PACIFIC ISLANDS FISHERIES SCIENCE CENTER

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August 2011

Administrative Report H-11-04

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INTRODUCTION

The Hawaii bottomfish fishery operates in deep-slope habitats at depths ranging from 100 to 400 meters on banks and along the margins of islands within the Hawaiian Archipelago. The fishery has been managed by regulating harvests in three bottomfish management zones: the main Hawaiian Islands (MHI) Zone in the southern part of the archipelago and the Ho'omalu and Mau Zones in the Northwestern Hawaiian Islands (NWHI) (Fig. 1). The fishery uses deepwater handline gear (baited hook-and-line) to target eteline snappers, carangids, and grouper. The commercial bottomfish fishery in the NWHI, consisting of eight permitted vessels in 2007 and 2008 and six in 2009 (DLNR, 2010), was permanently closed June 15, 2011 under ecosystem protection provisions of the Papahānaumokuākea Marine National Monument, established in the NWHI in 2006.

The bottomfish fishery continues to operate in the MHI in both State of Hawaii waters (0–3 nm offshore) and federal waters within the U.S. Exclusive Economic Zone (3–200 nm) under the Bottomfish Fishery Management Plan for Hawaii established by the Western Pacific Regional Fishery Management Council (WPRFMC). The MHI commercial fleet consisted of 170 registered vessels in 2009 (HDAR, 2010). Fourteen species captured in the fishery, found in both the MHI and NWHI, are recognized as bottomfish management unit species (BMUS) (Table 1). In Honolulu, Hawaii, ten of the BMUS are commonly sold on the United Fishing Agency (UFA) auction floor amongst other locations, and are available for biological sampling on location. Seven of the BMUS (six eteline snappers and one grouper) are referred to as the Deep 7 bottomfish, which are specifically targeted by the fishery because of their high market value. Catch levels of the Deep 7 species are regulated in the MHI by a 'Total Allowable Catch' (TAC) determined annually since 2007 by the WPRFMC and implemented by the National Marine Fisheries Service (NMFS). If the MHI commercial Deep 7 catch reaches the TAC during the September 1–August 31 fishing year, all fishing for Deep 7 species in the MHI must cease until the next fishing season begins. The most current stock assessment of MHI Deep 7 bottomfish by the Pacific Islands Fisheries Science Center (PIFSC) indicates that in 2010 the stock was not overfished and overfishing was not occurring (Brodziak et al., 2011); however, excess fishing mortality of MHI Deep 7 bottomfish occurred during most of the 1980s and 1990s. Uncertainties in stock assessment have been associated with difficulties in measuring fishing effort, lack of data on noncommercial catch, changes in fishing methods and fishing power, and shifts in target species. Another important factor is lack of species-specific biological information, particularly species-specific size composition. Until late 2007, biological data on recent bottomfish catch had not been regularly collected. These data are essential for estimating important life history parameters such as age, recruitment, size at sexual maturity, and mortality rates; many of the targeted species are thought to possess life history traits that make them especially susceptible to overfishing such as slow growth, late maturation, long life, and considerable variation in larval survival (Haight et al., 1993).

In order to acquire important biological information on the catch, PIFSC implemented a sampling program at the Honolulu-based United Fishing Agency (UFA) fish auction in October 2007. The UFA provided a reliable way to collect length, weight, and other biological data at a much lower cost than alternative approaches, such as an at-sea observer program. Although the focus of the UFA sampling program was bottomfish, attention was also given to sampling pelagic species (Table 2) when bottomfish were absent from the auction floor because of fishery closures or unfavorable bottomfish fishing conditions. The majority of pelagic species sampled were caught in the Hawaii-based longline fishery that targets tuna and swordfish. This report describes the species-specific length frequency sampling from October 2007 to December 2009 and presents estimates of size composition and length-weight relationships for bottomfish and pelagic fish species.

METHODS

The UFA fish auction is the largest of its kind in the United States. It is modeled after the traditional Japanese-style fish auction and was established in 1952; it has been a thriving entity ever since. Anywhere from 5000 to in excess of 120,000 pounds of fish move through the auction six days a week.

In October 2007, the Life History Program of the PIFSC Fisheries Biology and Stock Assessment Branch assigned two Fisheries Associates, employed by the University of Hawaii Joint Institute for Marine and Atmospheric Research (JIMAR) to sample bottomfish brought to the UFA fish auction. Length-weight frequency data were collected from a multitude of bottomfish species, however, BMUS, particularly the Deep 7 species (Table 1), were the focus of UFA sampling. Permission to perform sampling procedures was granted by managerial staff of the UFA fish auction prior to the project's commencement. Fish buyers inquiring about the presence of JIMAR staff were informed of the sampling procedures and purpose. The main objective of sampling was to collect species-specific length and weight data of accessible bottomfish sold at the auction. During the bottomfish fishery closure in the summer of 2008 and whenever bottomfish were not present, sampling efforts shifted to pelagic fish species prioritized by the PIFSC Stock Assessment Program (Table 2). Considerable attention was directed at sampling a key pelagic species, the opah (*Lampris* spp.), after a buyer, Garret Kitazaki of Diamond Head Seafood Company, pointed out that the catch consisted of two types of opah differing in appearance. These morphotypes were later confirmed to be two distinct species (Underkoffler et al., PIFSC, unpublished data). For this report, the two *Lampris* species are referred to as the bigeye opah and smalleye opah.

When first brought to the auction, bottomfish originating from Oahu were stored in a chill room in large plastic bins filled with ice. If bottomfish were flown in from other islands, they were kept in the shipping containers they arrived in until the weighing process began. Fish landed in the NWHI were off-loaded from their respective vessel, placed into large metal carts, and transported to the rear loading dock of the auction house. Calling the UFA hotline was an effective way to determine whether or not sampling on a particular day would be worthwhile. A recording, updated twice daily, notified buyers and the public of how many pounds of fish and the number of bottomfish that would be up for sale for that morning's auction. Bottomfish species were sold individually or grouped into lots consisting of multiple individuals of the same size (Ralston et al., 1986). Individual bottomfish and lots were weighed to the nearest half pound by UFA staff. The fish were then arranged onto large pallets and were either moved directly onto the auction floor or to the chill room temporarily for storage.

Individual fish sold at the UFA fish auction were assigned a barcode that served as the fish's unique identifier; a tag printed with this barcode was placed onto the fish. When fish were sold in lots, one fish in the lot was labeled with the barcode tag and the position of all fish included in that lot delineated which ones would be sold together. Other information was included on the tag, including the species, name of the vessel that brought in the catch, the weight of the fish, the number of fish in the lot (frequently a single fish), the date the fish were brought into the auction, and additional remarks about the fish such as their condition (gilled, gutted, gaffed, cookie cutter bites, etc.). Use of the barcoding system began in early 2009; prior to 2009, UFA staff handwrote this information. Barcodes assisted UFA personnel in tracking the disposition of the fish throughout the extent of the auction.

Initial data logged by NMFS were taken from information recorded on the tags applied by UFA staff (i.e., species, weight, vessel). Additional information such as fork length or total length, sex (in sexually dimorphic species), and weight measured by NMFS (during the first year of sampling when possible) to the nearest 0.01 kg was also recorded on a data collection sheet (Table 3).

Samplers could usually obtain a piece of information from all available fish of interest, but on days when bottomfish were plentiful, data were collected from a subsample of fish. In these circumstances, pallets that held the most accessible, individually weighed fish were sampled. If most of the fish were grouped into lots or buried under ice, measurements were taken from every third pallet. A fork length or total length was obtained from each fish positioned on the chosen pallet. If there were fish landed by numerous vessels, samplers would attempt to measure one pallet of fish originating from each vessel.

During the initial sampling period, fish lengths were measured to the nearest 0.1 cm using a 102-cm, straight-edge tree caliper, and fish were weighed with an electronic bench scale (referred to as NMFS weights). Because of the fast-paced nature of the auction, the method of obtaining individual weights for each bottomfish before it was placed onto a pallet proved to be inefficient. The weighing scale and calipers used for length measurements were too cumbersome and would often obstruct pallet movement onto the auction floor. In November 2008, to minimize interference with auction operations, measurement protocols were tailored to better fit the circumstances. Collection of NMFS independent fish weights ended and length measurements were obtained less obtrusively with a fabric measuring tape. Fork length (FL) or total length (TL) was recorded for fish sampled; both lengths were measured to the nearest 0.5 cm.

Length measurements followed the protocols described by Hubbs and Lagler (1947). For snappers of the Deep 7 and the five pelagic species sampled, measurements were taken from the tip of the lower jaw to the fork of the tail, and for hapu'upu'u, from the tip of the lower jaw to the center of the terminal end of the caudal fin. All measurements were taken in a straight line.

Length-weight relationships for five bottomfish species and five pelagic species were analyzed using a linear regression of log-transformed data. Length-weight relationships were fit with an allometric equation that expresses weight as a function of length:

$$W = A \cdot L^B \quad (1)$$

where W = weight, L = length, and A and B are parameters to be determined with the available length-weight data (Hayes et al., 1995). The coefficients A and B (Table 4) were found by log-transforming the length and weight measurements to linearize the exponential relationship as computed by Hayes et al. (1995) and Brodziak (pers. comm.):

$$\log W = \log A + B \cdot \log L = b0 + b1 \cdot \log L \quad (2)$$

The data were then fitted using simple linear regression to obtain estimates of the intercept parameter (b0) and the slope parameter (b1). These parameter estimates were used to determine coefficients A and B (Hayes et al., 1995). In particular, the estimate of B for the original allometric equation is:

$$B = b1 \quad (3)$$

and the estimate of A is:

$$A = \exp(b0)\exp\left(\frac{\sigma^2}{2}\right) \quad (4)$$

where σ^2 is the residual variance of the regression fit.

RESULTS AND DISCUSSION

Bottomfish Species

The auction sampling provided extensive data on the length composition of bottomfish landings (Figs. 2-20). A wide range of lengths were recorded for most bottomfish species sampled; however, the sample frequency was low at lengths near the minimum and maximum values. Because the bottomfish fishery is a targeted fishery, mid-range lengths were most common. There was a significant lack of data collected during the summer months, particularly during July–September. In 2007, sampling began in October, and for the 2007–2008 and 2008–2009 fishing years, the TAC was prematurely met (Federal Register, 2008 and 2009). Each year of sampling at the UFA fish auction revealed October through December to be the months of greatest bottomfish landings (Figs. 2–5, 9–20) for all species except hapu'upu'u (Figs. 6–8).

With 1461 individual fork lengths recorded, and 5090 fish sampled to some extent, opakapaka was the Deep 7 species most frequently seen at the auction (Table 1; Figs. 13–16, 21). Ehu, onaga, and uku were also regularly available and subsequently sampled during months of active fishing (Figs. 2–5, 9–12, 17–20). Auction-sampled bottomfish from the MHI greatly outnumbered fish from the NWHI for all species except hapu'upu'u (Table 4; Figs. 2–20); this most likely reflects the sizeable difference in permits allocated to MHI fishermen vs. NWHI fishermen. Uku is the only fish with a relatively equivalent sample size from both the MHI and NWHI (Table 4); this is most likely an outcome of its availability year-round and the shallower depths it inhabits. The total numbers of gindai, lehi, and kalekale sampled from each zone were too few to draw a comparison between the MHI and the NWHI (Fig. 21).

Sampling effort at the UFA fish auction increased annually for bottomfish and pelagic species. There were 12 sampling days in 2007, 30 days in 2008, and 68 in 2009. With increased sampling effort in 2009, the greatest amount of fish data was acquired; however, it would be difficult to evaluate length frequency trends for bottomfish over time because the number of visits to the auction varied by year, and sampling effort was affected by TAC closures and the time of year samples were taken. In 2007, species, vessel and weight data were collected from 892 individually weighed fish from the Deep 7 group along with 64 uku. In 2008, 377 individually weighed Deep 7 bottomfish and 123 uku were sampled and in 2009, 2440 individually weighed Deep 7 species and 491 uku were sampled. The number of specimens sampled originating from the MHI was significantly higher than the number from the NWHI for all Deep 7 species except hapu'upu'u.

No gonads were collected, so sex composition was unknown for all bottomfish species sampled at the UFA.

Upon first analysis of the bottomfish data, samples of the Deep 7 bottomfish species appeared to exhibit a wide range of lengths for the one-pound weight brackets. This was found to be a result of the fact that the lowest weight increment produced by the barcode-generating computer is one pound, so anything less is rounded to 1.0. Consequently, fish less than one pound were labeled as one-pound even though some bottomfish were actually less than one pound. UFA staff indicated these occurrences by writing a "less than" sign (<) on the barcode tag, and JIMAR associates collecting auction data made a note of these cases in the comments section of the data collection form. The greatest occurrence of a wide range of lengths being recorded in the one-pound weight bracket was observed in ehu. Size-frequency data for fish less than 30 cm and/or 1.0 pound were infrequent or absent from all bottomfish species except ehu. Fish less than one pound were omitted from the log-transformed data used to estimate weight-on-length relationships because it was uncertain what the actual weight of the fish was, 1.0 or 0.5 pounds. An unexplainable occurrence of a wide range of lengths seen in the one-pound weight bracket still remains for ehu. Onaga and opakapaka exhibit this tendency to some extent. Questionable data points were double-checked for accuracy and each was transposed correctly. There was no indication in the comments section that the weights were less than one pound so it is assumed that each fish recorded as one pound was one pound.

Analysis of Covariance (ANCOVA; proc GLM in PC SAS v. 9.1.3; SAS Institute, Inc., 2006) was used to evaluate the possible effect of collection area (MHI and NWHI) on weight-at-length relationships for the Deep 7 bottomfish species. Log-transformed round weight (in grams) and length (cm) data were examined for 5 of the Deep 7 species (ehu, hapu'upu'u, onaga, opakapaka, and uku). First, the slopes of comparable weight-at-length regressions (MHI vs. NWHI) were evaluated; if slopes were indistinguishable, the intercepts (levels) of the regressions were re-evaluated using a pooled (common) slope. A significance level of $P = 0.05$ was used.

