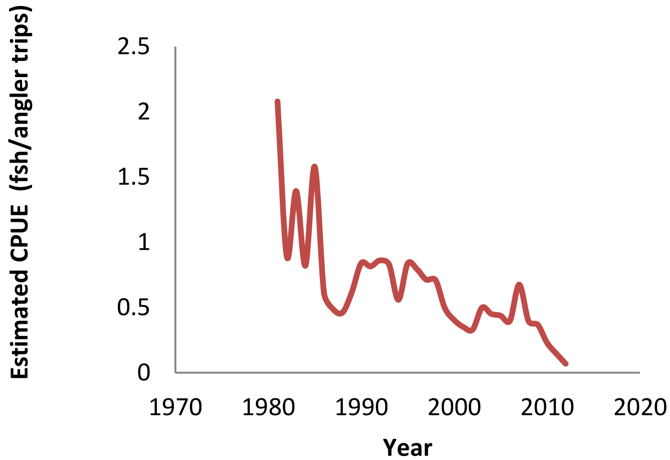


Figure 17. CPUE estimate was calculated from MRIP South Atlantic catch data. Note for 2006-2012, it was assumed that the effort term was estimated at 2% of the number of angler trips targeted king mackerel.

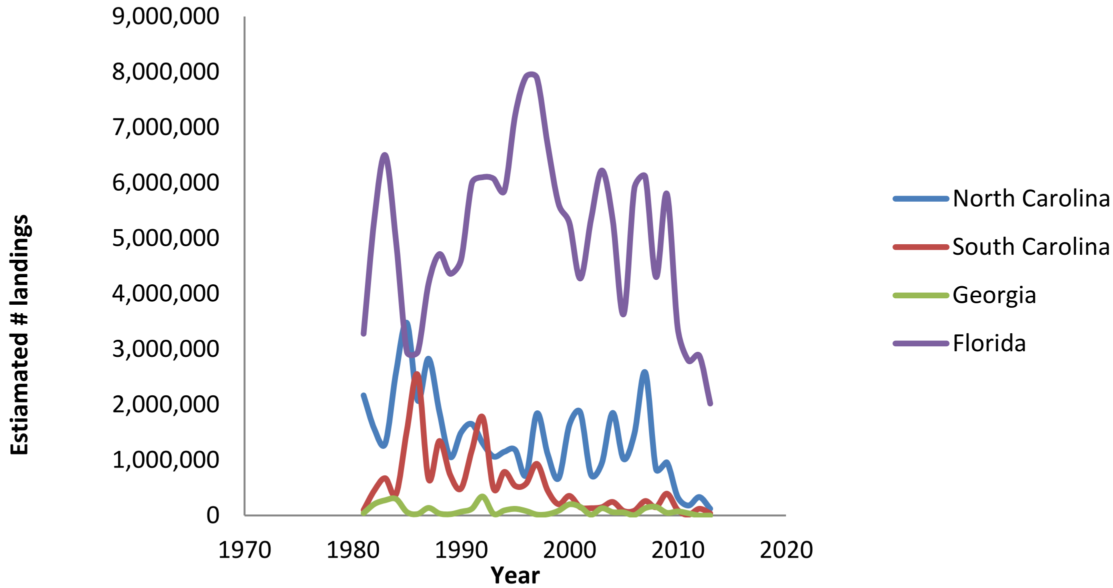


Figure 18. MRIP king mackerel landings by state in Southeastern U.S.

