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# PELAGIC OBSERVER PROGRAM DATA SUMMARY, GULF OF MEXICO BLUEFIN TUNA (*Thunnus thynnus*) SPAWNING SEASON 2007 AND 2008; AND ANALYSIS OF OBSERVER COVERAGE LEVELS.

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## Introduction

The Atlantic Bluefin tuna, *Thunnus thynnus,* is a large apex teleost that inhabits the pelagic environment in temperate and subtropical waters of the North Atlantic. While the species engages in long seasonal migrations throughout its range, it is believed that two major stocks exist, one in the eastern Atlantic and Mediterranean and one in the western Atlantic and Gulf of Mexico (Block et al., 2005). In the west, spawning activity is concentrated in the Gulf of Mexico during April, May, and June (Mather et al., 1995). The decline of both Eastern and Western stocks of Atlantic bluefin tuna has been well documented and the species is subject to major rebuilding efforts (ICCAT, 2007). Part of the rebuilding effort has been to increase the amount of information known about the basic biology of bluefin tuna, as well as collecting robust information regarding fisheries catch and bycatch. In the spring of 2007, and again in the spring of 2008, the National Marine Fisheries Service (NMFS) conducted enhanced observer coverage of the U.S. pelagic longline fleet operating in the Gulf of Mexico (GOMEX) in order to accurately quantify and characterize bluefin tuna bycatch in this fishery during spawning season, as well as collect biological samples to support various research into bluefin tuna age and growth, maturity, and reproduction. Here we provide background information on the GOMEX longline fishery and the summary statistics of the observer data collected during bluefin tuna spawning season coverage in 2007-2008; as well as analyses of levels of observer coverage needed to provide bycatch estimates of various precisions.

## GOMEX Fishery Background

The first documented U.S. Pelagic fisheries efforts in the GOMEX were fishery investigations conducted by the U.S. Fish and Wildlife Service between 1950 and 1963 (Bullis, 1955; Iwamota, 1965). Although commercial quantities of yellowfin tuna (*Thunnus albacares*) were identified, substantial domestic pelagic fishing in the GOMEX did not immediately develop. Instead, Japanese longline effort in the GOMEX, first reported in 1957 (Iwamota, 1965), quickly developed during the 1960's and reached a peak in the 1970's. Initially Japanese longliners targeted both yellowfin and bluefin tuna during various months of the year, but by the late 1970's effort was concentrated during the spring months (Wilson, 1988) coinciding with the appearance of spawning bluefin tuna in the GOMEX. Foreign fishing effort in the U.S.

Exclusive Economic Zone (EEZ) of the GOMEX ended in 1981. U.S. pelagic longline effort in the GOMEX gradually increased in the 1980's as vessels from the east coast expanded their range of operations (Berkeley and Waugh, 1989). Domestic effort in the GOMEX occurred during all months of the year and initially targeted swordfish (*Xiphias gladius*) or, increasingly, yellowfin tuna (Bertolino and Hoey, 1989), depending upon area and target species availability. Due to regulations that became effective in 1983, domestic longline fishermen in the GOMEX were prohibited from targeting bluefin (NRC, 1994). During this time period, domestic fishermen began to use live bait in order to target yellowfin tuna; these fishermen included a substantial number of Vietnamese-Americans. Regulations that became effective on February 1, 2001 closed a large portion of the eastern GOMEX to longline fishing (reducing the amount of swordfish directed fishing effort) as well as prohibiting the use of live bait in the GOMEX. Finally, in August 2004, regulations were implemented that required the use of circle hooks in the Atlantic pelagic longline fishery.

Description of the Present Fishery

The current domestic pelagic longline fishery in the GOMEX involves approximately 40 vessels, although some vessels only enter the area to fish occasionally and still other vessels only make a small number of pelagic longline trips during any given year. Pelagic longline vessels in the GOMEX are primarily based in Dulac, LA and Panama City, FL, although small numbers of vessels operate out of other ports including Stock Island (Key West) FL, Cortez, FL, Venice and Leeville, LA, and Galveston, TX. The fleet can be grouped loosely into three subdivisions based on area fished and gear configuration. The first group is a small number of vessels (2-5) that target swordfish on primarily short trips (2-6 days) operating from Stock Island, FL. These vessels set their gear in the evening and retrieve it in the morning, use mackerel or squid for bait with light sticks near every hook, and target fishing depths (depth from surface to hook) of 27-46 meters. Hooks are a mix of 16/0 and 18/0 circle hooks. The Stock Island subdivision of the fishery has a very low bycatch of tuna of any kind; the area of operation is generally the southeastern GOMEX. The second subdivision of the fishery (6-10 vessels) operates mainly out of the Florida Panhandle and targets primarily yellowfin tuna most of the year on 10-18 day trips, although some vessels also participate in other fisheries (e.g. swordfish pelagic longline, and shark or reeffish bottom longline) when those fisheries are more profitable. This segment of the fishery generally targets yellowfin tuna by setting gear in the morning and hauling back in the evening, uses sardine bait with no light sticks and 16/0 circle hooks, and targets fishing depths of 82-90 meters. This fishery operates primarily in the Eastern and Central GOMEX. The third and largest (25-30 vessels) subdivision operates primarily out of Louisiana and is made up of Vietnamese-American fishermen. This subdivision commonly employs two different fishing strategies. During time periods surrounding dark (new) moon phases, a strategy similar to the Florida Panhandle is used (day soaks), although lightsticks are sometimes scattered throughout a set in a small percentage (~20% of the total gangions) and use of squid bait is most common. The other fishing strategy is used surrounding bright (full) moon phases, when the gear is set much like swordfish gear (night soaks) but only about 50% of the hooks have lightsticks, and the bait is generally squid. This fishing strategy is designed to maximize the catch of swordfish while still catching yellowfin tuna, and can be regarded as a mixed target strategy, although yellowfin tuna remains the most desirable species. Regardless of the strategy used this subdivision targets fishing depths of 64-75 meters using 16/0 circle hooks, and generally operates in the central and western GOMEX. In all three subdivisions of the fishery, 3-5 hooks between floats are common.

Besides the target species of yellowfin tuna and swordfish (and small retention limits of bluefin tuna) domestic longliners operating in the GOMEX also land commercial quantities of bigeye tuna (*Thunnus obesus*), escolar (*Lepidocybium flavobrunneum*), wahoo (*Acanthocybium solanderi*), and dolphin fish (*Coryphaena hippurus*).

Enhanced observer coverage

The NMFS Southeastern Fisheries Science Center (SEFSC) conducts observer coverage on U.S. Atlantic pelagic longline vessels through the Pelagic Observer Program (POP). The POP normally attempts to place observers on a random sample of 8% of the fishing effort (defined as sets of gear) during any given calendar quarter and area strata (Keene et al., 2006). However, concerns over bycatch mortality of bluefin tuna during spawning season, and a critical need to collect biological samples, led to efforts to enhance observer coverage in the GOMEX during bluefin spawning season in 2007 and 2008. Budgetary limitations prevented the temporal range of enhanced coverage from extending during the entire time period that bluefin tuna occur in the GOMEX (January through June), however coverage focused on periods of peak abundance. In 2007, all vessels departing on pelagic longline trips into the GOMEX between April 15$^{th}$ and June 15$^{th}$ were required to take observers (if available); in 2008 the coverage period was March 9$^{th}$ through June 9$^{th}$. In addition to the enhanced observer coverage during these periods, in both 2007 and 2008, effort was observed in January, February, and March as part of the normal POP coverage. This report will include all observed effort in the GOMEX during January through June in both 2007 and 2008. Permit holders were notified of the enhanced coverage by selection letters as per standard POP procedure, although additional information regarding the purpose of the enhanced coverage was also provided (see Appendix 1 for example of 2008 project fact sheet).

## Methods

POP observers collected a suite of information, including gear configuration and deployment information, environmental information, and basic characteristics of catch and bycatch (Keene et al., 2006). Additional information about the POP can be found at http://www.sefsc.noaa.gov/pop.jsp Supplemental to the normal POP protocols, on all bluefin retained for sale as well as a portion of those discarded dead, the observers attempted to collect hard parts (otoliths, caudal vertebrae, and dorsal fin spines), tissue samples from skin, and a variety of fresh and fixed tissue samples from internal organs (gonads, liver, etc.).

Comparisons of bluefin size and catch per unit effort (CPUE) data were made by ANOVA; regression analysis was used to detect trends in size as the season progressed. In order to test if bluefin status at boatside (live or dead) was independent of sea surface temperature, Pearson's correlation was used.

## Observed Effort

During the two seasons (January through June each year), observers spent 1,675 sea days on 134 individual trips. The effort was observed on 40 different vessels and consisted of 1,169 hauls of longline gear deploying 876,723 hooks (Table 1). Effort was observed in each month of the spawning season, but the majority of effort was observed during April and May; biweekly effort (for the time period beginning January 1 and ending June $30^{th}$ 2007-2008) is shown in Figure 1. The goal of the enhanced coverage periods was to cover 100% of the domestic longline GOMEX fishing effort if possible. Several issues hampered these efforts, mainly an inability in the time given to recruit enough observers to deploy on every vessel conducting fishing operations, although non-compliance issues and a small number of observers' failure to adhere to protocols also resulted in a minor number of unobserved hauls. During the 2007 enhanced coverage period (April $15^{th}$ – June $15^{th}$), fleet effort (from logbook submissions) was 563 sets; observed effort was 405 sets for a coverage level of 72 %. For the 2008 period (March $9^{th}$ – June $9^{th}$), complete logbook submissions are not available at this time to enable a rigorous estimate of percent of observed effort. However, based on an estimate of trips known to have not been covered during the 2008 enhanced coverage period (24), it is estimated that approximately 75 % of trips were covered. Because generally the trips that were not covered were short in duration, they likely fall well below the average amount of effort (in both hauls and hooks) observed in the trips that were covered. Therefore, coverage during the 2008 enhanced period is assumed to be above 80%.

Sixty-three percent of the hauls observed were night time soaks (gear deployment occurred between 1200 and 2400 hrs); the remainder were daytime soaks. Most of the effort observed (67%) used a mixed target strategy, but 30% targeted tuna only and 3% targeted swordfish only (see above for description of different target configurations). Consistent with the target species, the majority of the observed hauls employed squid (77%) as the primary bait type (Figure 2) and the vast majority of sets (96%) used 16/0 non offset circle hooks.