The null hypothesis was accepted for all five Deep 7 species analyzed except for opakapaka (reject null hypothesis of slopes equal at $P = 0.0014$; intercept: test n/a) (Table 5). Weight-at-length relationships thus differed between the MHI and NWHI for opakapaka, and separate weight-length relationships were fitted for the MHI and NWHI (Figs. 22–23). For each of the remaining 4 species, intercepts of the pooled-slope regressions were then tested for equality. Intercepts for hapu'upu'u, onaga, and uku were indistinguishable (all $P \geq 0.067$; Table 5) and a single regression line for each of these species was estimated to describe weight-at-length for pooled MHI and NWHI fish (Figs. 24–25, 28). Regression intercepts for ehu differed between areas ($P = 0.047$) however; so separate regressions were described for ehu from the MHI and NWHI (Figs. 26–27).

Our length-weight regressions for bottomfish may have been affected by the large differences in sample size between the MHI and NWHI for all species except uku (Table 4). Further investigation of archival length-weight data obtained from specimens collected from the NWHI and MHI might provide useful complements to our UFA data. These historical data might be integrated with the UFA data to determine if the low sample sizes we have used for some species-areas have affected the conclusions of this report.

Again, there was a sizeable difference in sample size between the NWHI and MHI and the mean fork length was greater for fish originating from the NWHI in all bottomfish species sampled (Fig. 29). For the NWHI, minimum and maximum length ranges sampled at the UFA fish auction were not comparable to those for fish recorded at handline stations during cruises aboard the NOAA Ship *Townsend Cromwell* from 1977 to 1993 (Uchiyama and Kazama, 2003). Uchiyama and Kazama published maximum lengths of Deep 7 species that exceeded the maximum lengths observed at the UFA except for opakapaka and onaga. The maximum fork length measured at the auction was 4.6 cm longer for opakapaka and 0.5 cm longer for onaga than the lengths reported for these species by Uchiyama and Kazama (2003). The shortest fish lengths recorded at the

UFA were longer than the shortest fish lengths documented by Uchiyama and Kazama (2003).

At the auction, the time available to subsample fish before they are sold is limited, making it difficult to adequately sample the landings of vessels off-loading thousands of pounds of fish. Fishing effort in the MHI was practically nonexistent during the summer months because of TAC closures; uku landings also decreased significantly. Sampled onaga caught in the MHI greatly outnumbered those from the NWHI each quarter (Figs. 9–12); it is possible that the fishermen fishing in the NWHI did not specialize in the techniques used to catch onaga. The opposite was observed for hapu'upu'u (Figs. 6–8). Whether this is an indicator of specific targeting of hapu'upu'u or greater availability of this species in the NWHI has not been determined. The majority of the sample length frequency data from the NWHI came from one or two fishing trips. Because of the closure of the NWHI fishery, further analysis of bottomfish size composition in the NWHI will have to rely on archived data unless additional data are collected during future research expeditions to characterize and monitor the NWHI ecosystem.

Pelagic Species

During the 2007–08 fishing year, fishing for Deep 7 bottomfish species was prohibited in federal waters from May 1 through August 31, 2008 but the fishery did not reopen until November 15, 2008 (Federal Register, 2008). During this closure, auction sampling shifted to pelagic species. Data from pelagic species were also collected when the TAC was reached during the 2008-09 fishing year (Federal Register, 2009) and Deep 7 species were absent from the auction floor July 6 to September 1, 2009.

Sampling focused on four pelagic species caught by the longline fishery: opah (*Lampris* spp.), sickle pomfret (*Taractichthys steindachneri*), Smith's escolar (*Lepidocybium flavobrunneum*), and dolphinfish (*Coryphaena hippurus*) along with an insular pelagic species, opelu (*Decapterus* spp.), targeted by the nearshore, night-light hook-and-line-fishery (Figs. 30–35). Prior to arriving at the auction, pelagic bycatch species were often eviscerated at sea in a similar fashion to the tunas, billfish, and sharks. Weights collected from dolphinfish and Smith's escolar are from dressed specimens and the weights of opah, opelu, and sickle pomfret were from intact, whole specimens. All fork length measurements recorded for dolphinfish were derived from a single day of auction sampling.

Length-weight relationships for the five pelagic species sampled were estimated using the allometric equation described by Hayes et al. (1995); the linear regressions of the log transformed data are displayed in Figures 36–39 and 44–49. For opelu and Smith's escolar, sampling over a considerable size range provided fitted linear regression functions with $r^2 > 0.90$. Additional length-weight data over a greater size range are needed to improve the length-weight regression fits for dolphinfish, sickle pomfret, and opah.

The greater part of sampling effort for pelagic species was focused selectively on opah (Table 2, Figs. 30–35, Fig. 50), the result of a secondary study to evaluate the two morphotypes present among opah being sold at the UFA fish auction. Opah length-weight frequency histograms by quarter show the highest numbers of opah were sampled during the summer months when bottomfish were scarce (Figs. 40–43). Bigeye opahs were more frequently encountered than smalleye opahs (Figs. 44–45) and male opahs were more frequently seen than females (Fig. 46–49). Species within the genus *Lampris* will be thoroughly examined in future manuscripts.

CONCLUSION

The UFA fish auction provides a practical means to sample the landings of a significant portion of Hawaii's commercial fishing fleet. Both bottomfish and pelagic species are available. The auction allows for the potential to sample length-weight size frequency data of additional fish species, obtain biological tissue samples for species validation studies, and collect otoliths and gonads from rarely encountered large specimens of bottomfish. The data collected through sampling are essential to improving the biological models used in stock assessment and management analysis.

Sampling opportunities at the UFA have been extremely beneficial to the PIFSC. Information that is easily obtained at the UFA fish auction would be extremely costly to obtain by other means. Accordingly, we strive to enhance and expand our capabilities through positive interactions and feedback with buyers and UFA staff during our frequent auction visits. The fostering of good collaborative relations has been an integral component in the continued success of this valuable sampling program.

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Table 1.— Table of deepwater bottomfish species at the UFA fish auction and total number sampled from October 2007-December 2009. Total number sampled is the total number of fish encountered by samplers at the UFA fish auction with some type of information recorded, including those with only a UFA-recorded weight.

Scientific Name	Common Name	Family	Classification	Total Number Sampled	Fish with FL/TL	Fish with FL/TL & Weight
Etelis carbunculus	Ehu	Lutjanidae	Deep 7	2072	700	468
Pristipomoides zonatus	Gindai	Lutjanidae	Deep 7	318	61	43
Hyporthodus (Epinephelus) quernus	Hapu'upu'u	Seranidae	Deep 7	628	200	200
Pristipomoides sieboldii	Kalekale	Lutjanidae	Deep 7	661	193	72
Aphareus rutilans	Lehi	Lutjanidae	Deep 7	29	20	20
Etelis coruscans	Onaga	Lutjanidae	Deep 7	2845	980	790
Pristipomoides filamentosus	Opakapaka	Lutjanidae	Deep 7	5090	1461	858
Aprion virescens	Uku	Lutjanidae	BMUS	3144	822	522
Priacanthius meeki	Aweoweo	Priacanthidae	Non-BMUS	17	9	9
Polymixia berndti	Berndt's Beardfish	Polymixiidae	Non-BMUS	2	2	2
Caranx lugubris	Black Trevally	Carangidae	BMUS	9	3	3
Cookeolus japonicas	Bulleye	Priacanthidae	Non-BMUS	33	1	1
Pseudocaranx dentex	Butaguchi	Carangidae	BMUS	109	19	19
Caprodon unicolor	Elegant Anthias	Anthiinae	Non-BMUS	14	0	0
Erythrocles scintillans	Golden Rover	Emmelichthyidae	Non-BMUS	24	19	17
Pontius macrocephalus	Hogo	Scorpaeninae	Non-BMUS	228	83	77
Polydactylus sexfilis	Moi	Polynemidae	Non-BMUS	3	1	1
Iniistius pavo	Nabeta	Xyrichtyinae	Non-BMUS	45	0	0
Gnathanodon speciosus	Papa Ulua	Carangidae	Non-BMUS	6	2	2
Ariomma brevimanus	Shortfin Ariomma	Ariommatidae	Non-BMUS	1	1	1
Sarda orentalis	Striped Bonito	Scrombridae	Non-BMUS	4	0	0
Mulloidichthys vanicolensis	Weke Ula	Mullidae	Non-BMUS	18	4	4

Table 2.— Pelagic species encountered by samplers at the UFA fish auction October 2007-December 2009 and total number of fish sampled. Total number sampled reflects number of fish encountered having some type of information recorded, including those with only a UFA-recorded weight.

Scientific Name	Common Name	Family	Total Number Sampled	Fish with FL/TL	Fish with FL/TL and Weight
Coryphaena hippurus	Dolphinfish	Coryphaenidae	28	28	28
Lampris spp. (bigeye and smalleye)	Opah	Lamprididae	2860	1127	1127
Decapterus spp.	Opelu	Carangidae	340 boxes	133 indv.	133 indv.
Taractichthys steindachneri	Sickle Pomfret	Bramidae	278	88	75
Lepidocybium flavobrunneum	Smith's Escolar	Gempylidae	155	103	96
Acanthocybium solandri	Wahoo	Scrombidae	153	153	153

Table 3.—Example of the data sheet used during visits to the UFA fish auction.

Date: 11/28/07 **BF Fishing Vessel**	**Species**	**UFA_ Wt_Lbs**	**NMFS_FL_cm**	**NMFS_Wt_Kg**	**Sex**	**Page #: 1** **Comments**
Name of BF/V	Onaga	2@3.0	45.5	1.40	U	
			50.0	1.35	U	
	Paka	6.0	55.5	2.78	U	
		5.0	48.0	2.22	U	
	Uku	8.0	45.0	3.63	U	
		5.5	52.0	2.50	U	

Table 4. — Length and weight statistics of bottomfish for which both length and weight were measured at the UFA fish auction from October 2007-December 2009. Results are given separately for the MHI, the NWHI, and the combined areas. Coefficients A and B of weight-on-length regressions were determined using log-transformed length-weight data. Coefficients A and B were not calculated for the combined areas of *Etelis carbunculus* and *Pristipomoides filamentosus* because the slopes and/or y-intercepts were heterogeneous.

Species	Area	Sample Size	Mean FL_cm	Mean Wt _lbs	Min FL_cm	Max FL_cm	A	B
Etelis carbunculus	Both	468	39.9	2.5	23.9	64.0	–	–
	MHI	418	38.8	2.2	23.9	64.0	3.311E-05	2.7993
	NWHI	50	49.3	4.6	31.5	63.0	1.490E-05	3.0199
Hyporthodus	Both	200	75.0	17.7	24.0	110.0	2.895E-05	2.8764
(Epinephelus) quernus	MHI	53	60.2	8.9	38.5	87.0	6.408E-05	2.6948
	NWHI	147	80.4	20.8	48.6	110.0	2.474E-05	2.9129
Etelis coruscans	Both	790	57.9	6.9	29.0	94.0	2.650E-05	2.8436
	MHI	756	57.5	6.8	29.0	94.0	2.606E-05	2.8411
	NWHI	34	65.2	9.1	43.0	87.5	1.945E-05	2.9208
Pristipomoides	Both	858	51.0	5.2	29.0	85.0	–	–
filamentosus	MHI	778	49.0	4.5	29.0	80.0	6.378E-05	2.7621
	NWHI	80	69.8	11.8	33.0	85.0	1.323E-05	3.0290
Aprion virescens	Both	522	66.2	9.7	31.5	101.0	1.359E-05	3.0081
	MHI	330	63.2	8.6	31.5	98.5	1.175E-05	3.0434
	NWHI	192	71.3	11.6	42.0	101.0	2.102E-05	2.9052

Table 5.— Summary results of ANCOVA analysis (proc GLM, SAS v. 9.1.3) testing the possible effect of area of origin (MHI vs. NWHI) on weight-at-length relationships for 5 of the Deep 7 bottomfish species examined. Conclusion not to pool areas for final analysis is based on whether the slope or intercept of the weight-at-length relationship differed between the two origins.