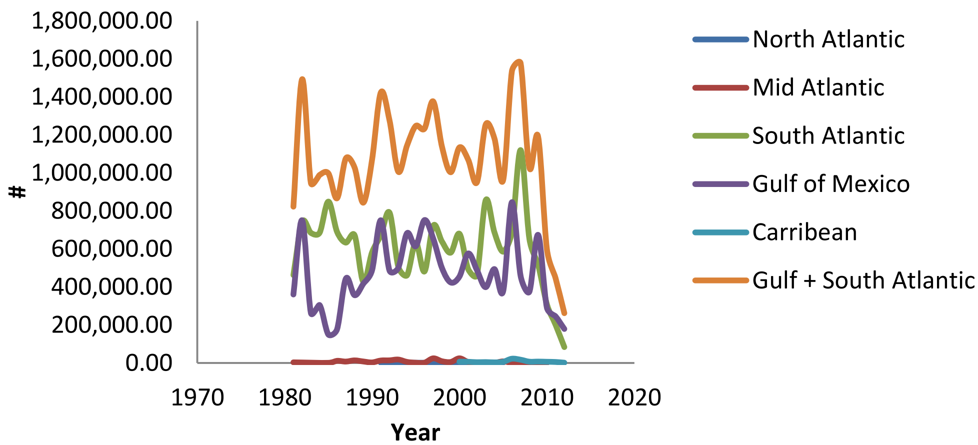


Figure 19. MRIP recreational king mackerel landings by management region.

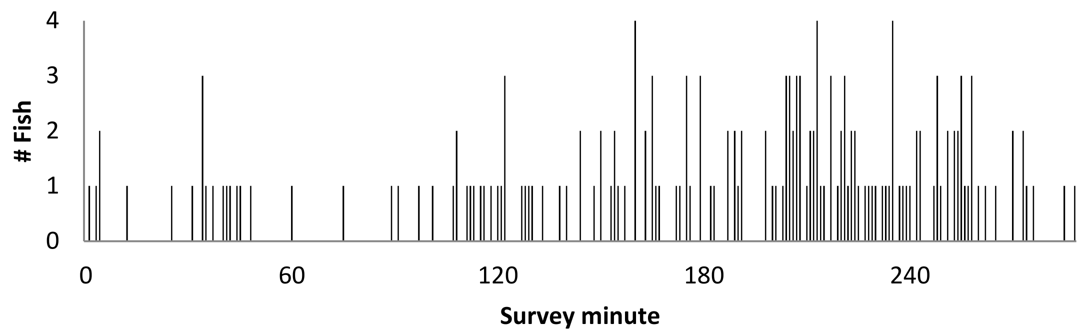


Figure 20. Number of fish (all species) by minute during 5/29/2009 on-site survey.

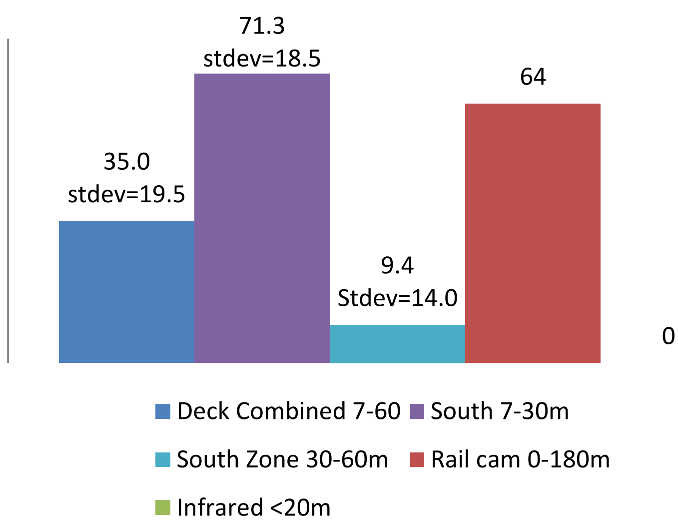
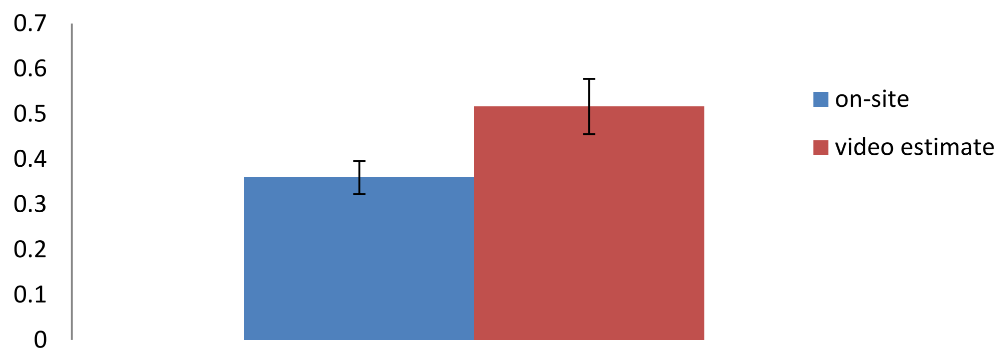