Observed Catch

Numbers of major market species and their disposition is shown in Table 2. Numerically, the greatest percentage of this catch was made up of swordfish and yellowfin tuna (35% and 34%, respectively); bluefin tuna made up only 3% of the market catch (and 2% of the catch of all species). The number of market species discarded dead (primarily swordfish) made up 23% of the total number caught. Incidental takes of protected resources (sea turtles, marine mammals, and seabirds) made up less than 0.4 % of the total observed catch.

## Characteristics of Bluefin Tuna Catch

### *Size*

Summary size statistics for observed bluefin are shown in Table 3. The average fork length was 228 cm; however this includes estimated lengths (79% of all measurements) which are normally taken to the nearest foot and then converted to centimeters. Routinely only fish that the fishermen intend to retain are brought aboard for processing; the actual measurements taken from fish brought on board were significantly larger than the estimated measurements from released/discarded fish ($F$ = 81.18; df = 1, 463; $P$ < 0.0001). Length frequencies of actual measurements and estimated measurements are shown in Figure 3. To analyze for temporal effects, length data were sorted by bi-weekly periods; average length did not change significantly as the spawning season progressed ($P$ = 0.75); however the average length of bluefin caught in 2008 was 11.7 cm longer than the average length of those observed in 2007 ($F$ = 12.49; df = 1, 463; $P$ < 0.0005). While only a relatively small part of the total of all bluefin caught were landed and weighed ($n$ = 78; 15 %); the average dressed weight was 224 kg (Table 3). There were no significant differences in dressed weight either within season or between years 2007 and 2008. Males and females were not significantly different in either lengths or weight.

### *Disposition, status, and sex ratio*

A total of 511 bluefin tuna were observed in 2007 and 2008 (Table 2); of these 15 % were retained and sold, 55 % were discarded dead, and 23 % were released alive. Status at boatside (live/dead) was positively correlated ($r$ = 0.63) with sea surface temperature (Figure 4). Only a portion (25 %) of the observed bluefin were able to be sexed, but slightly more females (60 % of total) were observed than males. Boatside status was not significantly dependent of sex ratio ($\chi^2$ = 3.09, df = 1, $P$ > 0.05).

*CPUE*

For both years combined, the nominal bluefin catch per unit effort (CPUE) was 0.585 bluefin per 1,000 hooks; mean CPUEs estimated by bootstrapping (1000 replications) were 0.476 in 2007, 0.671 in 2008, and 0.594 for both years combined (Table 4). Bluefin CPUE was significantly higher in 2008 than in 2007 ($F$ = 6.319; df = 1, 1167; $P$ < 0.05). Mean bluefin tuna CPUE estimates and confidence intervals for biweekly periods beginning January 1$^{st}$ though June 30$^{th}$ are shown in Figure 5; zero values occur in biweeks 2, 3, 4, and 13 (no bluefin were observed in those biweeks). Bluefin CPUE peaked in April and May, but quickly declined in June.

In general, gear configurations and deployment methods had little effect on bluefin CPUE. Sets employing squid bait did not have a significantly different CPUE than sets using sardines ($F$ = 0.437; df = 1, 1144; $P$ > 0.5). Hook depth, calculated as the combined length of droplines, gangions, and leaders, had no significant effect on bluefin CPUE ($F$ = 0.524; df = 3, 1221; $P$ > 0.5). Day vs. night soaks had no significant effect on CPUE ($F$ = 0.202; df = 1, 1167; $P$ >0.5); however, swordfish target sets had significantly lower bluefin CPUE than either tuna target sets or mixed (swordfish and tuna) target sets ($F$ = 4.759; df = 2, 1166; $P$ < 0.05); no bluefin were observed on swordfish directed sets. No significant differences were seen between tuna and mixed target sets ($F$ = 2.51; df = 1, 1134; $P$ > 0.05). The small amount of swordfish directed effort observed makes any strong conclusions regarding why these sets caught no bluefin tuna difficult; although most likely the area fished was more important than the gear configuration. All swordfish directed sets occurred either southwest of Key West, Florida, or close to the mouth of the Mississippi River; neither of these locations had bluefin tuna catches regardless of target type (Figure 6).

*Biological Sampling*

Table 5 lists the data and samples observers attempted to collect on each bluefin tuna.
A total of 131 individual fish were sampled during the two years of the project; this was approximately all of the kept fish, but only 36 % of the individual fish presumably “available” for sampling (i.e. either dead boatside or brought on board for processing) actually were. The boarding of large bluefin tuna is a time-consuming, difficult, and in some conditions, a

dangerous procedure. Since observer regulations do not allow observers to interfere in the normal fishing activities of the vessel, requests to bring dead bluefin on board for sampling met with limited success. Further issues in sample collection included the method of processing the tuna; commonly in the GOMEX the head of a bluefin tuna is cut off right behind the eyes, then the lower jaw, opercles, and gill structures are removed. The otoliths usually (but not always) remain in the portion of the head still on the carcass. During the unloading operation at the dock, this piece is generally trimmed off prior to the carcass being weighed. Although otolith sagittae in large bluefin tuna are relatively large (1.5 – 2 cm), this method of processing removes the frame of reference for easily locating the otoliths. Some observers had difficulty locating the otoliths in these situations, however whenever possible large portions of the trimmings were sent back to the lab for dissection.

Analysis of the impact of observer coverage on estimates of bluefin tuna catch

The impact of observer coverage on the precision of by-catch estimates (landings plus dead discards) for bluefin tuna in the Gulf of Mexico longline fishery was investigated using two methodologies. The first uses a Generalized Linear Modeling (GLM) approach to relate the precision of catch estimates to the frequency with which bluefin are encountered by set, using all available data collected by the POP during 2000-2008 for the period April to June (i.e., the second quarter, when the majority of bluefin by-catch takes place in the GOM). The second method examines the precision of by-catch estimates using the data collected in 2008, where the actual observer coverage approached 100% between mid-March and mid-June. This method is based on resampling, without replacement, the observations from the empirical distributions.

*Method 1: GLM*

Estimates of the longline catches (kept, released alive, and discarded dead) by species were constructed using the Delta-lognormal method described by Pennington (1983). The method assumes a lognormal distribution of the positive catch rate observations. Effectively, the estimates were constructed as a product of the proportion of successful occurrences of an event and the average rate at which the event occurs for those successful events. The variance was a function of the variability of the positive catch rates as well the number of successful and unsuccessful sets. Strata were defined as in previous reports (Johnson *et al*., 1999; Yeung, 1999*a*, 1999*b,* 2001*a*, 2001*b*; Yeung *et al.* 2000). The term “catch” is used here in the inclusive sense, to include both directed (targeted) catch as well as bycatch, both retained and discarded. Total catch in each stratum was estimated as:

$$C_t = H \frac{m_c}{N} e^L G_{m_c}(\frac{s_L^2}{2}), \tag{1}$$

where $H$ is the reported number of hooks set per analytical stratum, divided by 1000; $m_c$ is the number of sets wherein a catch of the species or species group of concern was observed; $N$ is the total number of sets observed per analytical stratum;

$L = \frac{\Sigma \log_e L_i}{m_c}$ is the average of the $i$ =1,.., $m_c$ observations of $\log_e$-transformed catch per 1000 hooks fished, $L_i = \log_e(catch_i/hooks_i \mathrm{x} 1000)$;

$s_L^2 = \sqrt{\frac{\Sigma(L_i - L)^2}{m_c - 1}}$ is the sample variance of the $\log_e$-transformed positive catch rates;

and the function $G_{m_c}(\frac{s_L^2}{2})$ is the cumulative probability from the Poisson distribution:

$$G_{m_c}(\frac{s_L^2}{2}) = 1 + \frac{m_c - 1}{m_c}(\frac{s_L^2}{2}) + \sum_{j=2}^{\infty} \frac{(m_c - 1)^{2j-1}}{m_c^j (m_c+1)(m_c+3)...(m_c+2j-3)} \times \frac{(\frac{s_L^2}{2})^j}{j!}. \tag{2}$$

Numerically, the series was computed over $j$ terms, until a convergence criterion of <0.001 change in the function was achieved (usually less than 10 terms were required). The estimate of variance of the catch takes the form:

$$V(C_t) = \frac{m_c}{N}(He^L)^2 \left[ \frac{m_c}{N} G_{m_c}^2 \left(\frac{s_L^2}{2}\right) - \left(\frac{m_c - 1}{N - 1}\right) G_{m_c} \left(\frac{m_c - 2}{m_c - 1} s_L^2\right) \right]. \tag{3}$$

Catch estimates by stratum were assumed independent and as such estimated catch and the associated variances were summed across strata to produce region-wide annual estimates. The coefficient of variation for the stratum-wise estimate of catch was taken as:

$$CV = \frac{\sqrt{\frac{V(C_t)}{N-1}}}{C_t} \tag{4}$$

and approximate 1-α confidence intervals were constructed assuming a lognormal distribution as: $(U_{1-\alpha/2}, L_{1-\alpha/2}) = (C_t k, C_t/k)$, where $U_{1-\alpha/2}$ and $L_{1-\alpha/2}$ represent the upper and lower confidence bounds, $k = \exp[z_\alpha(\log_e(1+CV^2))^{1/2}]$, and $z_\alpha$ the associated 1-α $z$-score.

***Expected Precision*:** Expected levels of precision for the data and estimation methods used herein were modeled as a function of the proportion of sets with positive catch (sets which caught at least one individual of a particular species), or PPC, and the percent sampling coverage by observers on the fleet (PERCOV) within the stratum. First, a finite population correction factor was applied to all stratified estimates of coefficient of variation (CV):

$$CV_{finite} = \sqrt{\frac{V(C_t)}{N-1}} \frac{\sqrt{(1-\Phi)}}{C_t}$$

where $\Phi$ is the (number of observed sets)/(total number of sets) (Snedecor and Cochran 1967).

The contributions of PPC and PERCOV to the variability of the CV ($\log_e$-transformed) of the bycatch estimates were examined with a loglinear regression model:

$$\log_e(CV) = b_0 + b_1(PERCOV) + b_2(PPC) + e, \quad (6)$$

where $b_i$ (i=0-2) are the regression parameters and $e$ is the error term. A GLM using a lognormal error assumption was applied to this model of the finite population corrected, stratified CVs of the 1992-1999 bycatch estimates of all observed species. The resulting model predictions were used to evaluate the relative contribution to precision by PERCOV and PPC for the species observed in this fishery.