Species	*n*	$F_{(1, n-4)}$-value	P-value	$F_{(1, n-3)}$-value	P-value	Pool MHI & NWHI?
		Slopes		Intercepts		
Etelis carbunculus	468	3.070	0.0802	3.960	0.0471	NO
Hyporthodus (Epinephelus) quernus	200	3.290	0.0711	0.4900	0.4861	YES
Etelis coruscans	790	0.390	0.5316	0.2400	0.6260	YES
Pristipomoides filamentosus	858	10.21	0.0014	—	—	NO
Aprion virescens	522	3.370	0.0670	0.1000	0.7559	YES

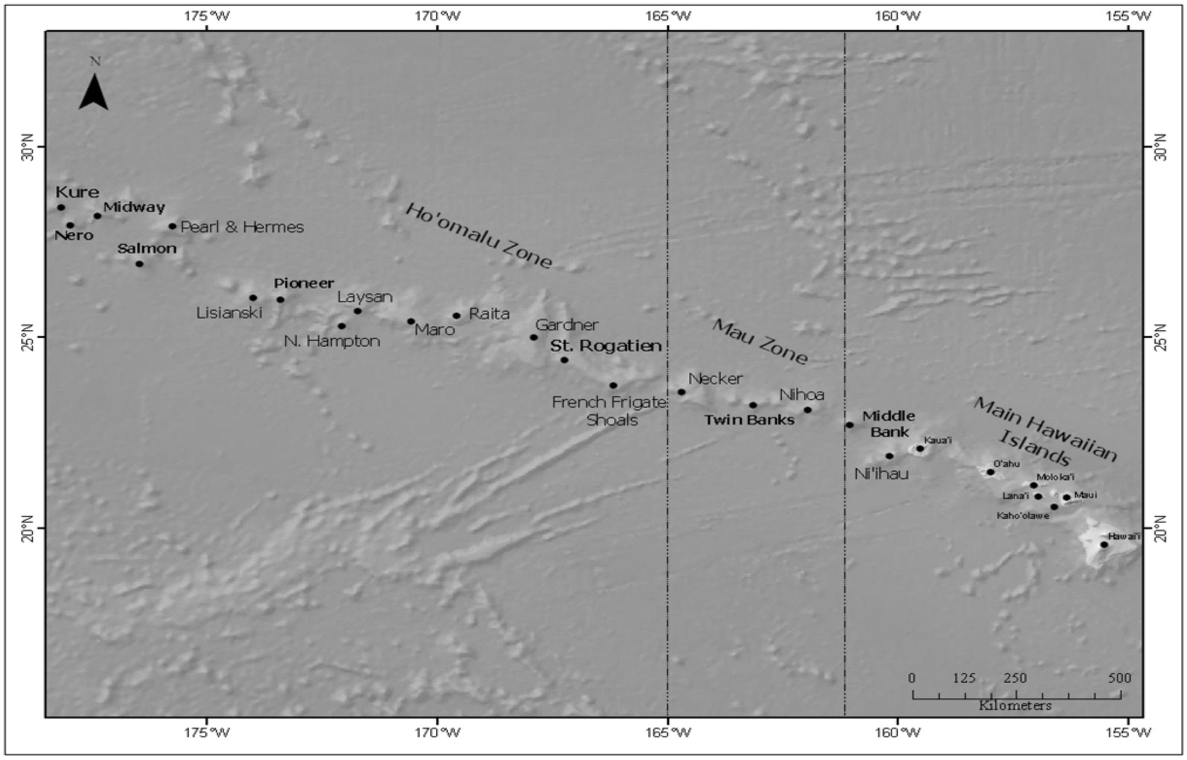

Figure 1.—Map of Hawaiian Archipelago delineating the three bottomfish fishery management zones.

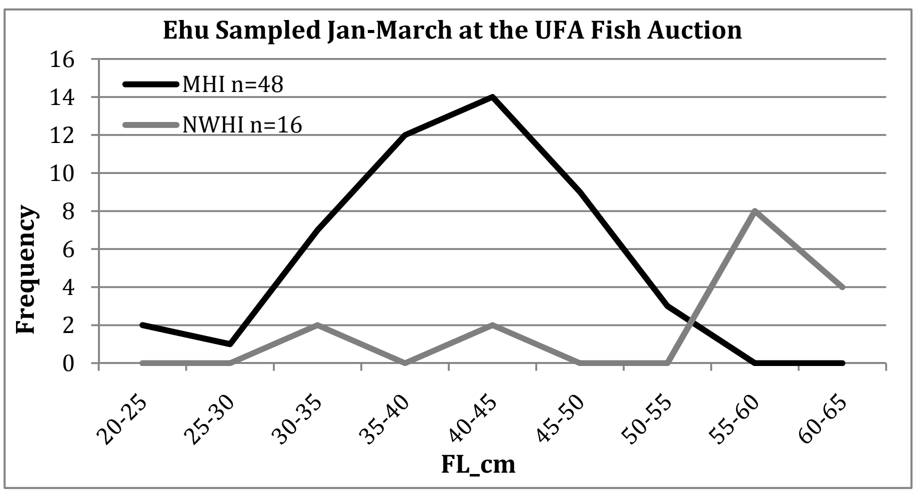

Figure 2.—Ehu sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the first quarter separated by origin (MHI and NWHI).

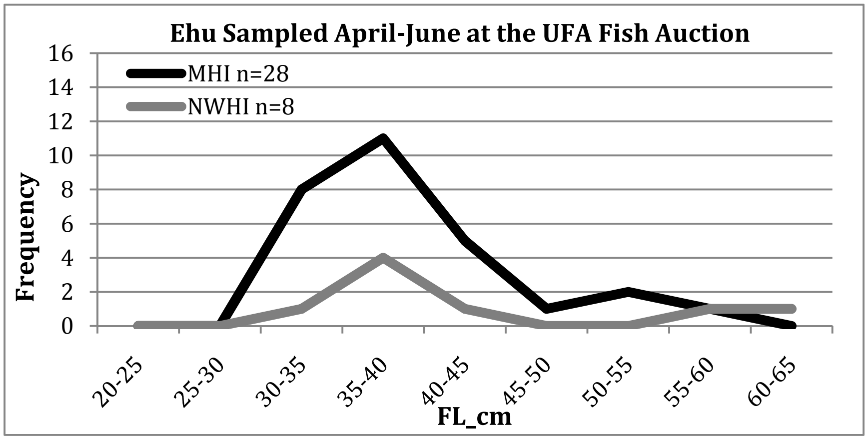

Figure 3. —Ehu sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the second quarter separated by origin (MHI and NWHI).

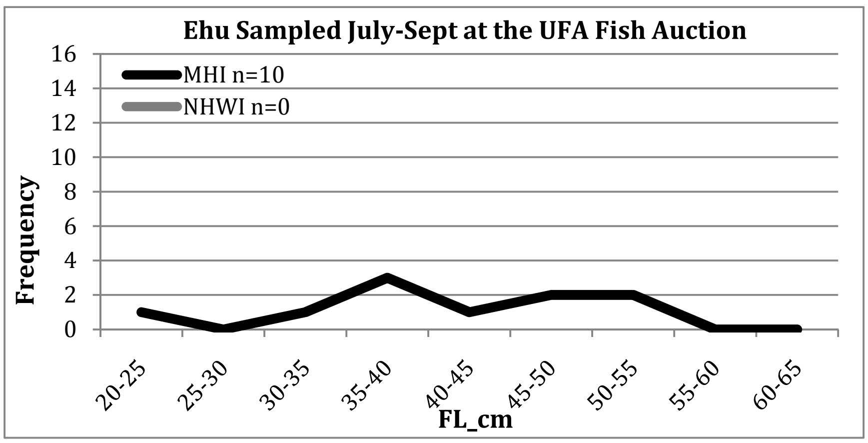

Figure 4. —Ehu sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the third quarter separated by origin (MHI and NWHI).

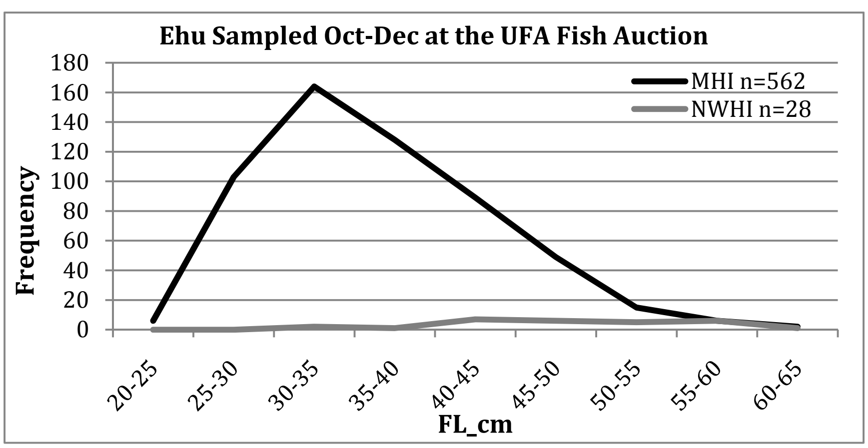

Figure 5. —Ehu sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the fourth quarter separated by origin (MHI and NWHI).

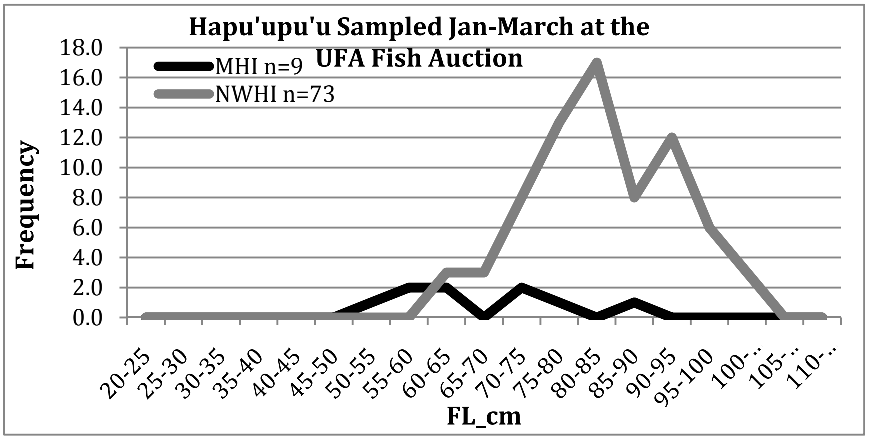

Figure 6. —Hapu'upu'u sampled at the UFA fish auction with total length collected October 2007-December 2009 during the first quarter separated by origin (MHI and NWHI).

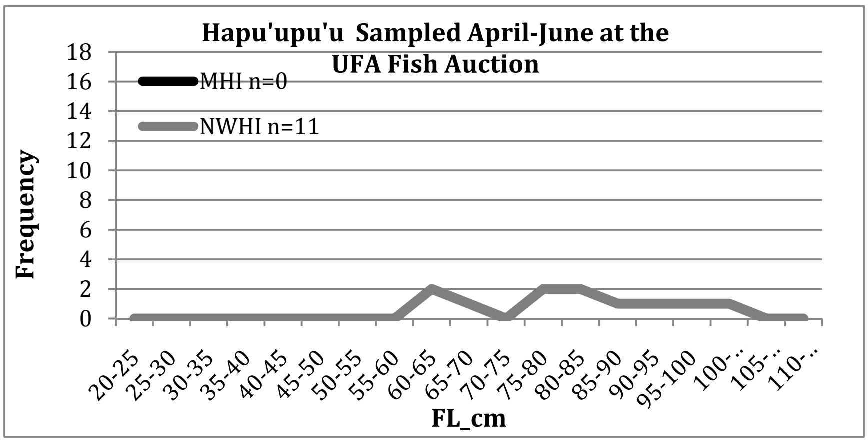

Figure 7. —Hapu'upu'u sampled at the UFA fish auction with total length collected October 2007-December 2009 during the second quarter separated by origin (MHI and NWHI).

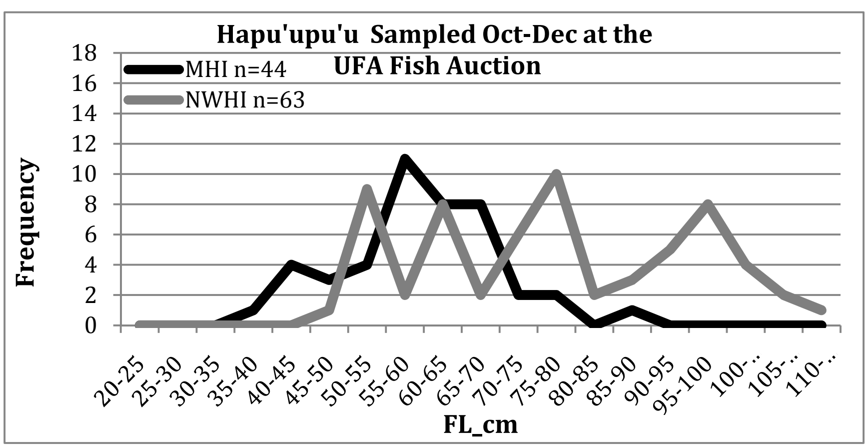

Figure 8. —Hapu'upu'u sampled at the UFA fish auction with total length collected October 2007-December 2009 during the fourth quarter separated by origin (MHI and NWHI).

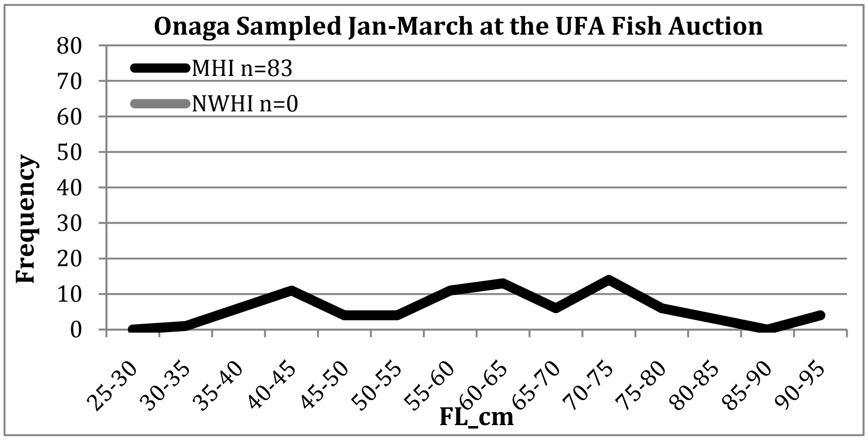

Figure 9. —Onaga sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the first quarter separated by origin (MHI and NWHI).

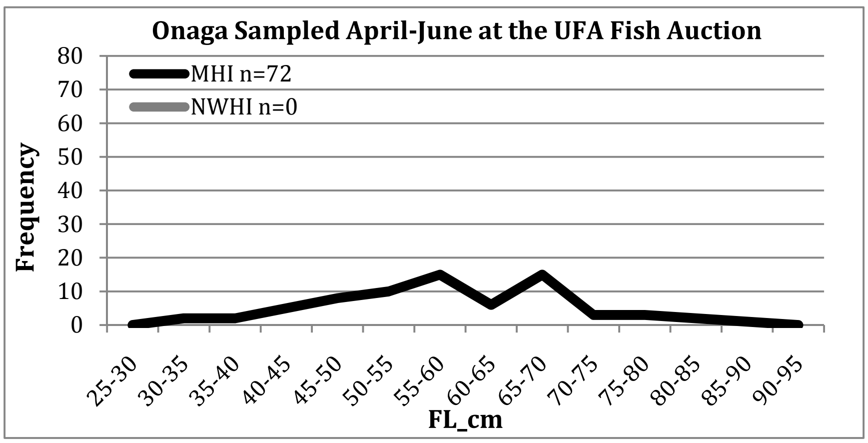

Figure 10. —Onaga sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the second quarter separated by origin (MHI and NWHI).