Figure 21. Landing confirmation percentage as detected by varying camera angles.

a)



b)

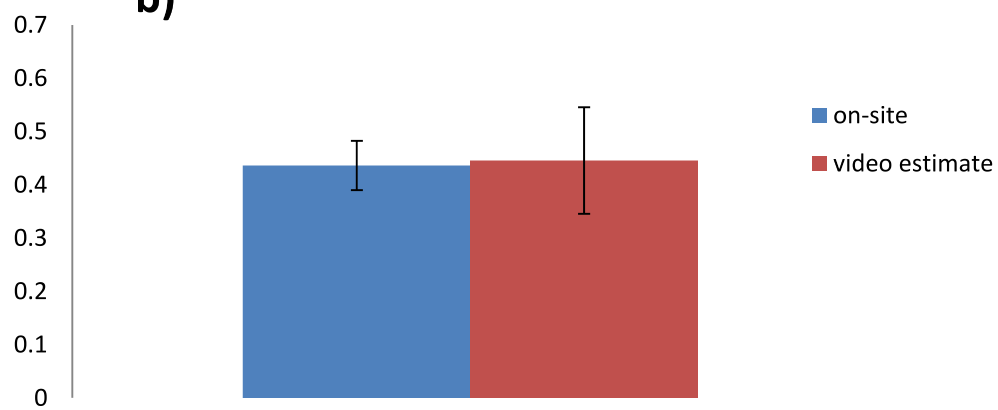


Figure 22.a) On-site versus video estimates of CPUE (fish/rod*quarter hour). T-test resulted in a p<.05 so estimates are significantly different. **22.b)** On-site versus video estimates of CPUE (fish/angler*quarter hour). Based on 54, 15 minute intervals of square root transformed data. T-test resulted in no significant difference.

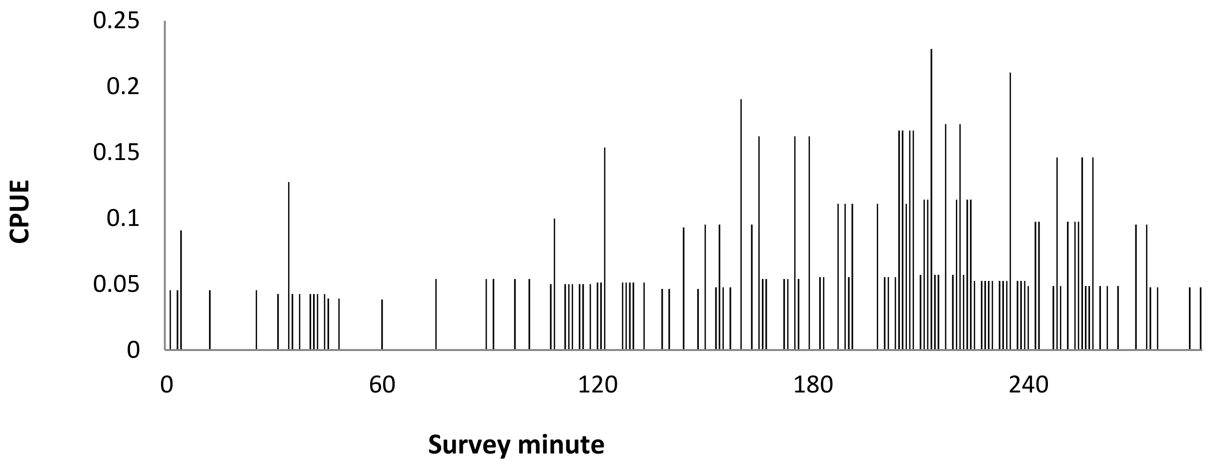


Figure 23. CPUE (fish/rod*minute) during on-site survey for all landings. Non-parametric runs test for serial randomness indicates landings are not random along a time continuum.