The GLM model results for both the U.S. Atlantic (including the Gulf of Mexico) and the Gulf of Mexico only pelagic longline fishery are shown in Table 6. As expected, the model indicates that an increase in either PERCOV or PPC reduces $\log_e(CV)$. The $r^2$ values suggest that these factors explain much of the variability in the bycatch estimates. Additional variability in the $\log_e$-transformed CV estimates could likely be explained by factors such as fishing area, time of year, and other variables related to the catchability of different species. It should be cautioned, however, that this particular approach to estimating bycatch ignores any cluster effects on the bycatch rates (such as within sets, trips or vessels); cluster effects could potentially have a large impact on estimate precision.

Nevertheless, the expected CV in the Atlantic fishery for a given combination of PERCOV and PPC can be identified using Figure 7, on which the CV predictions derived from the model are plotted. For comparison, a historically typical Pelagic Observer Program target of an 8% sampling level is shown, as well as a hypothetical level of 50% sampling coverage. The results from the Gulf of Mexico model are shown in Figure 8.

The actual CVs for the historical estimates of bluefin tuna bycatch in the Gulf of Mexico are overlaid on the CV prediction plot, based upon the relevant actual PERCOVs and PPCs, in Figure 9. In general, the model does a fairly good job of predicting the actual CVs.

During the peak spawning season of April-June in the Gulf of Mexico, bluefin tuna have typically occurred on about 20% of sets in recent years. The expected precision of bycatch estimates given various levels of sampling coverage, assuming a 20% occurrence rate, is shown in Figure 10. These results demonstrate that a bluefin tuna bycatch estimate CV of 0.2 is expected to be achieved when about 40% of sets are observed.

*Method 2: Coverage based on simulation*

The basic idea of this method is to use the distribution of bluefin tuna catch rates that was observed during the expanded observer program in 2008. The coverage in the second quarter approached 100%, such that these data can be treated as a finite population that is resampled via simulation using different coverage rates. The data for trips made between April and June, 2008, are treated together, ignoring possible seasonal differences in catch rates. The method follows sampling theory for finite population (Cochran, 1977). The data used are the total number of sets made and total number of bluefin caught and discarded dead in each trip. These are summarized in Table 7. Bluefin catches in the Gulf of Mexico longline fishery are highly aggregated, and this is evident in the table.

The basic calculation of total catch used here is based on the product between catch rate and total effort. Total effort and total number of trips are assumed to be known, while the catch rates are obtained by resampling the catch and effort observations corresponding to a fixed number of trips. The equations used are (the subscript *i* denotes a given trip chosen at random from the observed population of trips):

Total number of trips (known): $N$
Number of trips resampled (coverage): $n$
Total Effort (number of sets, known): $E$
Resampled catch for a given trip: $c_i$

Resampled effort for a given trip: $e_i$

Average catch rate from resampled trips: $\hat{U} = \frac{\sum_{i=1}^{n} c_i}{\sum_{i=1}^{n} e_i}$

Total bluefin bycatch: $\hat{C} = \hat{U}E$

The simulations were carried out using the software Poptools[1], an Excel add-in that includes algorithms for resampling and for accumulating results from Monte Carlo simulations. Different levels of *n* were chosen to cover the range *n*/*N* from approaching 0 to 1. For each level of *n*, 1000 simulations were made and the mean value of $\hat{C}$, its variance, and 95% confidence intervals were calculated. The results are presented in Table 8 and in Figures 11 and 12. It is evident that the catch estimates from the ratio estimator are unbiased on average at all levels of coverage, however, they tend to be imprecise at low coverage levels (Figure 11). The CV of the dead discard estimates initially falls off very rapidly with increasing sampling fraction (Figure 12, Table 8). However, when the sampling fraction is 40% or higher, gains in precision require a relatively higher effort to increase coverage. For example, increasing the number of trips with observers from 8 to 16, reduces the CV from 0.48 to 0.32 (a 33% change in precision); a similar increase in trips covered from 40 to 48 trips would only reduce the CV from 0.16 to 0.14 (a 13% change in precision).

The target coverage of the POP in years other than 2007 and 2008, when an expanded coverage effort was made, is 8%. These empirical simulation results suggest that the resulting estimates of bluefin dead discards may have a large coefficient of variation, in the order of 48% or higher (see Figure 12). More precise estimates can be achieved with higher coverage rates. Of course, 100% coverage would essentially result in a census of discard estimates, with absolute precision, but such a coverage rate is both expensive and difficult to achieve for logistical reasons. The tradeoff between precision and sampling fraction becomes then a management question. The simulation results based on 2008 observer data suggest that the number of dead discards can be estimated with a CV of 0.2 with a sampling fraction of 33% (32 of 96 trips).

[1] http://www.cse.csiro.au/poptools/download.htm

The results of the analyses indicate that a CV of 0.2 can likely be achieved in estimates of bluefin tuna bycatch in the Gulf of Mexico during the peak of spawning season with 33% - 40% observer coverage (Figure 13). This level of precision exceeds the levels recommended for rare event species such as turtles and marine mammals (CV<0.3; NMFS 2004a, 2004b), which make up a substantially smaller percentage of the GOMEX pelagic longline catch relative to bluefin tuna. Babcock *et al.* (2003) suggested that at least 50% observer coverage was needed to estimate bycatch of "rare" species (defined as less than 0.1 % of catch; bluefin bycatch made up 2.5% of total catch in this study). Consistent with these recommendations, our results indicate that 40% observer coverage in the Gulf of Mexico should result in bluefin tuna discard estimates with desired levels of precision.

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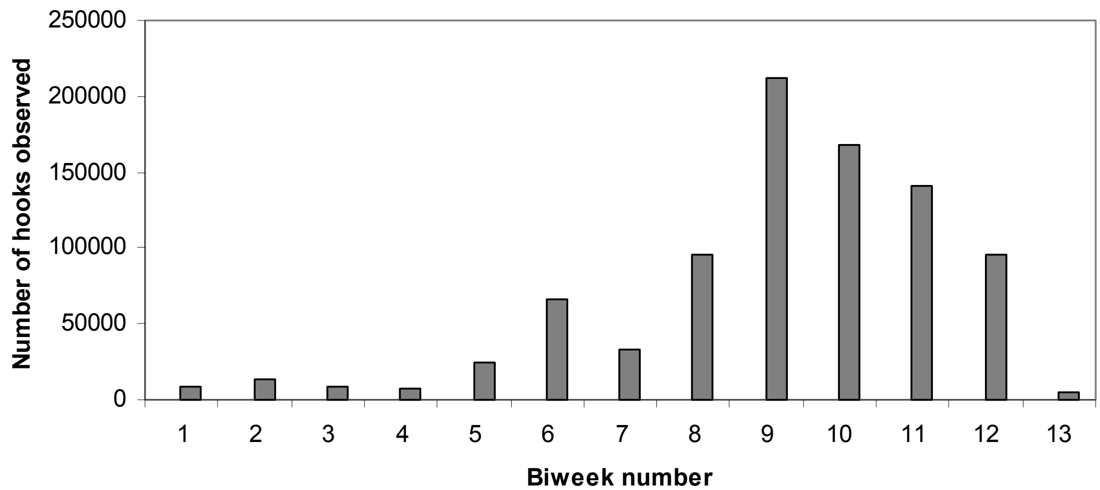



Figure 1. Effort (number of hooks) observed by the POP in biweekly periods January $1^{st}$ through June $30^{th}$, 2007 and 2008 in the Gulf of Mexico.

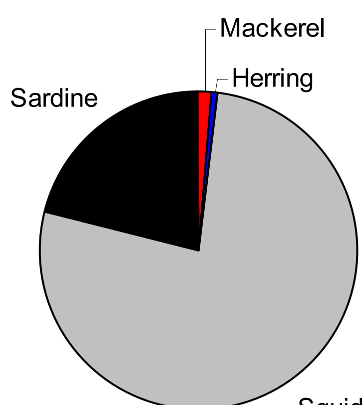



Figure 2. Primary bait types observed during pelagic longline operations in the GOMEX during January - June, 2007 and 2008.