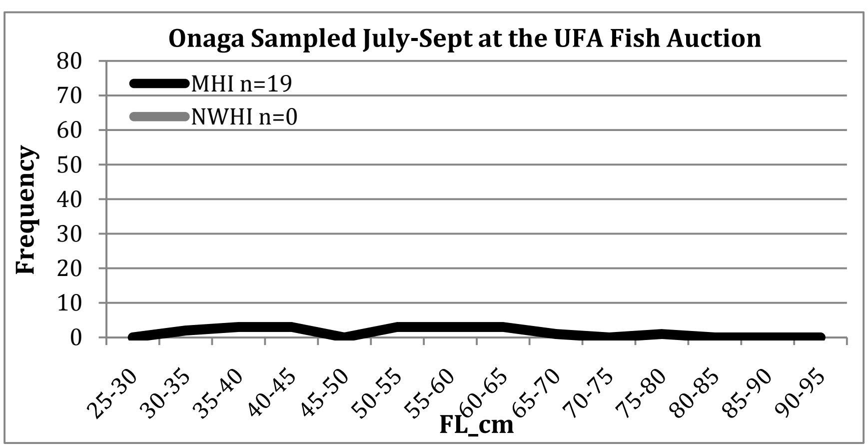

Figure 11. —Onaga sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the third quarter separated by origin (MHI and NWHI).

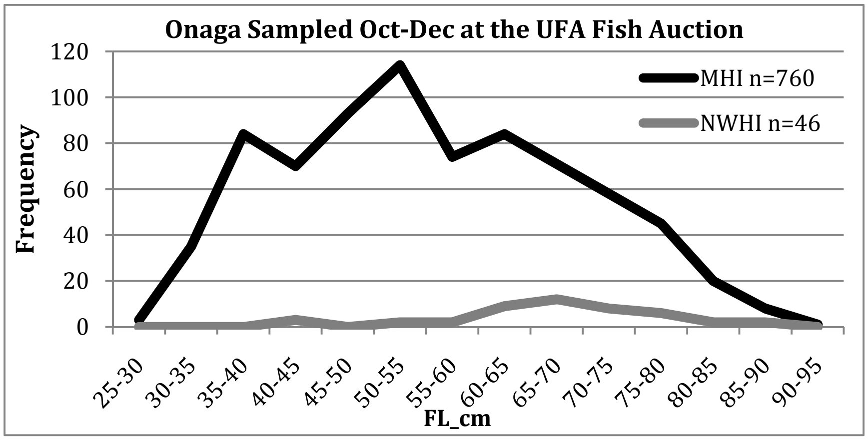

Figure 12. —Onaga sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the fourth quarter separated by origin (MHI and NWHI).

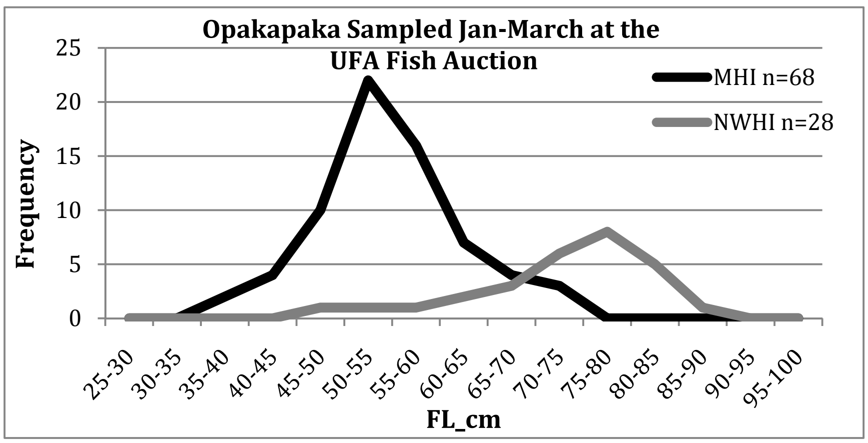

Figure 13. —Opakapaka sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the first quarter separated by origin (MHI and NWHI).

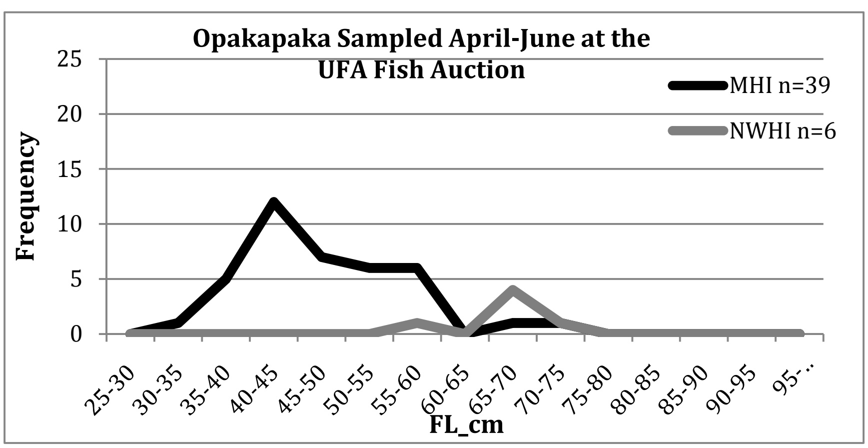

Figure 14. —Opakapaka sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the second quarter separated by origin (MHI and NWHI).

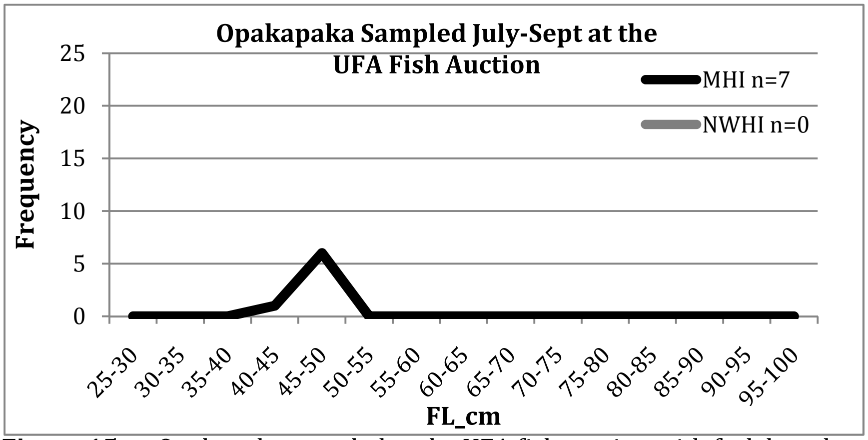

Figure 15. —Opakapaka sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the third quarter separated by origin (MHI and NWHI).

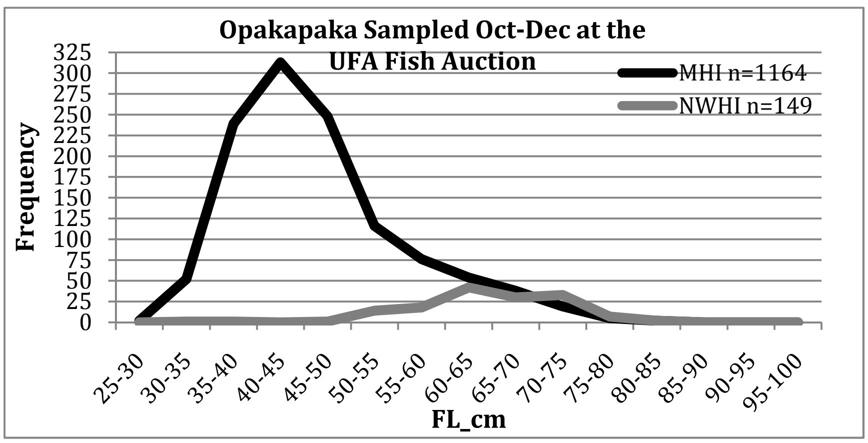

Figure 16. —Opakapaka sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the fourth quarter separated by origin (MHI and NWHI).

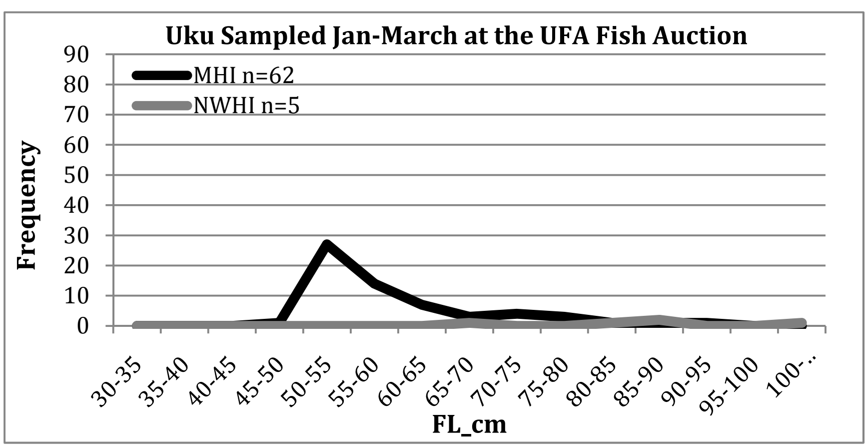

Figure 17. —Uku sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the first quarter separated by origin (MHI and NWHI).

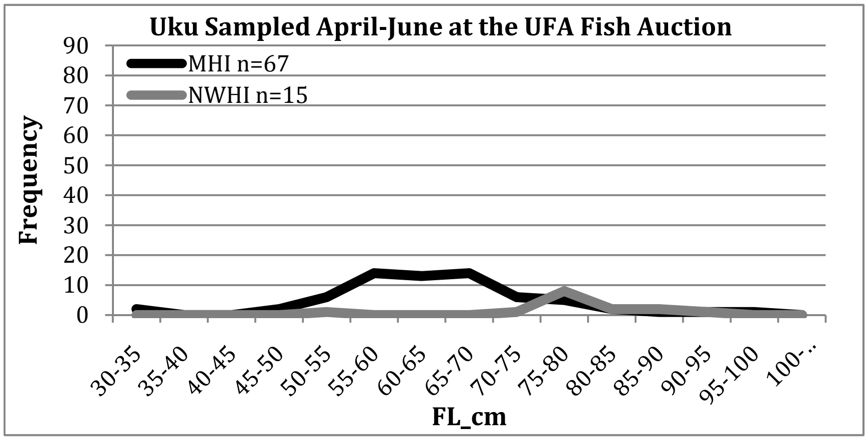

Figure 18. —Uku sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the second quarter separated by origin (MHI and NWHI).

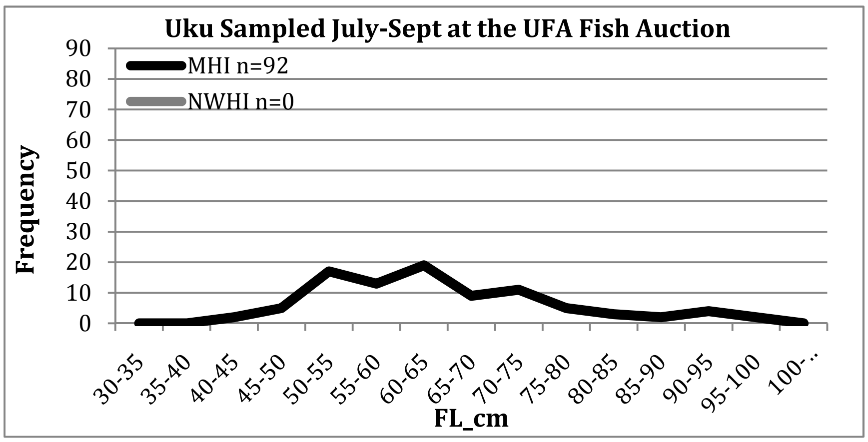

Figure 19. —Uku sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the third quarter separated by origin (MHI and NWHI).

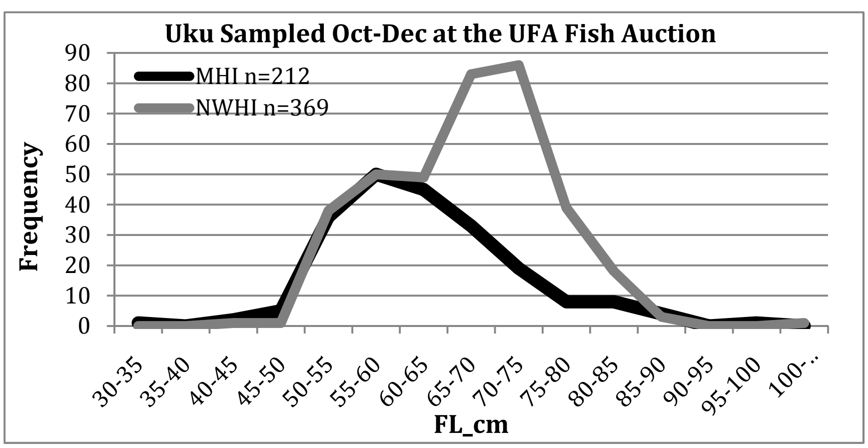

Figure 20. —Uku sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the fourth quarter separated by origin (MHI and NWHI).