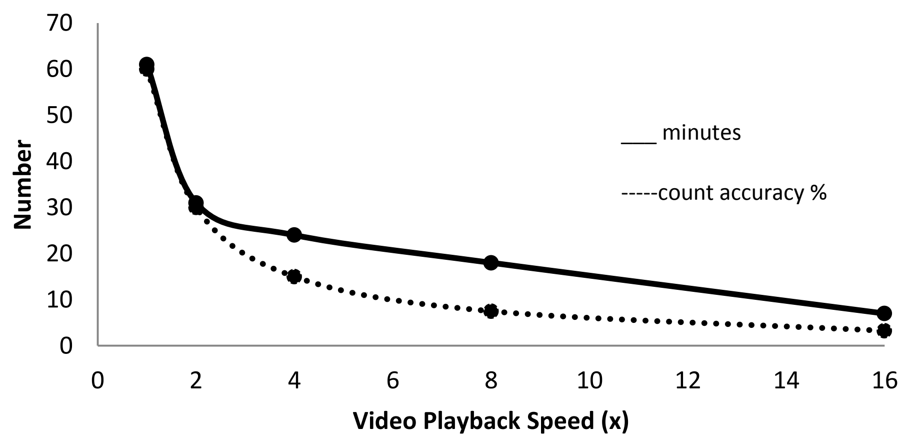


Figure 24. Reduction in time spent watching video with increasing playback speed.

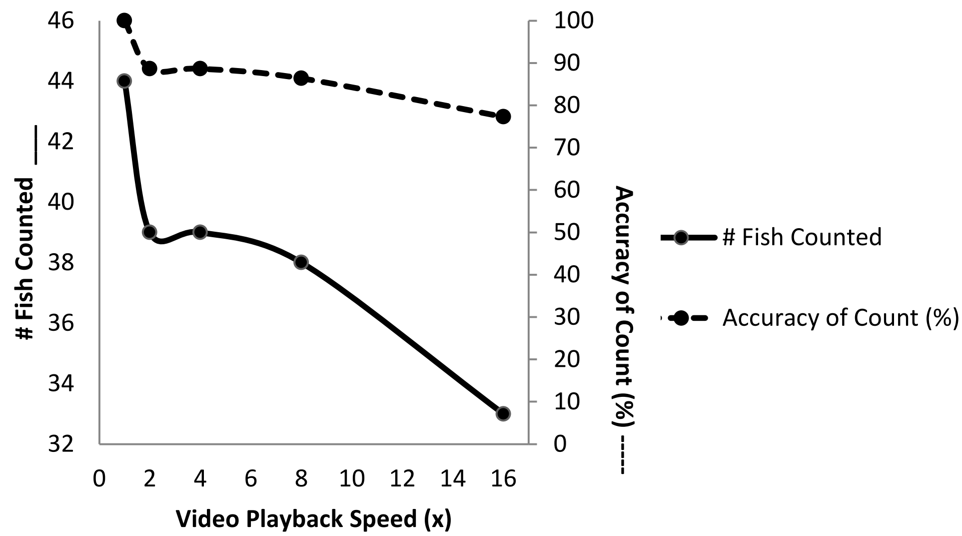


Figure 25. The number of fish and count accuracy (%) with increasing playback speed.