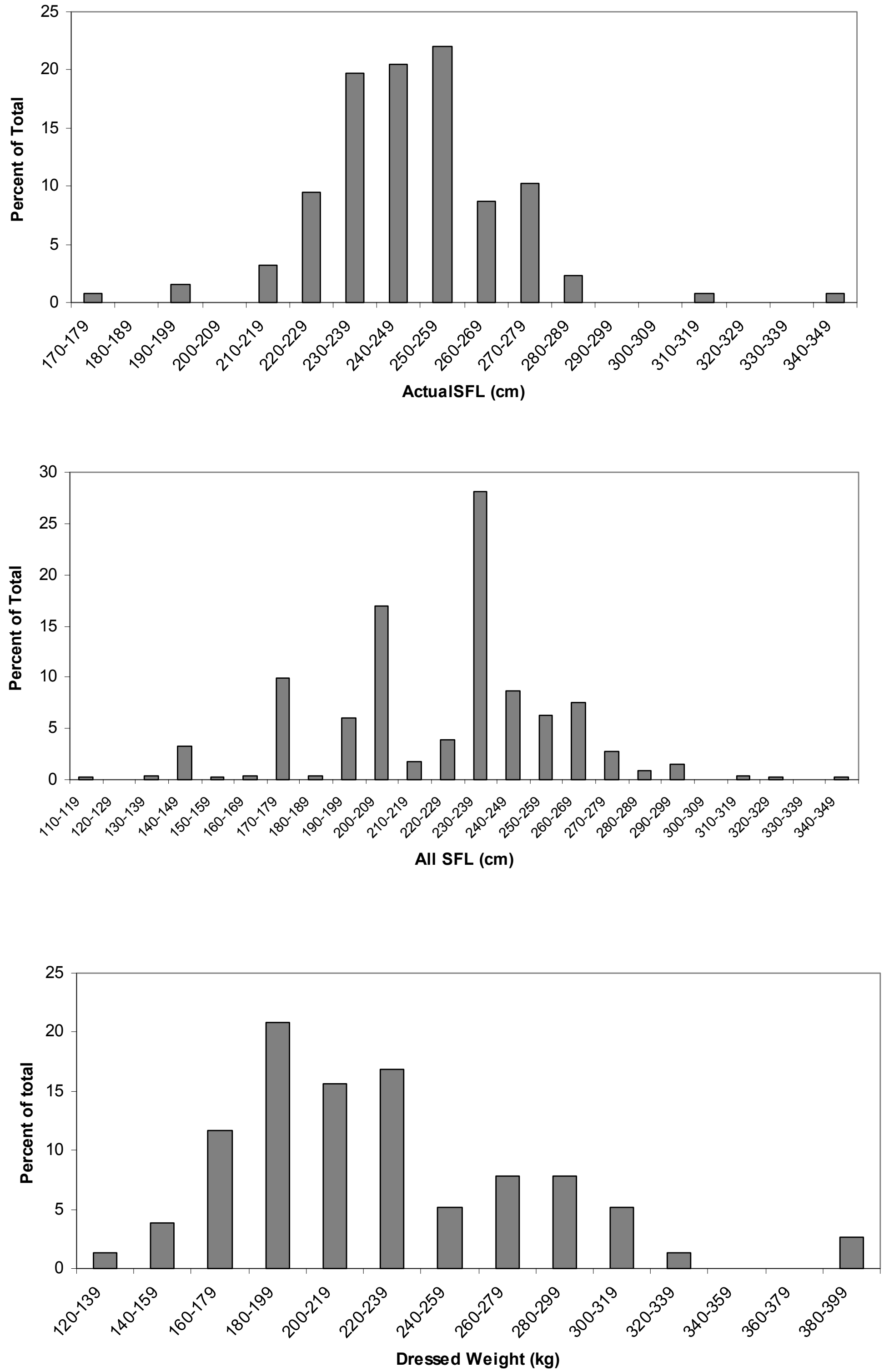



Figure 3. Size frequencies of bluefin tuna observed in the Gulf of Mexico during 2007 and 2008 spawning seasons. Top: standard fork lengths (cm) of bluefin actually measured, (center) standard fork lengths (cm) of all bluefin, including estimated measurements, and (bottom) dressed weight (kg).

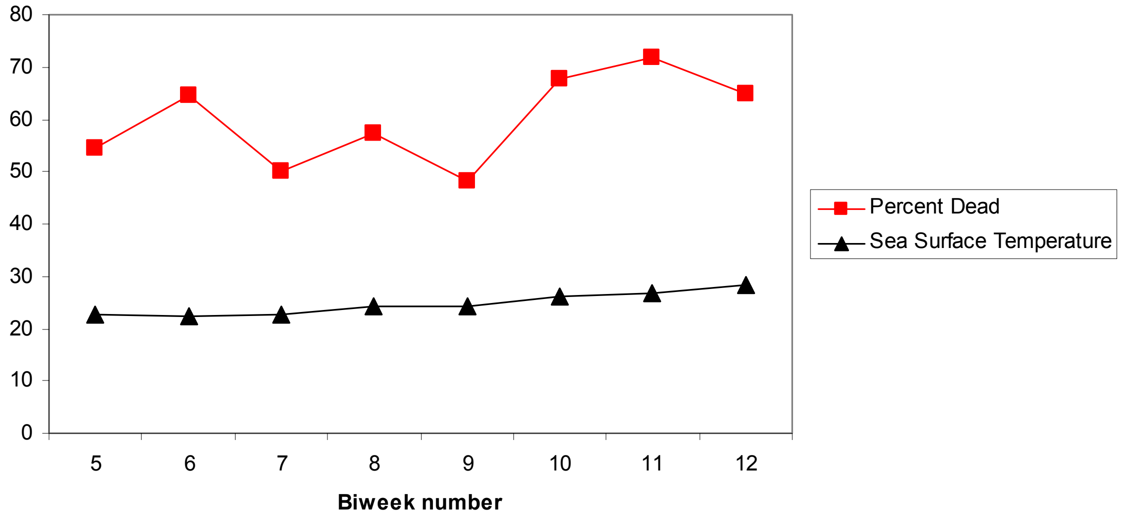



Figure 4. Percent dead (at boatside) and observed sea surface temperature (Celsius) for bluefin tuna observed in the Gulf of Mexico during bluefin spawning season 2007 and 2008. Biweek numbers 1, 2, 3, 4, and 13 not included because only one bluefin was caught during those periods.

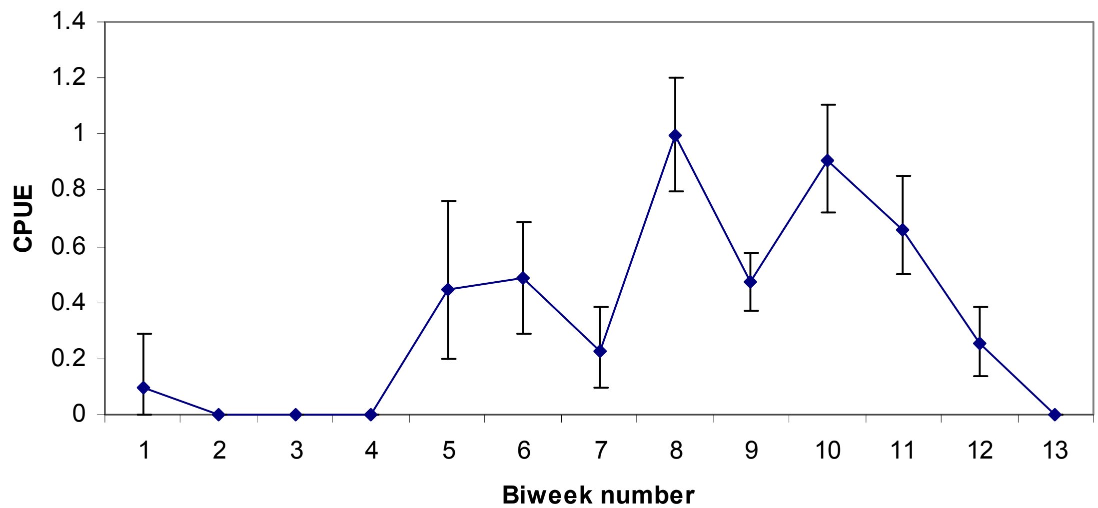



Figure 5. Bootstrapped estimates and 95 % confidence intervals for bluefin tuna catch per unit effort (catch per 1000 hooks) during biweekly periods January 1st through June 30th, 2007 and 2008 in the Gulf of Mexico.

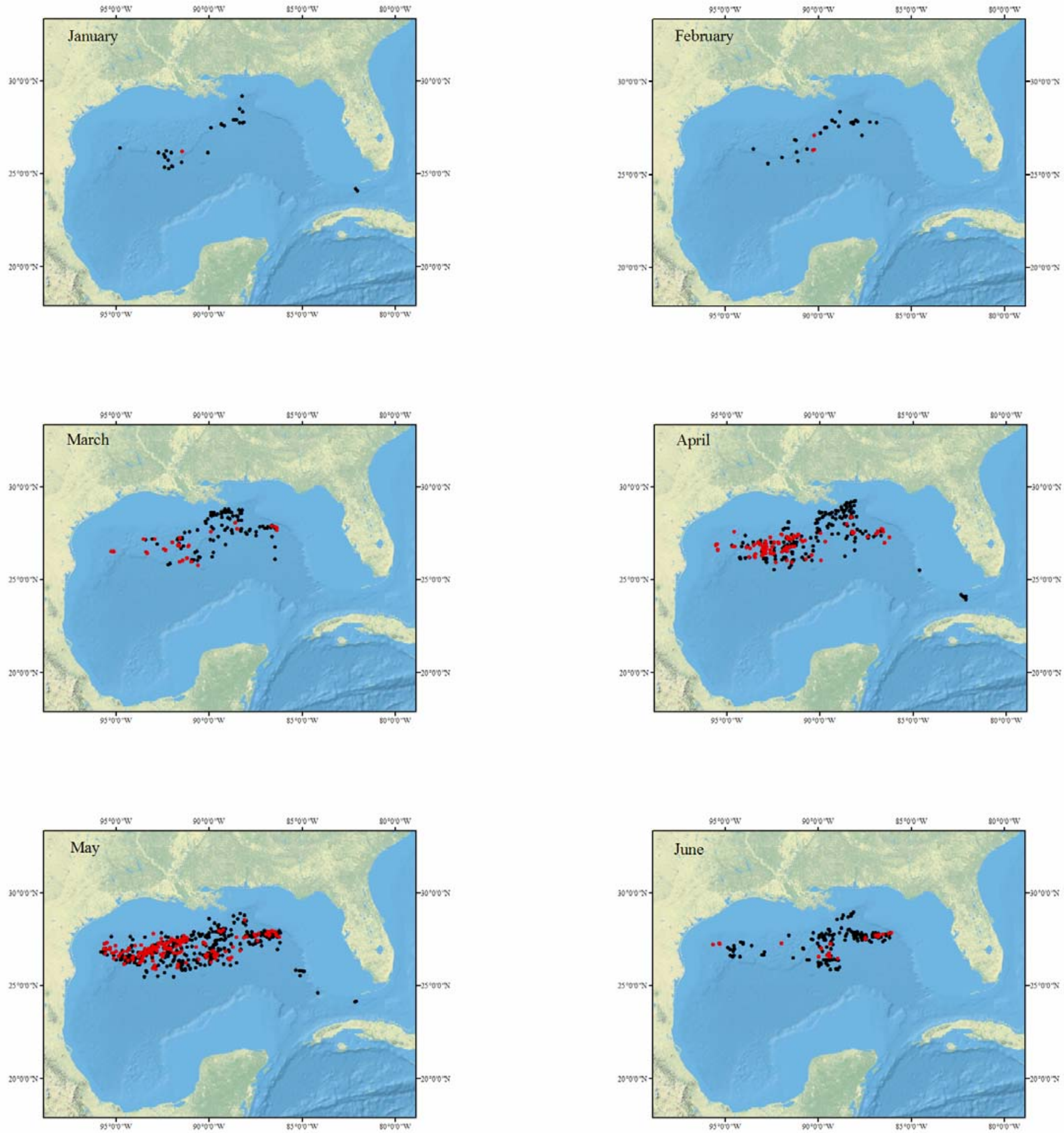



Figure 6. Observed haul locations (black) and bluefin tuna catch locations (red) January–June, 2007 and 2008.