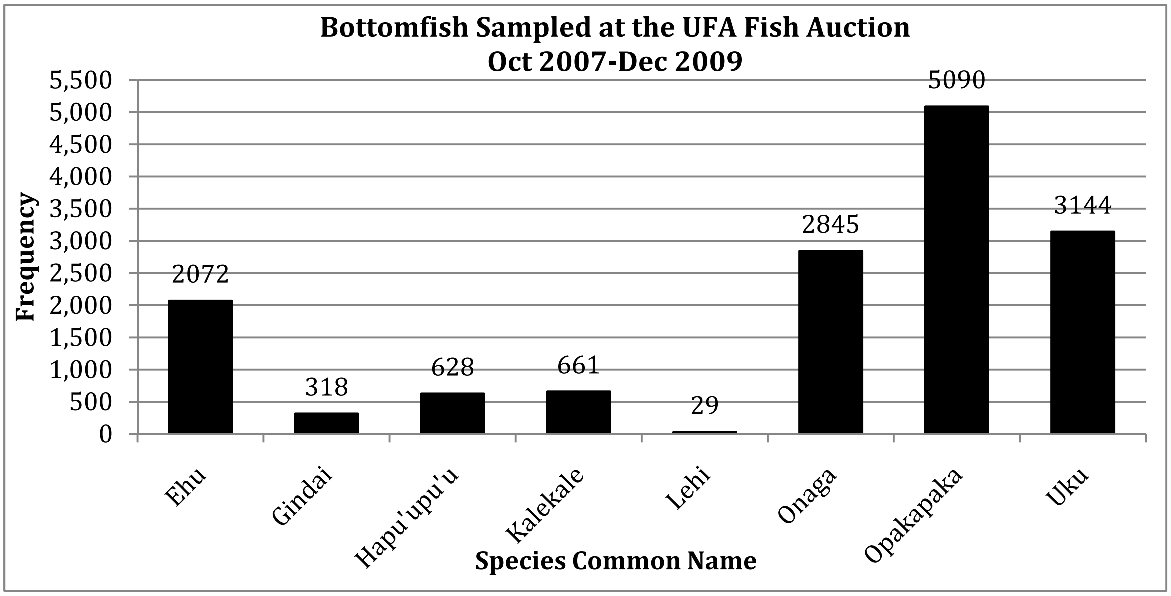

Figure 21. —Bottomfish species sampled at the UFA fish auction October 2007-December 2009. Total number reflects all fish encountered. For some specimens, the only data collected was UFA weight.

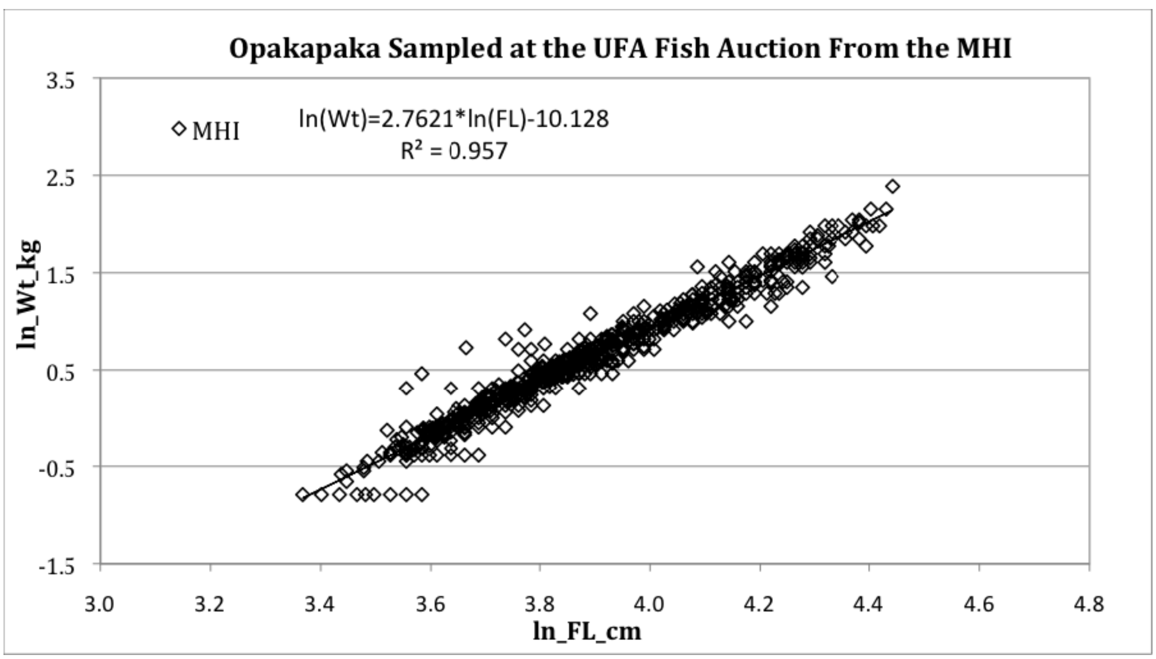

Figure 22. —Opakapaka sampled October 2007-December 2009 at the UFA fish auction with both length and weight collected in the MHI n=778. Linear regression trendline of log-transformed weight-length data displayed. Slopes of the two areas were heterogeneous so separate regressions were computed.

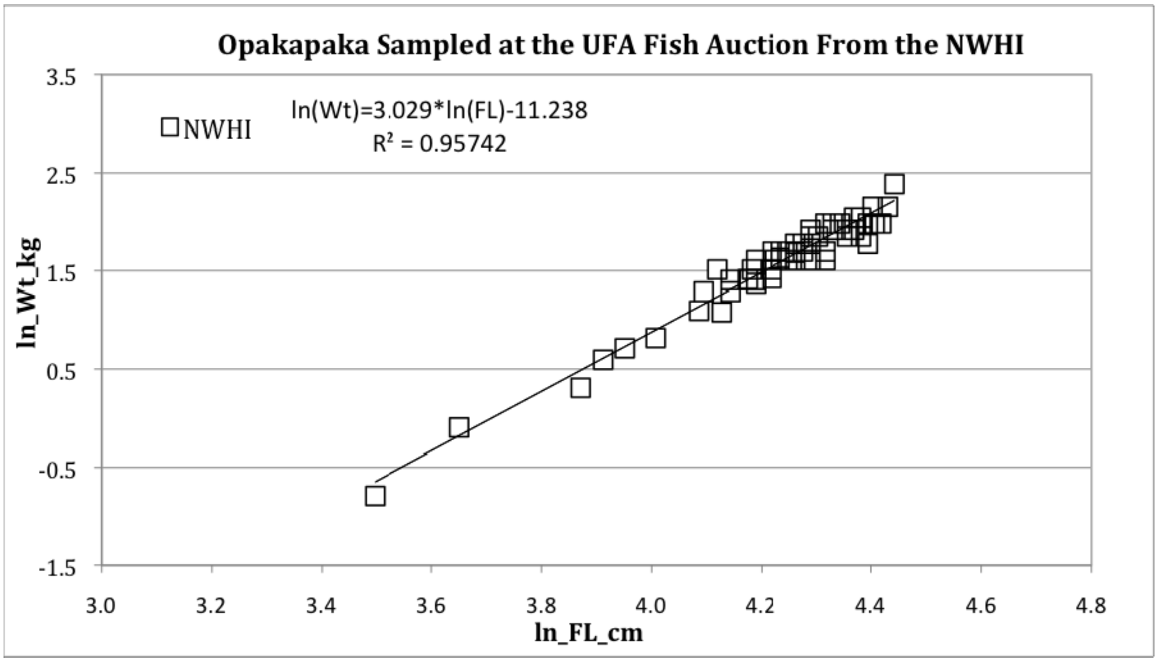

Figure 23. — Opakapaka sampled October 2007-December 2009 at the UFA fish auction with both length and weight collected from the NWHI n=80. Linear regression trendline of log-transformed weight-length data displayed. Slopes of the two areas were heterogeneous so separate regressions were computed.

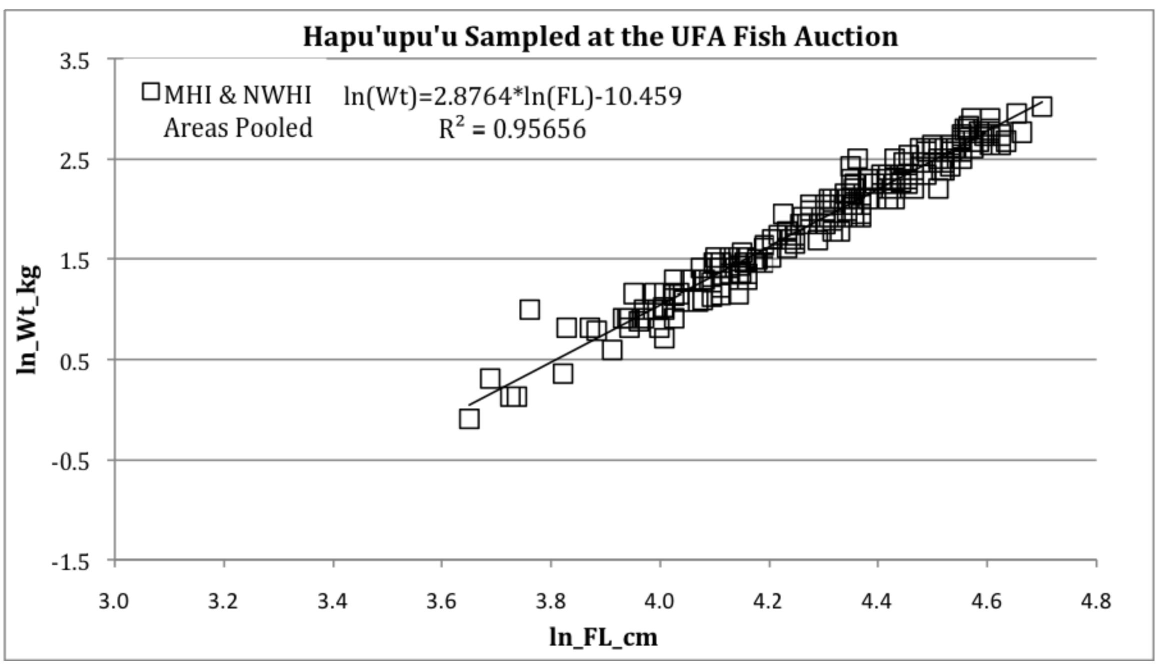

Figure 24. —Hapu'upu'u sampled October 2007-December 2009 at the UFA fish auction with both length and weight collected from both the MHI and NWHI (MHI n=53 and NWHI n=147). Linear regression trendline of log-transformed weight-length data displayed. Intercept and slope values for the two areas were homogeneous so data were pooled together.

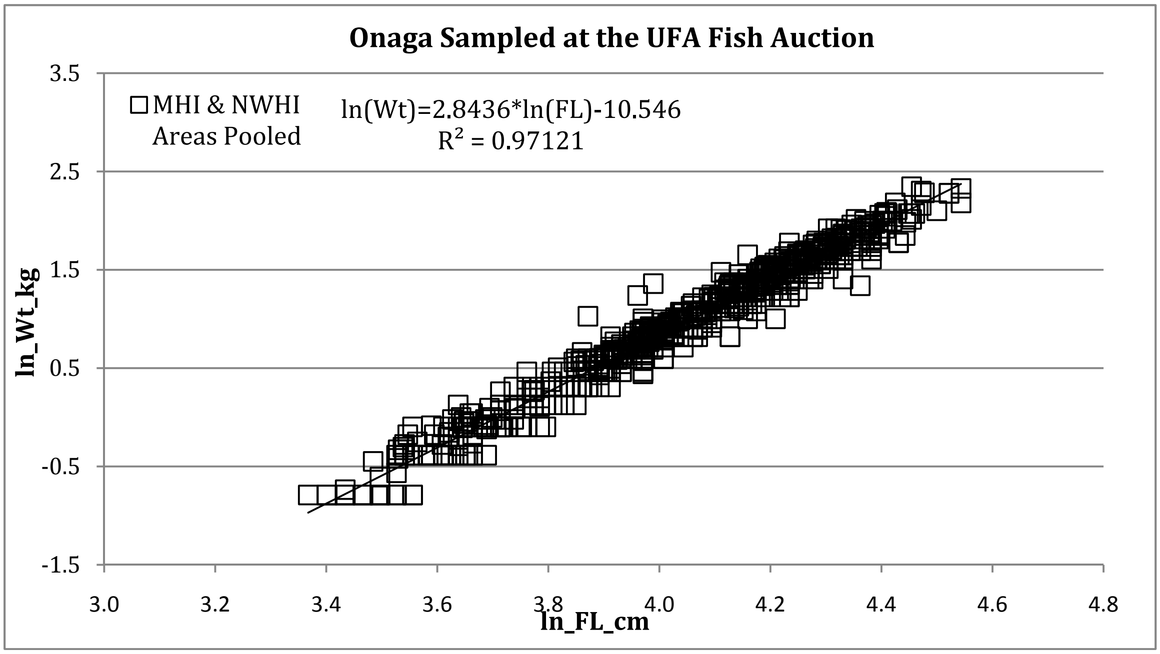

Figure 25. —Onaga sampled October 2007-December 2009 at the UFA fish auction with both length & weight collected from both the MHI and NWHI (MHI n=756 and NWHI n=34). Linear regression trendline of log-transformed weight-length data displayed. Intercepts and slopes for the two areas were homogenous so data were pooled together.