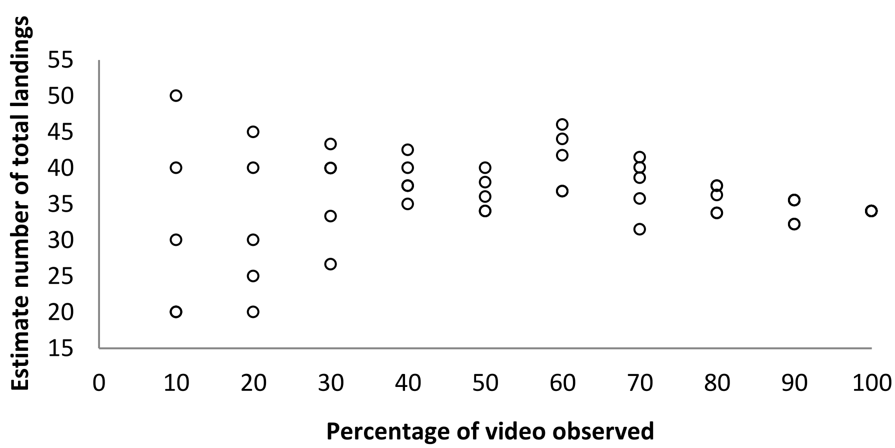


Figure 26. Estimate of total landings versus the percentage of video observed based on five estimates at each percentage of video watched. The value at 100% represents the actual catch. Portions with less than five visible points is where estimates were equal and therefore overlapping.

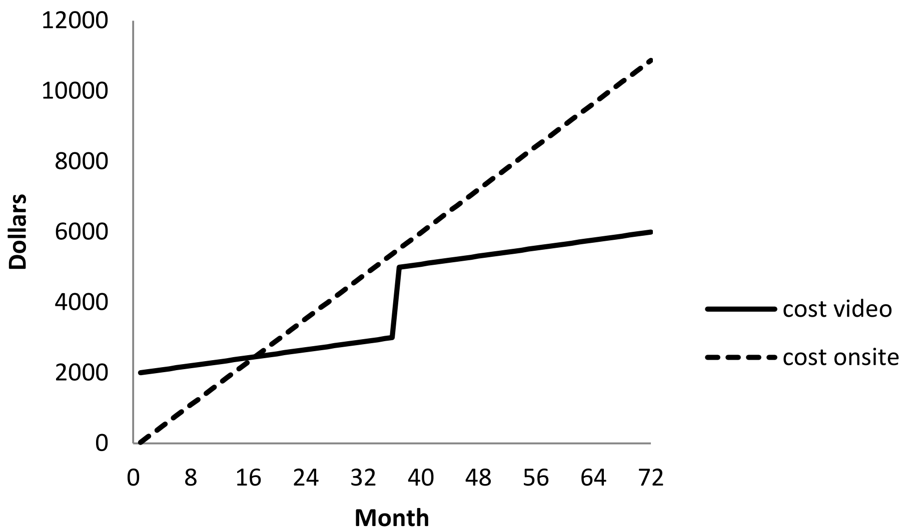


Figure 27. Cumulative cost comparison between on-site and remote video surveys.

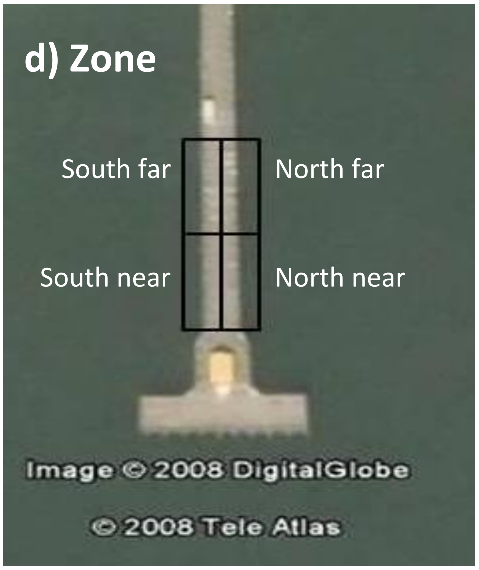
Appendices


a) Deck
Image © 2008 DigitalGlobe
© 2008 Tele Atlas
Google
Camera 02
b) Rail
2009/05/04 09:18:23
c) Infrared
Image © 2008 DigitalGlobe
© 2008 Tele Atlas
Google


Camera 01
2009/06/02 14:12:11


Google
33°45'44.13" N 78°46'49.82" W
elev 0 m
Eye alt 322 m


Camera 01
2009/06/16 21:33:22



Appendix 1a-d. Camera angle coverage and screen shots; a) deck camera, b) rail camera, c) infrared night vision, d) experimental zone breakdown used for caluclations.