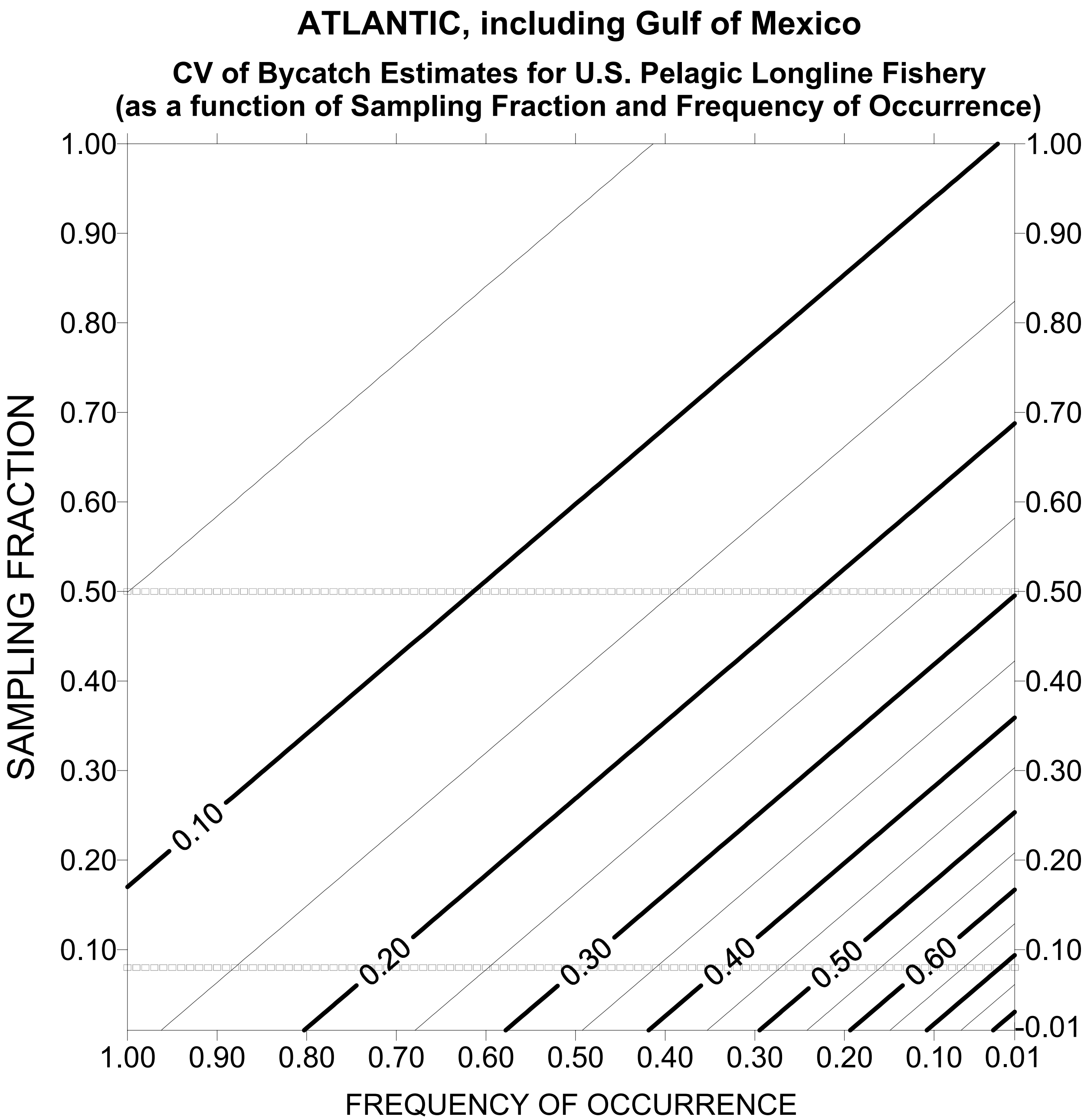



Figure 7. Contour plot showing the predicted coefficients of variation of bycatch estimates for the U.S. Atlantic pelagic longline fishery (including the Gulf of Mexico) as a function of sampling fraction (observed sets/total sets within a stratum) and frequency of occurrence (sets with bycatch of a particular species/total sets within a stratum). Horizontal gray lines indicate a typical 8% sampling level target and, for comparison, a 50% sampling level.

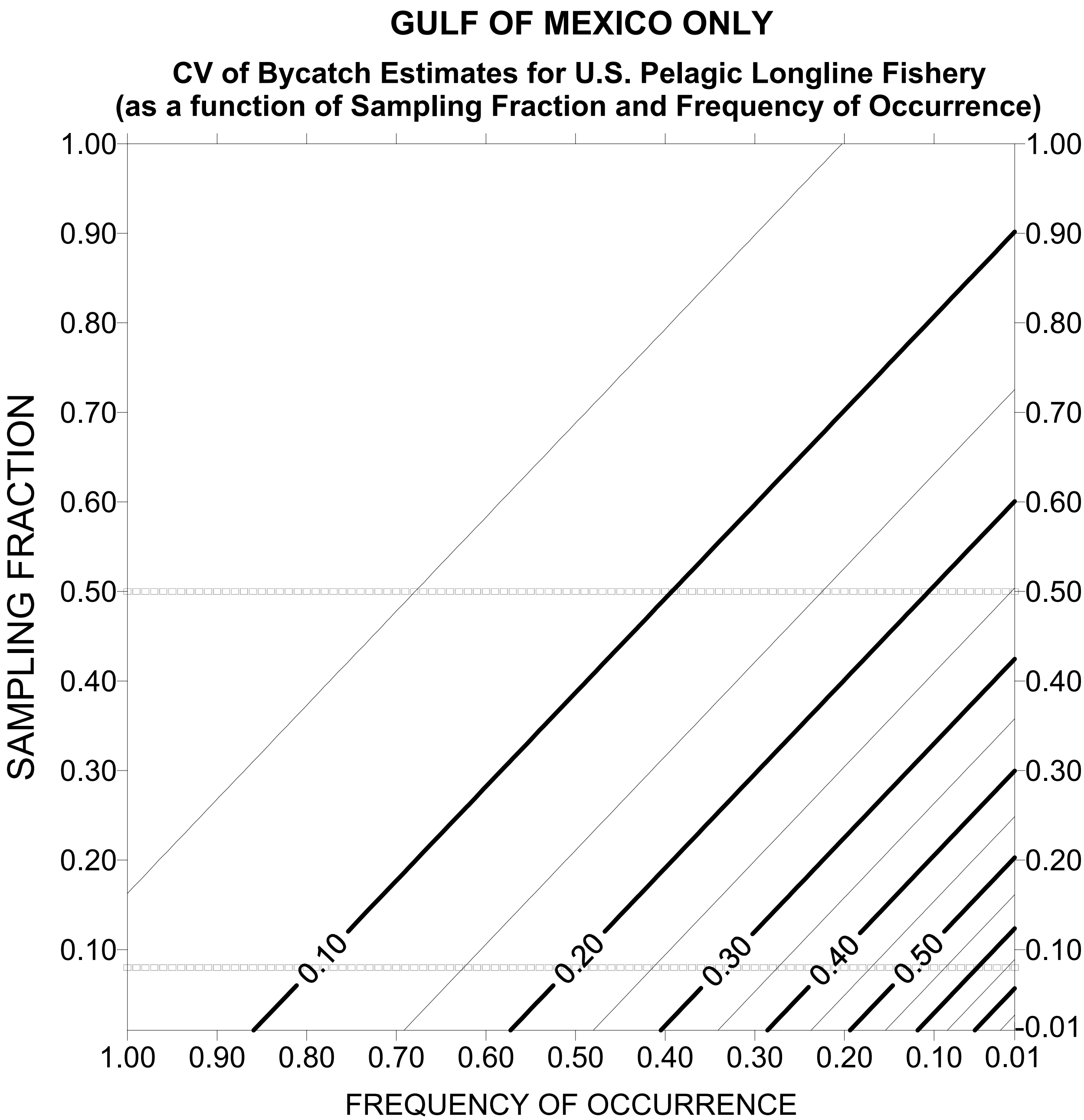



Figure 8. Contour plot showing the predicted coefficients of variation of bycatch estimates for the U.S. pelagic longline fishery in the Gulf of Mexico as a function of sampling fraction (observed sets/total sets within a stratum) and frequency of occurrence (sets with bycatch of a particular species/total sets within a stratum). Horizontal gray lines indicate a typical 8% sampling level target and, for comparison, a 50% sampling level.