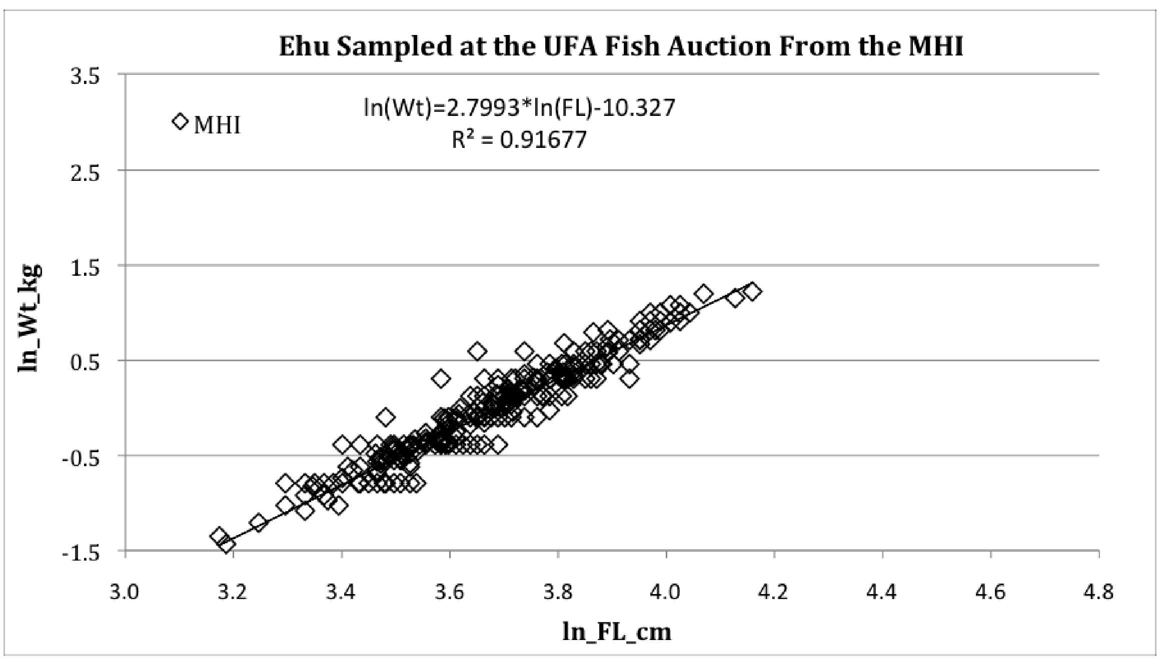

Figure 26. — Ehu sampled October 2007-December 2009 at the UFA fish auction with both length and weight collected in the MHI n=418. Linear regression trendline of log-transformed weight-length data displayed. Y-intercepts of the two areas were heterogeneous so separate regressions were computed.

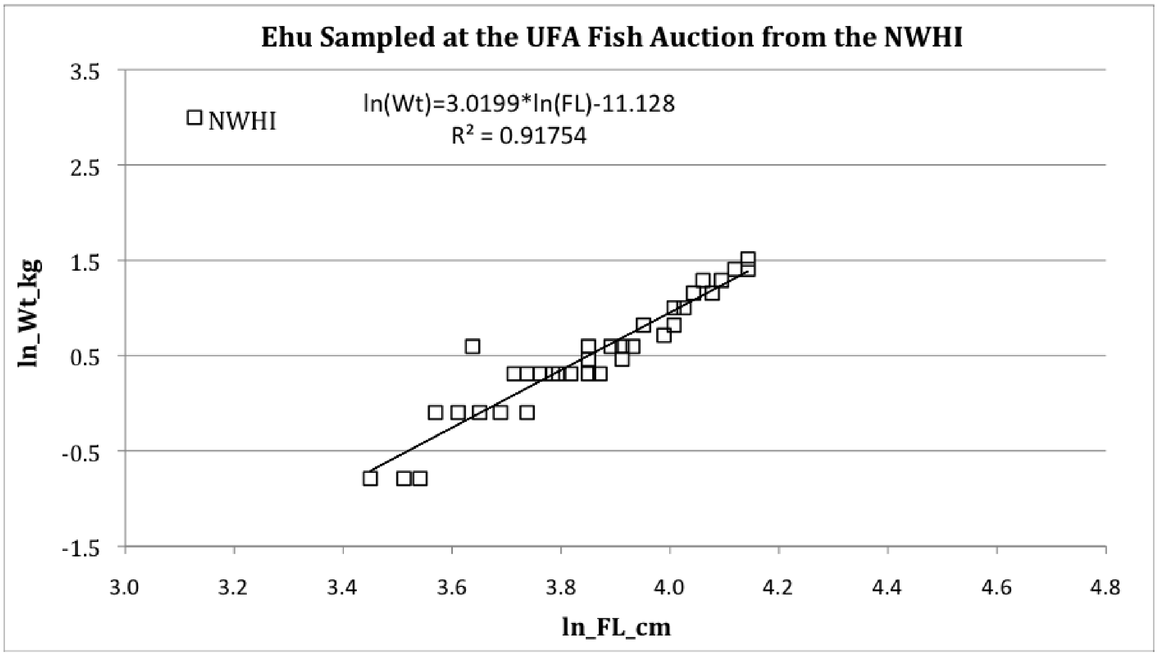

Figure 27. — Ehu sampled October 2007-December 2009 at the UFA fish auction with both length and weight collected in the NWHI n=50. Linear regression trendline of log-transformed weight-length data displayed. Y-intercepts of the two areas were heterogeneous so separate regressions were computed.

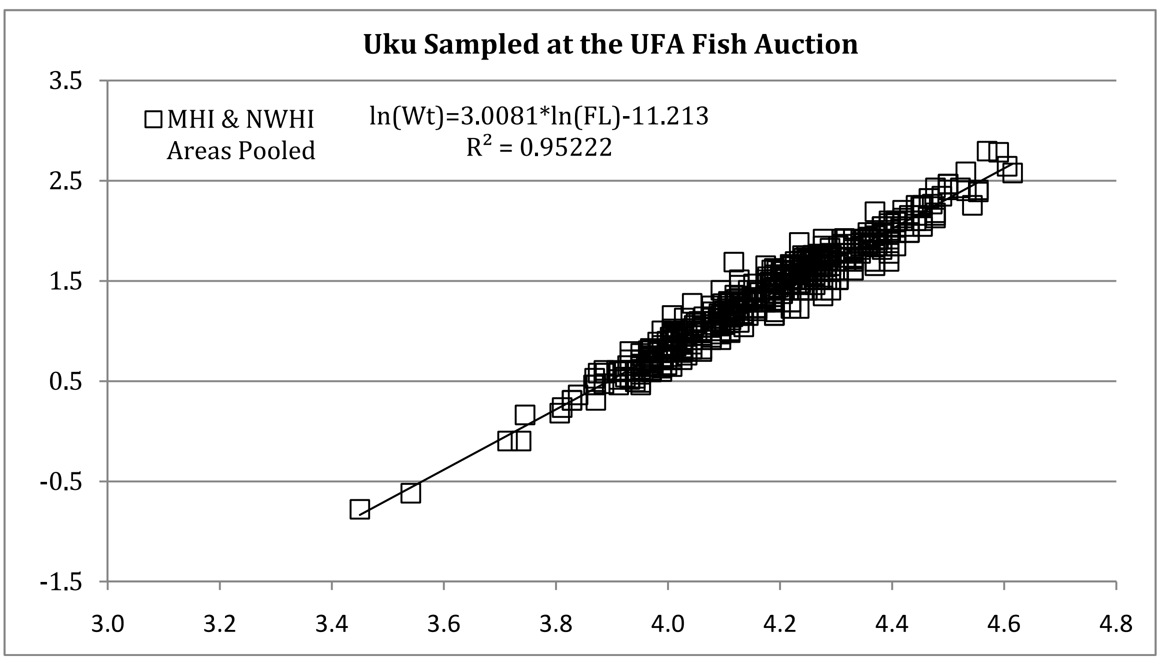

Figure 28. —Uku sampled October 2007-December 2009 at the UFA fish auction with both length and weight collected from both the MHI and NWHI (MHI n=330 and NWHI n=192). Linear regression trendline of log-transformed weight-length data displayed. Intercepts and slopes of the two areas were homogenous so data were pooled together.

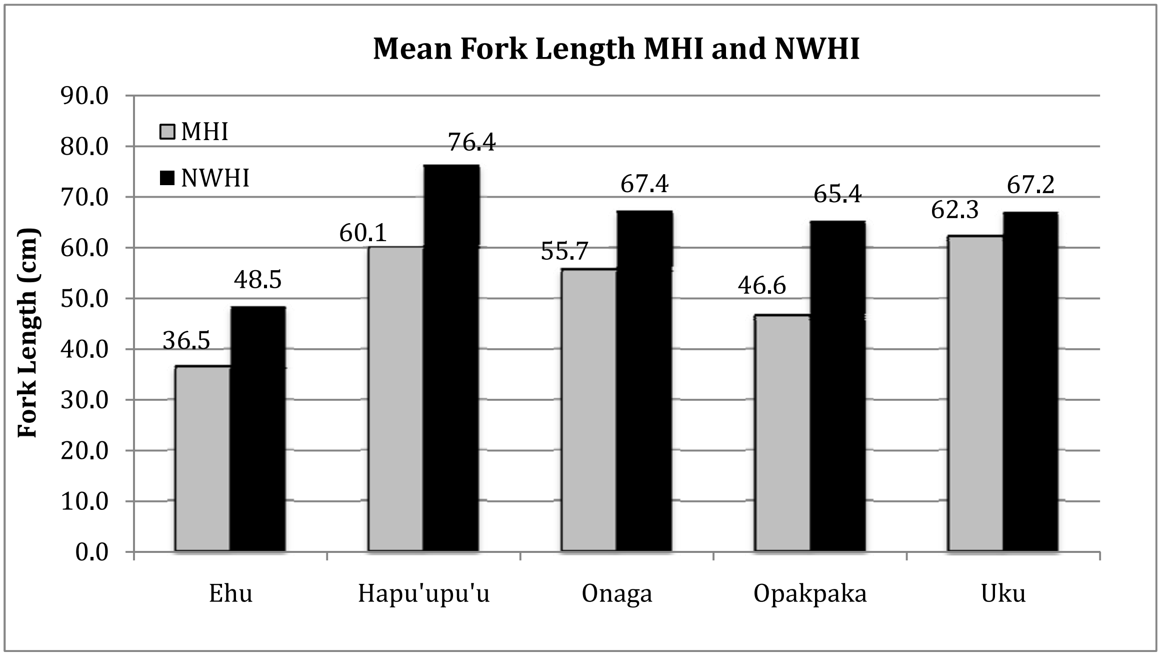

Figure 29. — Mean length by area of origin for the 5 heavily sampled bottomfish species with length recorded from the UFA fish auction (MHI n= 3,346 and NWHI n=837) October 2007-December 2009. Sample size of fish having a length recorded is greater than the sample size of fish with length and weight recorded; which explains why the lengths here vary from the lengths in Table 4.

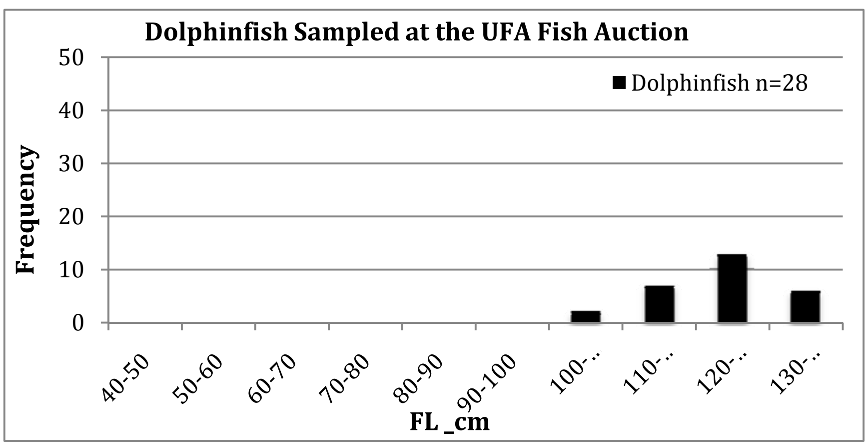

Figure 30. —Dolphinfish sampled at the UFA fish auction with fork length collected October 2007-December 2009; all fish sampled were male.

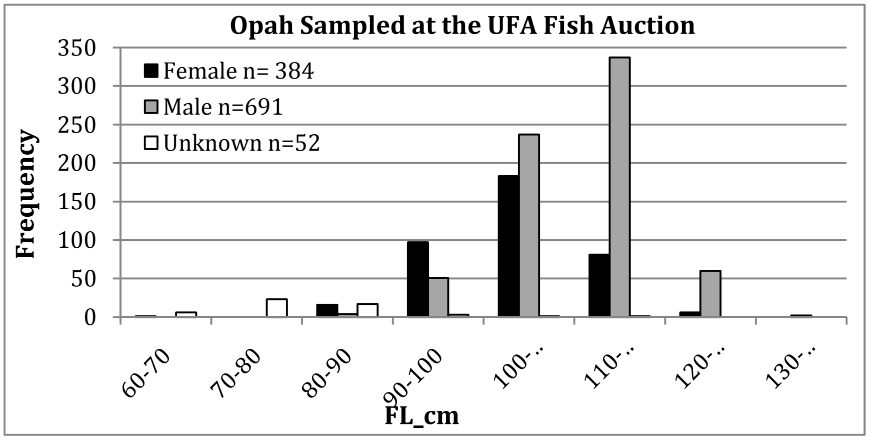

Figure 31. —Opah (both *Lampris* spp. bigeye and smalleye) sampled at the UFA fish auction with fork length collected October 2007-December 2009 separated by sex.

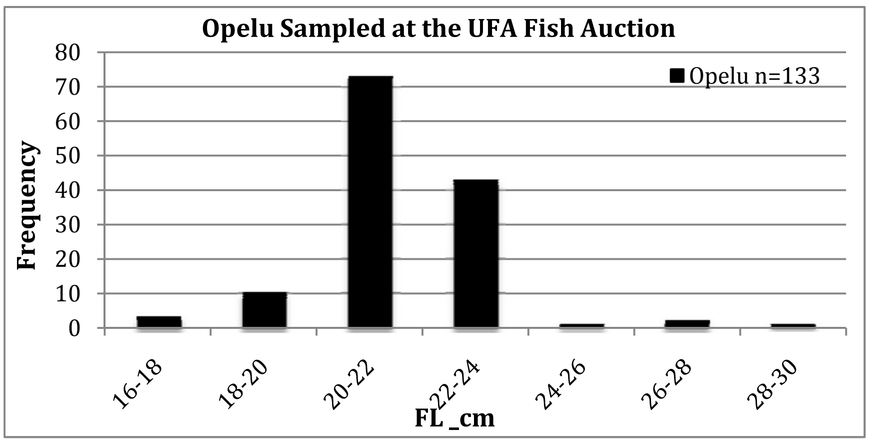

Figure 32. —Opelu (*Decapterus* spp.) sampled at the UFA fish auction with fork length collected October 2007-December 2009; sex unknown.

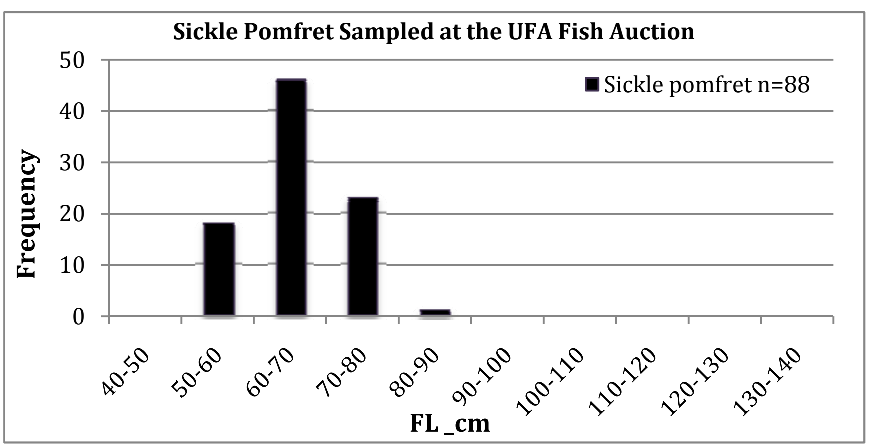

Figure 33. —Sickle pomfret sampled at the UFA fish auction with fork length collected October 2007-December 2009; sex unknown.

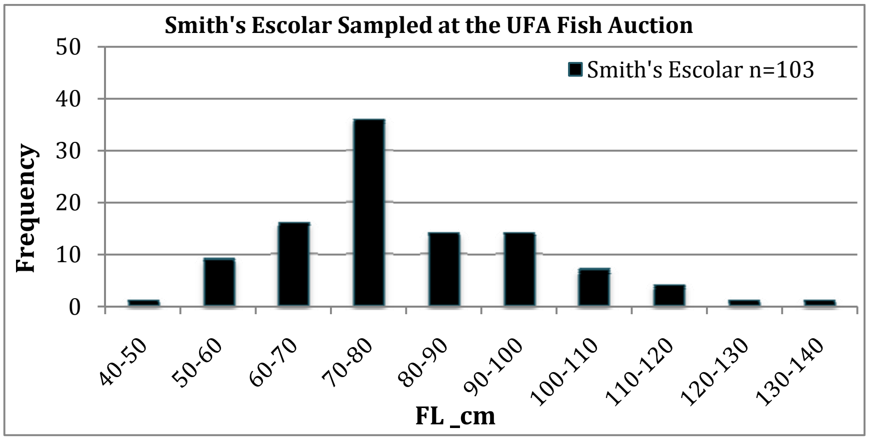

Figure 34. —Smith's escolar sampled at the UFA fish auction with fork length collected October 2007-December 2009; sex unknown.

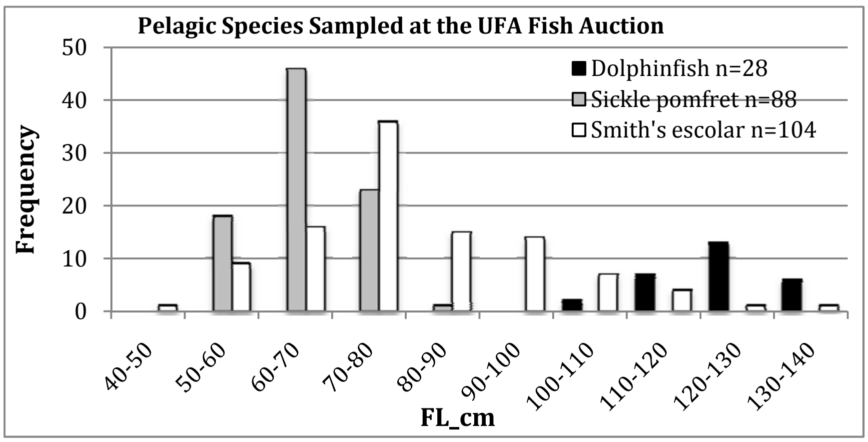

Figure 35. —Pelagic species sampled at the UFA Fish auction October 2007-December 2009 with fork length collected; does not include opah or opelu.

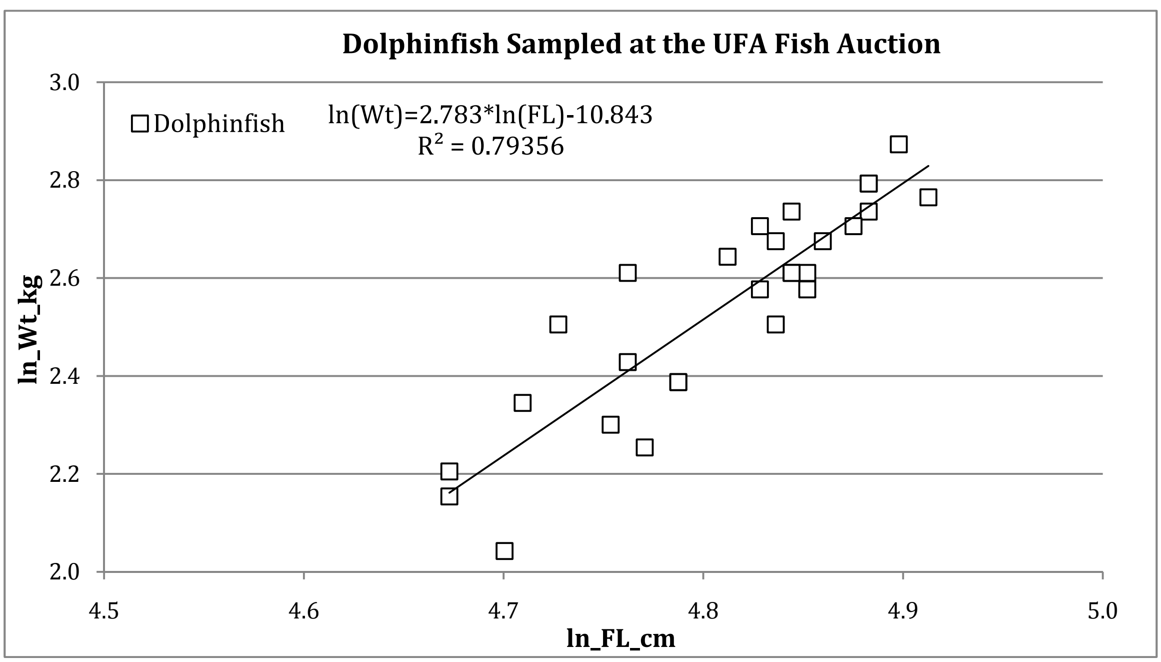

Figure 36. —Dolphinfish sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=28). All fish were male. Weight is of dressed animal; specimens were eviscerated at sea.

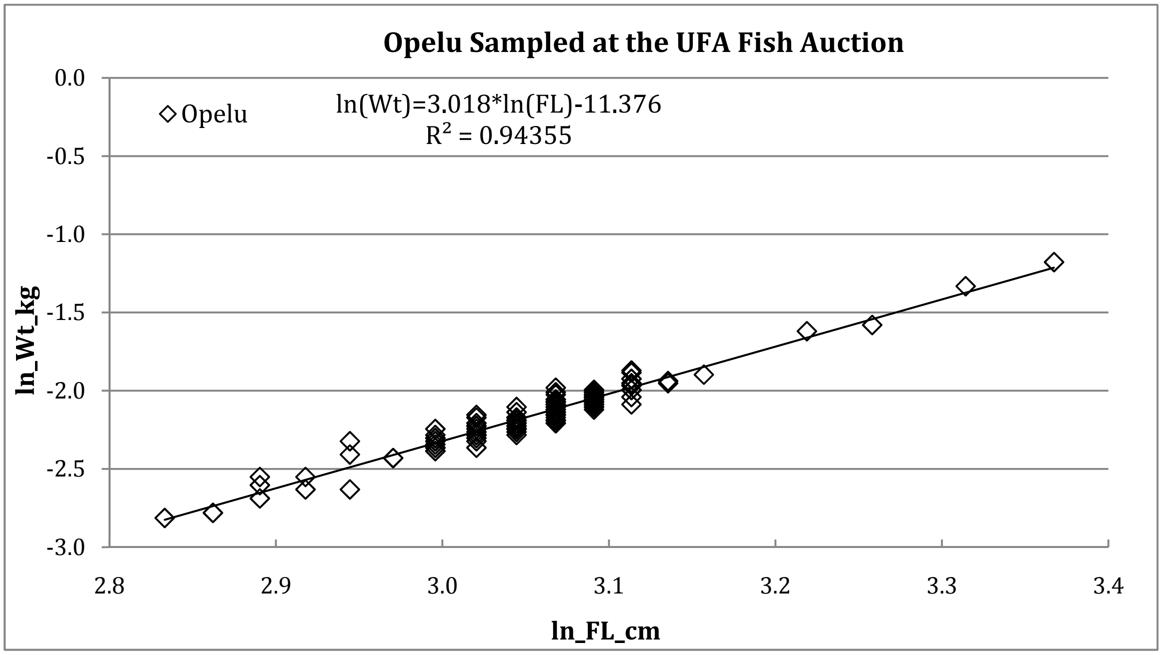

Figure 37. —Opelu (*Decapterus* spp.) sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=133). Sex unknown. Weight is of whole animal; specimens were not eviscerated at sea.

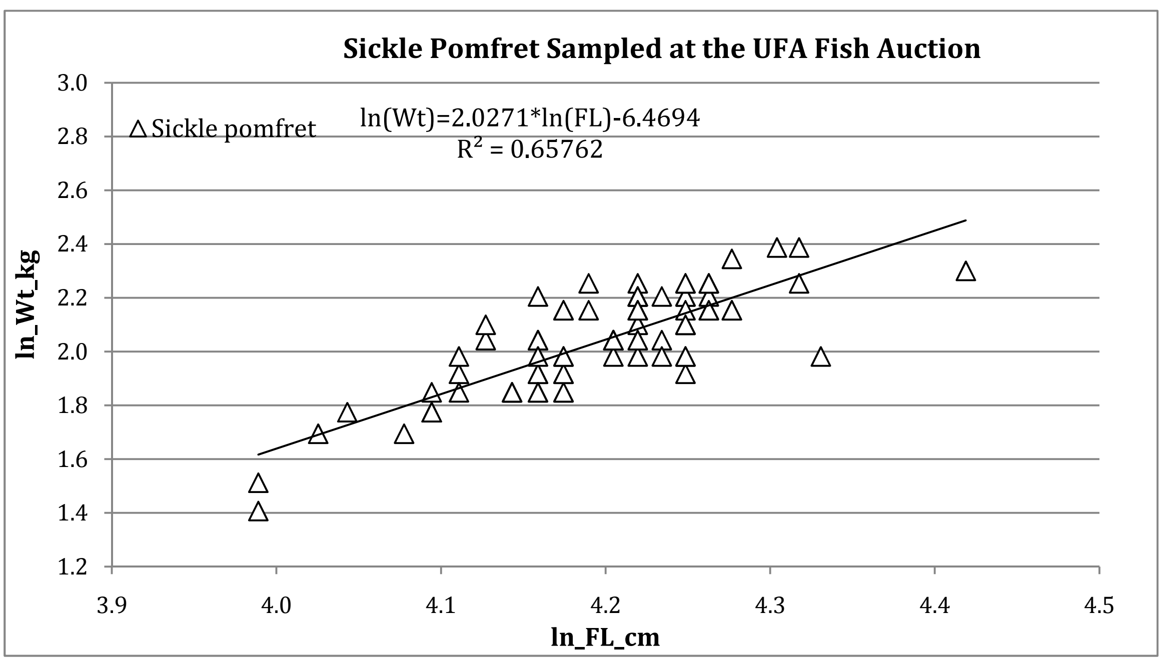

Figure 38. —Sickle pomfret sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=75). Sex unknown. Weight is of whole animal; specimens were not eviscerated at sea.

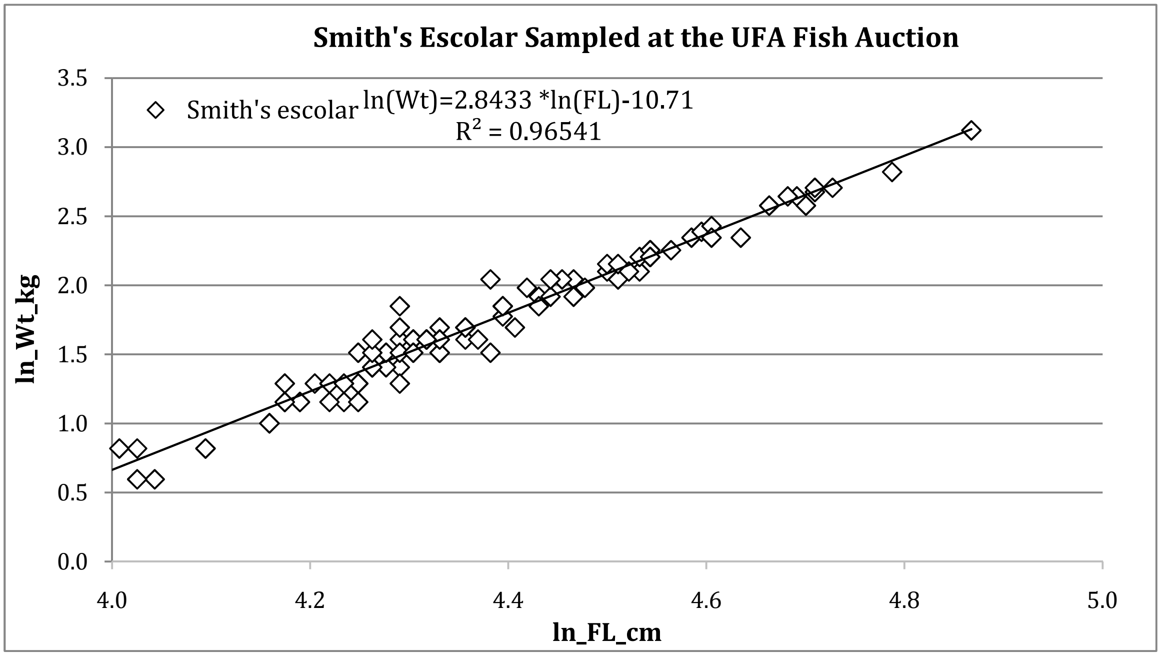

Figure 39. —Smith's escolar sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=96). Sex unknown. Weight is of dressed animal; specimens were eviscerated at sea.