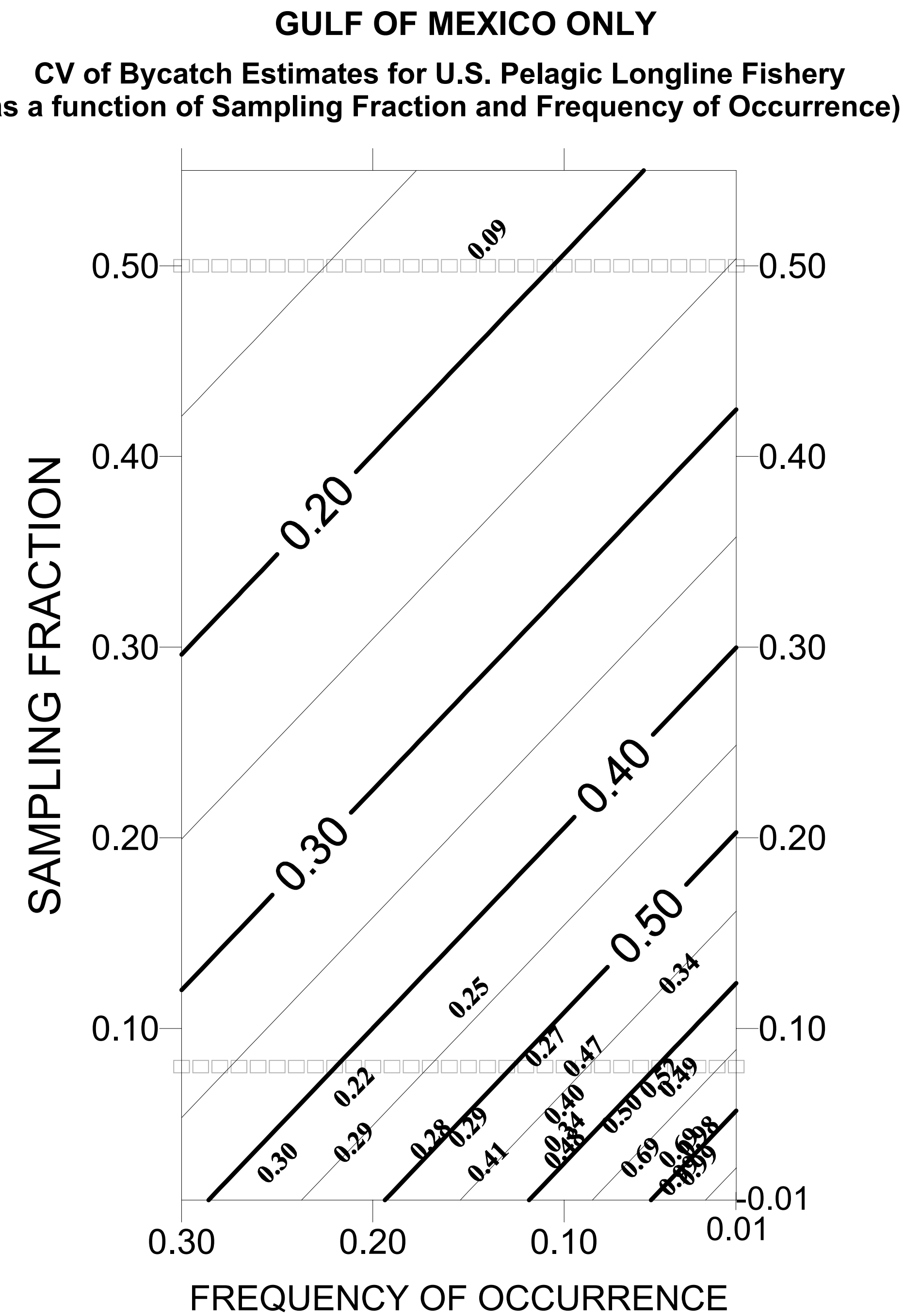



Figure 9. The coefficients of variation of individual stratum estimates of bluefin tuna dead discards are shown on the contour plot showing the predicted CVs of bycatch estimates for the U.S. pelagic longline fishery in the Gulf of Mexico as a function of sampling fraction (observed sets/total sets within a stratum) and frequency of occurrence (sets with bycatch of a particular species/total sets within a stratum). The plot is restricted to the actual range of estimates. Horizontal gray lines indicate a typical 8% sampling level target and, for comparison, a 50% sampling level.

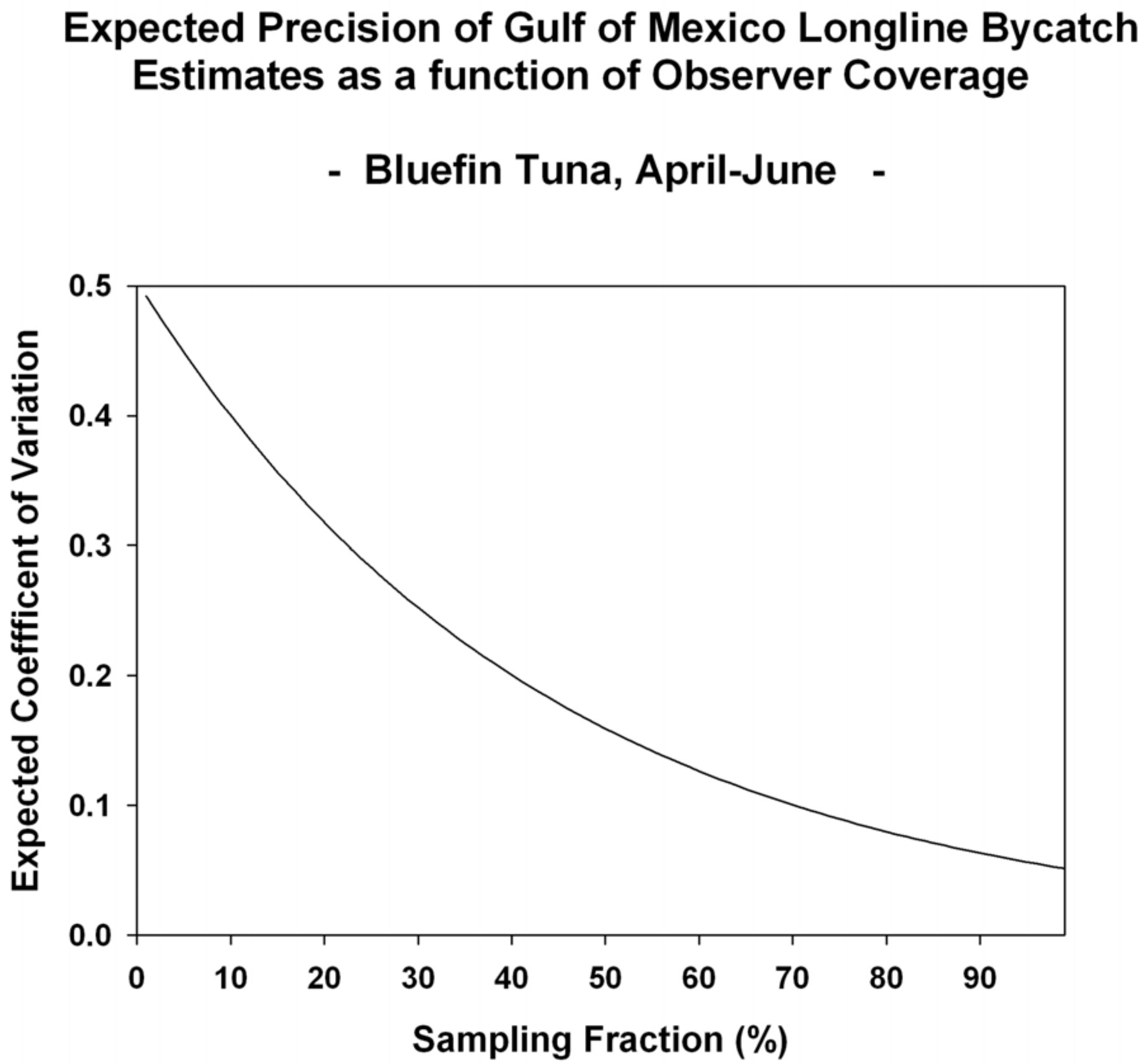



Figure 10: The predicted coefficients of variation of bycatch estimates for the U.S. Atlantic pelagic longline fishery in the Gulf of Mexico as a function of sampling fraction (percentage of total sets which are observed within a stratum) and a particular frequency of occurrence (percentage of sets within a stratum sets with bycatch of a particular species). The example shown is for bluefin tuna catch assuming the typical 20% frequency of occurrence on sets during April-June.

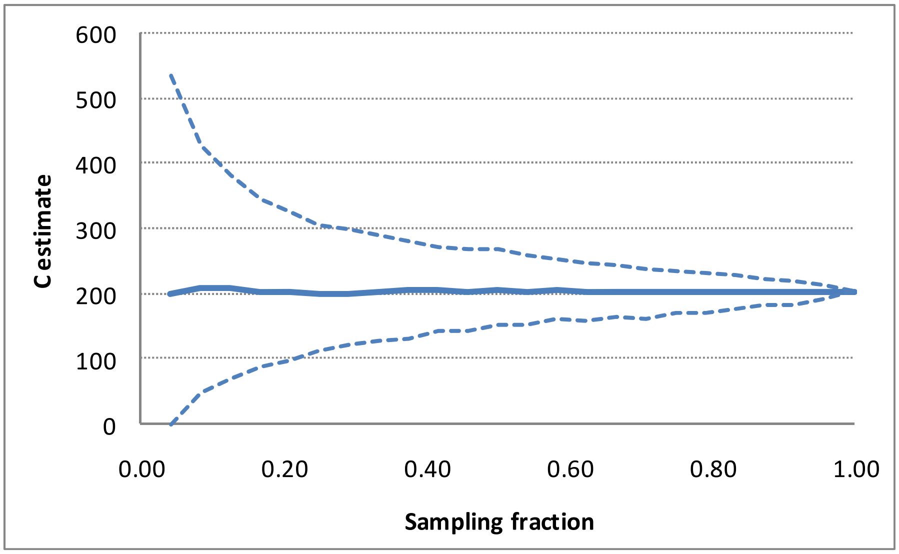


Figure 11. Precision of bluefin dead discard estimates for the second quarter of 2008, depending on observer coverage. The figure shows the mean of 1000 simulations and 95% confidence limits.

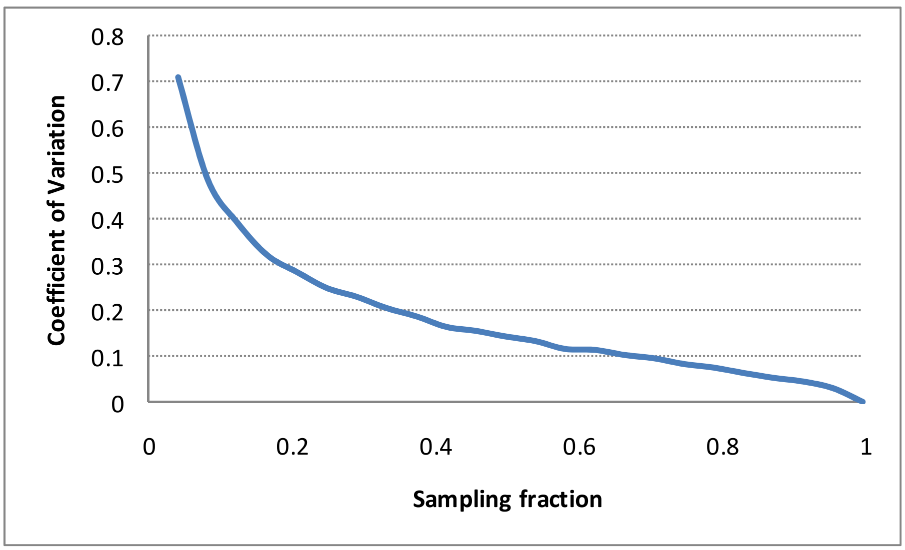
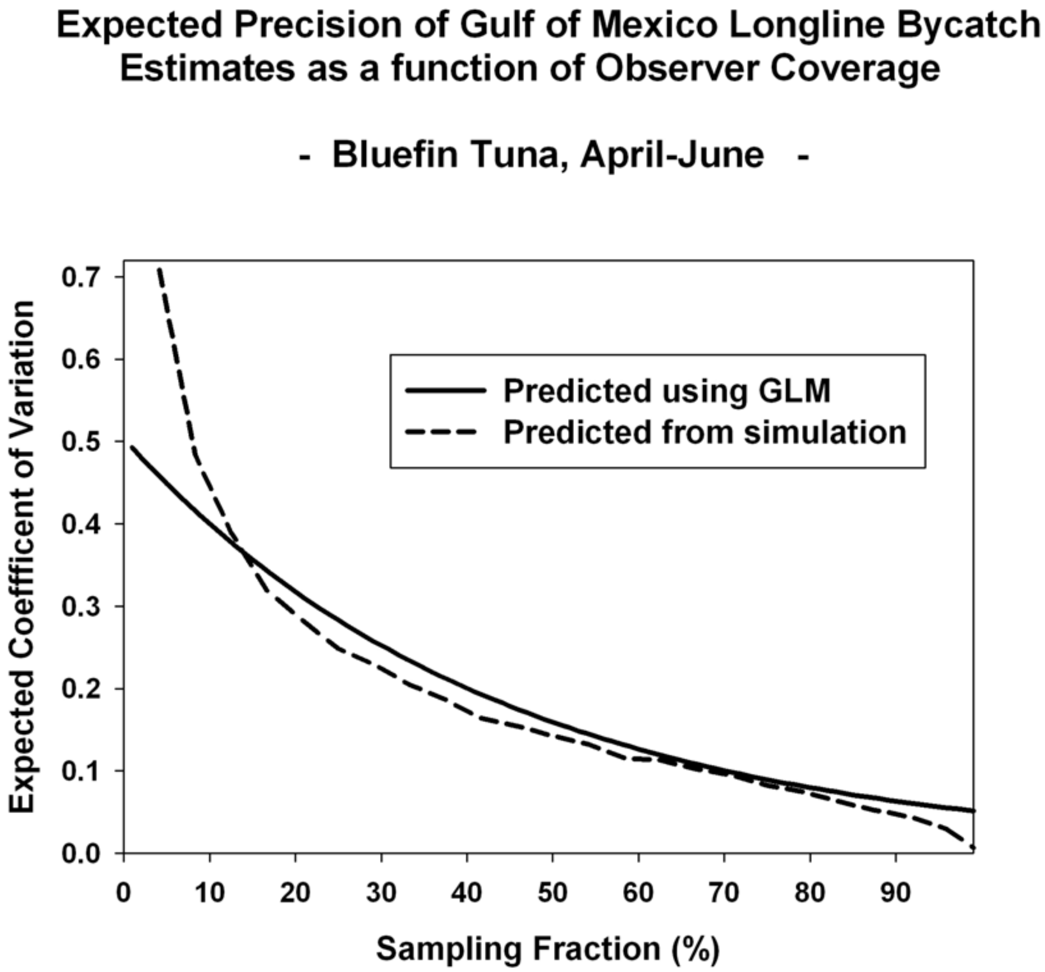



Figure 12. Coefficient of variation of the estimated number of dead discards for the second quarter of 2008, as a function of fraction of the trips covered.




Note: Sampling fraction refers to the percentage of sets made which were covered by the Pelagic Longline Observer Program. The GLM analysis assumes the typical 20% frequency of bluefin tuna occurrence on sets during April-June.

Figure 13. Comparison of the predicted coefficient of variation of the estimated number of bluefin tuna dead discards in the Gulf of Mexico for the second quarter of 2008, as a function of fraction of the trips covered, for two methods (GLM and simulation).

Table 1. Observed effort January - June, 2007 and 2008 in the Gulf of Mexico.

| Effort | 2007 | 2008 | Total |
|---|---|---|---|
| *Trips* | 59 | 75 | 134 |
| *Hauls* | 476 | 693 | 1,169 |
| *Hooks* | 353,555 | 523,168 | 876,723 |
| *Sea days* | 684 | 991 | 1,675 |

Table 2. Observed catch and disposition of market species in the Gulf of Mexico during January - June, 2007 and 2008.

| Species | Total | Kept | Released Alive | Discarded Dead | Lost |
|---|---|---|---|---|---|
| *Bluefin Tuna* | 511 | 79 | 117 | 282 | 33 |
| *Yellowfin Tuna* | 5,789 | 4,993 | 186 | 546 | 64 |
| *Swordfish* | 5,984 | 2,304 | 833 | 2,703 | 144 |
| *Bigeye Tuna* | 62 | 40 | 8 | 13 | 1 |
| *Escolar* | 1,485 | 1,198 | 84 | 111 | 92 |
| *Wahoo* | 364 | 316 | 1 | 43 | 4 |
| *Dolphinfish* | 2,702 | 2,407 | 59 | 139 | 97 |

Table 3. Summary size statistics for bluefin tuna observed in the Gulf of Mexico during January - June, 2007 and 2008.

| **Measurement** | ***n*** | **Mean** | **Minimum** | **Maximum** | ***SD*** |
|---|---|---|---|---|---|
| ***SFL (cm)*** Actual measurements only | 128 | 248.5 | 180 | 341 | 20.7 |
| ***SFL (cm)*** All measurements | 466 | 227.8 | 120 | 341 | 33.4 |
| ***Dressed weight (kg)*** | 78 | 224.1 | 122 | 399 | 53.8 |

Table 4. Bootstrapped estimates and 95 % confidence limits of observed bluefin tuna catch per 1000 hooks in the Gulf of Mexico, January - June, 2007 and 2008.

| | $\bar{x}$ | *LCI* | *UCI* |
|---|---|---|---|
| *2007 and 2008 summary data* | 0.5936 | 0.5314 | 0.6602 |
| *2007* | 0.4757 | 0.3930 | 0.5595 |
| *2008* | 0.6705 | 0.5807 | 0.7607 |

Table 5. Types of samples collected from bluefin tuna during observed trips in the Gulf of Mexico during January - June, 2007 and 2008.

| **Sample type** | **Number collected per fish** |
|---|---|
| *Otolith (sagittae)* | 2 |
| *Dorsal fin spine* | 1 |
| *Caudal Vertebrae (#35)* | 1 |
| *Skin subsample (preserved by freezing)* | 1 |
| *Muscle subsample (preserved by freezing)* | 1 |
| *Liver subsample (preserved by freezing)* | 1 |
| *Liver subsample* [1] *(preserved in formalin)* | 1 |
| *Whole gonad weight (pair)* | 1 |
| *Gonad subsamples (preserved in formalin)* | 6 |
| *Gonad subsample* [1] *(preserved by freezing)* | 1 |

[1] Only collected in 2008

Table 6: Analysis of variance results for the loglinear model $\log_e(CV) = b_0 + b_1 (PERCOV) + b_2 (PPC) + e$, where a finite population correction was used to calculate the coefficient of variation. The variable CV is the stratum-wise (year-area-quarter) coefficient of variation for the estimated bycatch for the species observed caught by U.S. pelagic longline vessels operating in the Atlantic during 1992-2007. The variable PPC represents the proportion of positive sets for each species category in the year-area-quarter strata. The variable PERCOV is the percent coverage per year-area-quarter, expressed as sets observed divided by sets reported in logbooks. In the analysis, the percent coverage and the proportion positive were treated as continuous variables to predict the CVs applying the Generalized Linear Model:

$$\log_e(CV) = b_0 + b_1(PERCOV) + b_2(PPC) + e$$

(*i.e.* natural log of finite population corrected coefficient of variation of the estimate =
intercept+sampling fraction +frequency of occurrence of species on sets +error)

The predicted CV was obtained by:

$$CV=EXP((INTERCEPT+(INTSE^2/2))+( PERCOV *(b_1+(PCSE^2/2)))+( PPC *( b_2+((PPSE^2)/2))))$$

## Results for the Atlantic fishery (including the Gulf of Mexico):

Number of observations = 5976
$R^2$ = 0.587

Parameters –

$b_1$ (sampling fraction PERCOV) = -2.111310102
$b_2$ (frequency of occurrence PPC) = -1.803416341
$b_0$ (INTERCEPT) = -0.140724248
standard error of intercept (INTSE) = 0.00739413
standard error of PERCOV (PCSE) = 0.05806582
standard error of PPC (PPSE) = 0.02108224

**Results for the Gulf of Mexico fishery only:**

Number of observations = 1985
$R^2$ = 0.688

Parameters –

$b_1$ (sampling fraction PERCOV) = -2.307379140
$b_2$ (frequency of occurrence PPC) = -2.419585374
$b_0$ (INTERCEPT) = -0.201783708
standard error of intercept (INTSE) = 0.01123868
standard error of PERCOV (PCSE) = 0.09020513
standard error of PPC (PPSE) = 0.03821461

Table 7. Observed data from 2008 used as the basis for the simulations. For each of 96 trips, the effort (number of sets) and catch (dead discards) are shown.

| *Trip* | No. Sets | Discards | *Trip* | No. Sets | Discards | *Trip* | No. Sets | Discards |
|---|---|---|---|---|---|---|---|---|
| *1* | 10 | 3 | *33* | 10 | 2 | *65* | 3 | 1 |
| *2* | 10 | 2 | *34* | 5 | 0 | *66* | 7 | 4 |
| *3* | 8 | 0 | *35* | 8 | 7 | *67* | 1 | 0 |
| *4* | 8 | 5 | *36* | 10 | 2 | *68* | 8 | 10 |
| *5* | 4 | 0 | *37* | 10 | 0 | *69* | 12 | 0 |
| *6* | 12 | 0 | *38* | 5 | 2 | *70* | 11 | 0 |
| *7* | 13 | 2 | *39* | 12 | 2 | *71* | 15 | 2 |
| *8* | 10 | 11 | *40* | 10 | 2 | *72* | 9 | 7 |
| *9* | 11 | 0 | *41* | 11 | 0 | *73* | 5 | 8 |
| *10* | 1 | 0 | *42* | 8 | 3 | *74* | 8 | 4 |
| *11* | 9 | 8 | *43* | 11 | 5 | *75* | 12 | 0 |
| *12* | 11 | 0 | *44* | 8 | 0 | *76* | 6 | 0 |
| *13* | 11 | 2 | *45* | 13 | 4 | *77* | 12 | 0 |
| *14* | 9 | 10 | *46* | 10 | 2 | *78* | 9 | 2 |
| *15* | 6 | 0 | *47* | 11 | 0 | *79* | 11 | 0 |
| *16* | 12 | 1 | *48* | 7 | 0 | *80* | 9 | 0 |
| *17* | 9 | 1 | *49* | 8 | 6 | *81* | 11 | 4 |
| *18* | 12 | 0 | *50* | 13 | 0 | *82* | 8 | 0 |
| *19* | 14 | 1 | *51* | 5 | 0 | *83* | 7 | 0 |
| *20* | 12 | 0 | *52* | 10 | 2 | *84* | 13 | 2 |
| *21* | 4 | 0 | *53* | 11 | 2 | *85* | 6 | 0 |
| *22* | 10 | 3 | *54* | 11 | 0 | *86* | 10 | 0 |
| *23* | 9 | 6 | *55* | 10 | 4 | *87* | 3 | 2 |
| *24* | 4 | 2 | *56* | 8 | 3 | *88* | 7 | 6 |
| *25* | 11 | 0 | *57* | 10 | 0 | *89* | 11 | 7 |
| *26* | 9 | 0 | *58* | 6 | 0 | *90* | 10 | 0 |
| *27* | 9 | 0 | *59* | 10 | 3 | *91* | 13 | 3 |
| *28* | 6 | 0 | *60* | 6 | 0 | *92* | 9 | 0 |
| *29* | 2 | 0 | *61* | 9 | 5 | *93* | 9 | 3 |
| *30* | 8 | 15 | *62* | 1 | 0 | *94* | 9 | 1 |
| *31* | 2 | 0 | *63* | 4 | 0 | *95* | 11 | 2 |
| *32* | 11 | 2 | *64* | 10 | 0 | *96* | 10 | 6 |

Table 8. Results of the simulations of sampling coverage using 2008 observer data. For a given number of trips or sampling fraction, the table shows the mean, variance, coefficient of variation, and upper/lower 95% confidence limits of the estimate of dead discards.

| No. Trips | Fraction | Mean | Variance | CV | Lower CL | Upper CL |
|---|---|---|---|---|---|---|
| *4* | 0.04 | 201.3 | 20309.0 | 0.71 | 0.0 | 533.9 |
| *8* | 0.08 | 208.9 | 10228.8 | 0.48 | 48.2 | 427.8 |
| *12* | 0.13 | 208.8 | 6633.2 | 0.39 | 69.6 | 382.4 |
| *16* | 0.17 | 203.8 | 4239.0 | 0.32 | 88.4 | 345.1 |
| *20* | 0.21 | 204.8 | 3356.1 | 0.28 | 98.9 | 325.6 |
| *24* | 0.25 | 202.5 | 2526.4 | 0.25 | 113.7 | 305.2 |
| *28* | 0.29 | 202.4 | 2148.6 | 0.23 | 120.4 | 299.8 |
| *32* | 0.33 | 203.7 | 1736.4 | 0.20 | 128.3 | 289.6 |
| *36* | 0.38 | 205.1 | 1464.1 | 0.19 | 132.2 | 281.0 |
| *40* | 0.42 | 205.2 | 1127.0 | 0.16 | 141.7 | 272.6 |
| *44* | 0.46 | 204.3 | 998.9 | 0.15 | 142.1 | 267.2 |
| *48* | 0.50 | 207.0 | 870.0 | 0.14 | 151.4 | 267.6 |
| *52* | 0.54 | 204.9 | 736.3 | 0.13 | 153.6 | 258.8 |
| *56* | 0.58 | 205.8 | 563.9 | 0.12 | 161.0 | 253.3 |
| *60* | 0.63 | 204.2 | 534.8 | 0.11 | 157.3 | 246.1 |
| *64* | 0.67 | 203.9 | 433.4 | 0.10 | 163.6 | 244.6 |
| *68* | 0.71 | 202.9 | 369.5 | 0.09 | 162.7 | 236.9 |
| *72* | 0.75 | 204.3 | 282.4 | 0.08 | 170.4 | 235.1 |
| *76* | 0.79 | 203.8 | 230.0 | 0.07 | 171.9 | 231.5 |
| *80* | 0.83 | 203.9 | 164.1 | 0.06 | 176.5 | 227.5 |
| *84* | 0.88 | 204.6 | 114.8 | 0.05 | 182.2 | 222.5 |
| *88* | 0.92 | 203.8 | 80.9 | 0.04 | 183.6 | 217.8 |
| *92* | 0.96 | 204.2 | 36.9 | 0.03 | 190.8 | 213.1 |
| *96* | 1.00 | 204.0 | 0.0 | 0.00 | 204.0 | 204.0 |

Appendix 1.

# National Marine Fisheries Service
## Fact Sheet

## Mandatory Observer Coverage for all Pelagic Longline Vessels Fishing the Gulf of Mexico from March 9 - June 9, 2008

**Why is National Marine Fisheries Service (NMFS) increasing observer coverage for pelagic longline vessels in the Gulf of Mexico to 100% during this time period?** NMFS is increasing observer coverage to collect biological data on Atlantic bluefin tuna that may be caught incidentally in directed longline fishing for yellowfin tuna and swordfish. Bluefin tuna are valuable and highly exploited in international fisheries, and effective management relies on good quality data about the biology of the species and fisheries that harvest it. The International Commission for the Conservation of Atlantic Tunas (ICCAT) is responsible for the management of Atlantic bluefin tuna stocks, and implemented a rebuilding plan in 1982. In November 2006 and 2007, ICCAT scientists noted concerns about continuing declines of catches and catch rates for the western Atlantic bluefin tuna stock. The Gulf of Mexico is considered the primary spawning grounds for the western stock of Atlantic bluefin tuna, and most spawning is believed to occur between April and June. Atlantic bluefin tuna also spawn in the Mediterranean Sea. Scientific evidence suggests mixing between the two stocks. NMFS is expanding observer coverage to help scientists better understand bluefin tuna stock structure, biology and behavior, and assist in the rebuilding of this valuable resource.

The pelagic longline fishery catches bluefin tuna in this area as bycatch while fishing for swordfish or other tunas. Observers will collect biological information such as ear bones used to determine age, muscle tissue, and sex organs from harvested bluefin tuna or dead discards. This will provide critical data for scientists performing stock identification and stock structure analyses. The increase in observer coverage also will supplement scientific research on the bycatch of protected and prohibited species, in the pelagic longline fishery, and the effectiveness of circle hooks in reducing bycatch. Observer coverage will also provide data on the effectiveness of management actions to reduce bycatch of sea turtles (especially loggerhead and leatherback) in longline fishing gear, and to reduce the bycatch of billfishes.

**Are there any exceptions to the mandatory observer coverage?** The ONLY exception to mandatory observer coverage for pelagic longline fishing trips is the unavailability of an observer. If an observer is unavailable, NMFS will provide a written waiver for that trip only. Vessels may not fish for or retain any Atlantic highly migratory species (HMS, including billfish, swordfish, tuna, and sharks) unless the NMFS assigned-observer, or any written waiver issued by NMFS, is on board. Vessels that are required to carry an observer, but are inadequate or unsafe for the purpose of carrying an observer (e.g., no valid safety decal) or for allowing operation of normal observer functions (e.g., no berth), are prohibited from fishing per 50 Code of Federal Regulations (CFR) 600.746(f).

Appendix 1 (continued).

**If I am making a trip using pelagic longline gear in the Gulf of Mexico between March 9 and June 9, 2008, how do I arrange to carry an observer?** You must contact the Pelagic Observer Program at the NMFS Southeast Fisheries Science Center (SEFSC) Miami Laboratory in writing (mail or FAX) ***at least five business days*** prior to your departure, and provide the following information: (1) departure information including port, dock, date, and time; and (2) expected landing information, including port, dock, and date. Contact: Larry Beerkircher or Sascha Cushner, NMFS SEFSC, 75 Virginia Beach Drive, Miami, Florida, 33149; FAX 305-361-4282; PHONE 1-800-858-0624.

**If I have vessel permits that allow the use of pelagic longline gear, but plan to fish with other gear types between March 9 and June 9, 2008, must I still contact the NMFS Pelagic Observer Program prior to a non- pelagic longline trip?** Yes, you must still contact the NMFS Pelagic Observer Program in writing five business days prior to departure, even if you are not fishing with pelagic longline gear.

**What does NMFS consider the Gulf of Mexico?** West of 82 degrees W longitude and north of 22 degrees N latitude is considered the Gulf of Mexico.

**If my vessel began a fishing trip prior to March 9, 2008, must I return to port to pick up an observer for the rest of the trip**? No, you may continue your fishing trip without an observer. However, you must carry an observer if you return to port and start another fishing trip prior to June 9, 2008.

**When carrying an observer, must my vessel meet any special requirements (e.g. safety equipment)?** Yes, your vessel must meet safety requirements for commercial vessels and those specified under NMFS regulations for the observer program (50 CFR 600.746). In addition, please note that observers may be either male or female. For additional information on requirements for carrying observers, please contact the NMFS Pelagic Observer Program at 1-800-858-0624.

**What is the Pelagic Observer Program?** The NMFS Pelagic Observer Program collects catch and effort data for the U.S. Atlantic pelagic longline fleet fishing for swordfish and tunas. This information provides NMFS, university, and international scientists with information on the biology and sustainability of the sampled stocks, and is used by fishery managers to ensure the health of the marine ecosystem. Further information about the Pelagic Observer Program can be found at http://www.sefsc.noaa.gov/pop.jsp.

**Do NMFS regulations authorize the use of observers for the pelagic longline fishery?** Observer coverage for Atlantic HMS fisheries is addressed in the CFR at 50 CFR 635.7. Observer coverage for domestic fisheries is addressed in general at 50 CFR 600.746. You can access these regulations at the following website: http://www.gpoaccess.gov/cfr/index.html.

**How can I find out more about management of HMS fisheries?** You can access HMS fishery management information from the NMFS website at the following address: http://www.nmfs.noaa.gov/sfa/hms/. You can also receive email informational messages about current HMS fishery management issues by signing up for Atlantic HMS News at: http://www.nmfs.noaa.gov/sfa/hms/newslist/. For information regarding management of bluefin tuna, contact Sarah McLaughlin at 978/281-9260.