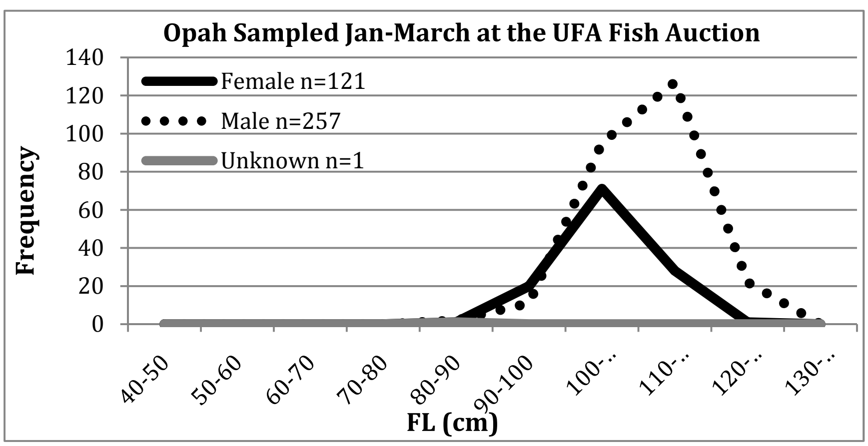

Figure 40. —Opah (both *Lampris* spp. bigeye & smalleye) sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the first quarter separated by sex.

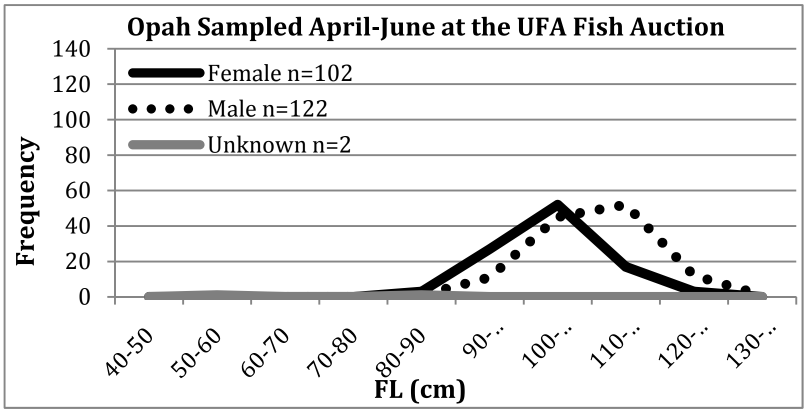

Figure 41.—Opah (both *Lampris* spp. bigeye & smalleye) sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the second quarter separated by sex.

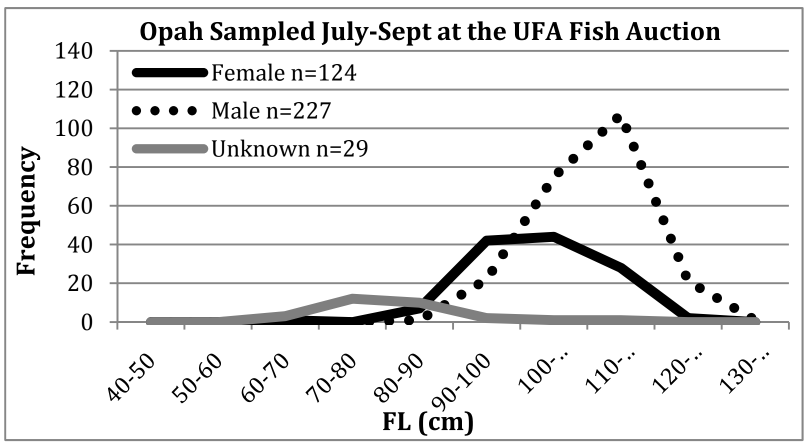

Figure 42.—Opah (both *Lampris* spp. bigeye & smalleye) sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the third quarter separated by sex.

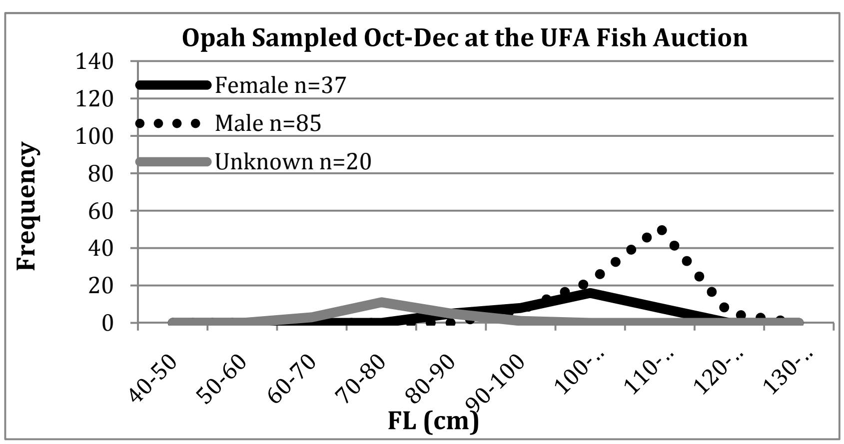

Figure 43.—Opah (both *Lampris* spp. bigeye & smalleye) sampled at the UFA fish auction with fork length collected October 2007-December 2009 during the fourth quarter separated by sex.

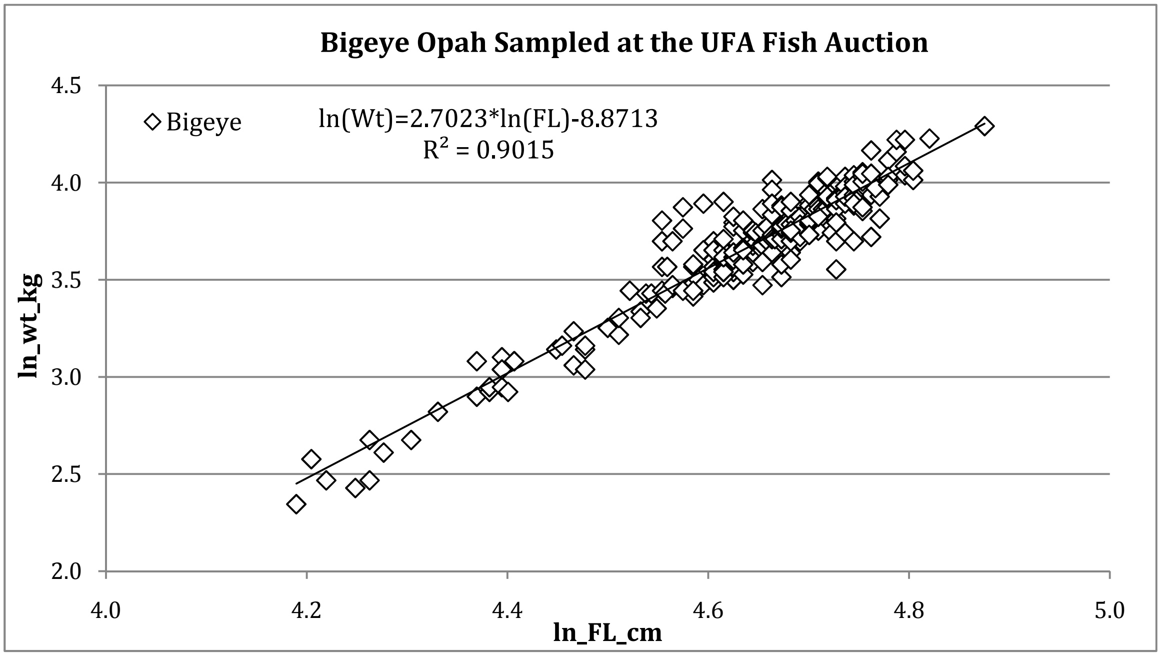

Figure 44.—Bigeye opah recorded and visually identified as bigeye sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=253). Weight is of whole animal; specimens were not eviscerated at sea.

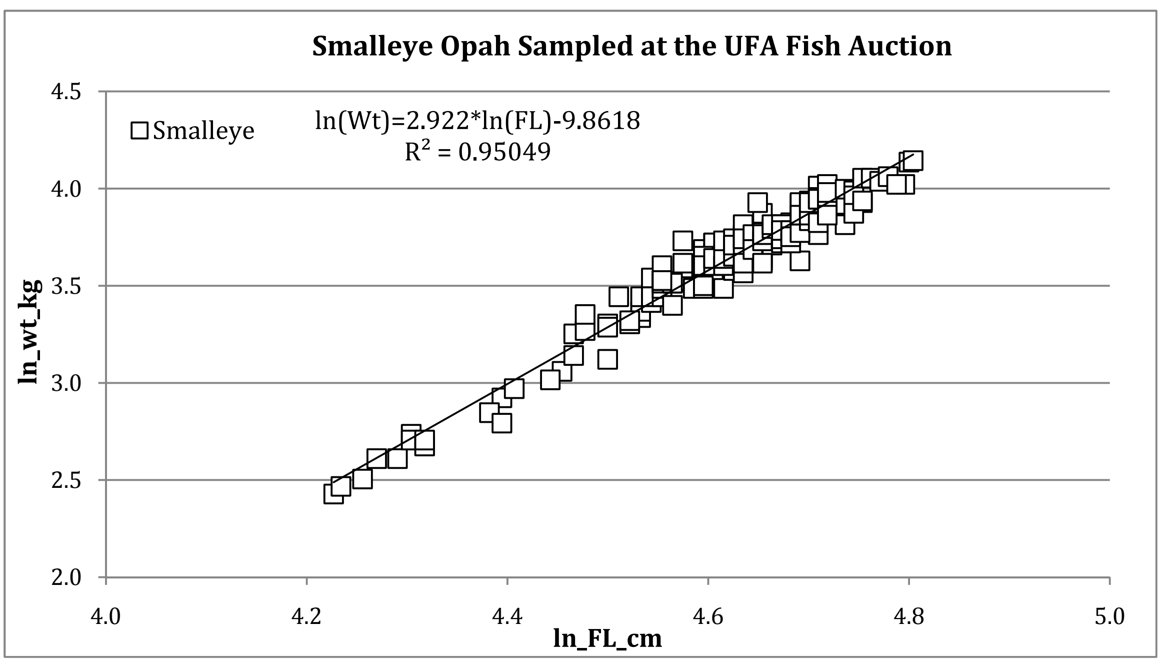

Figure 45.—Smalleye opah recorded and visually identified as smalleye sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=173). Weight is of whole animal; specimens were not eviscerated at sea.

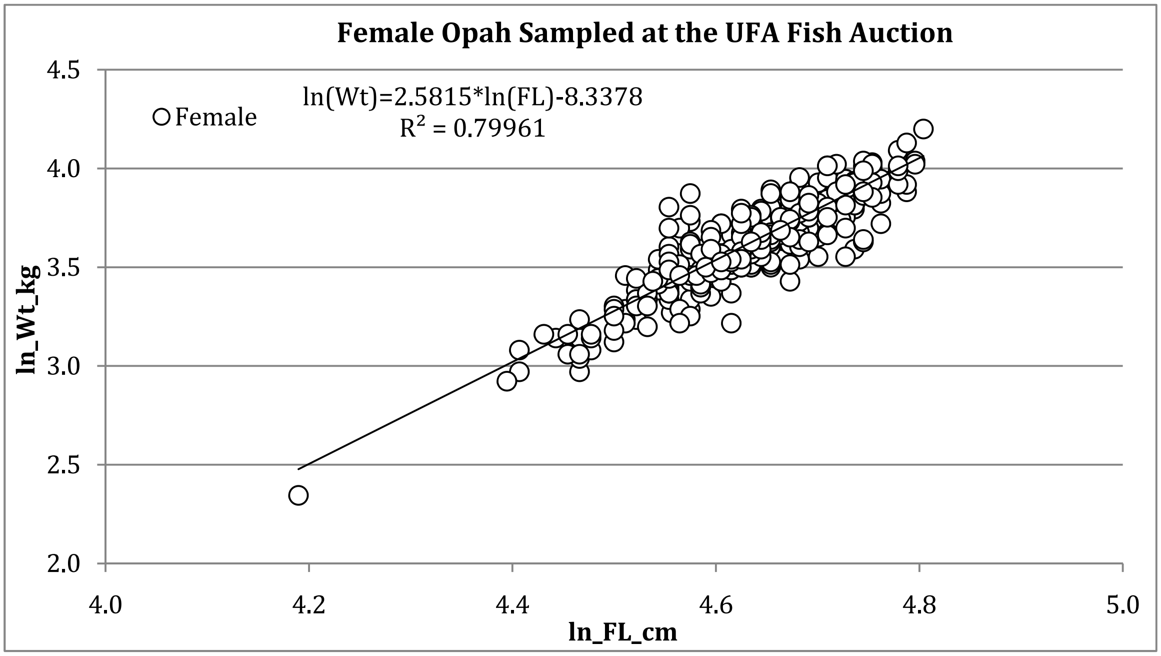

Figure 46.—All female opah (both *Lampris* spp. bigeye and smalleye) sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=384). Weight is of whole animal; specimens were not eviscerated at sea.

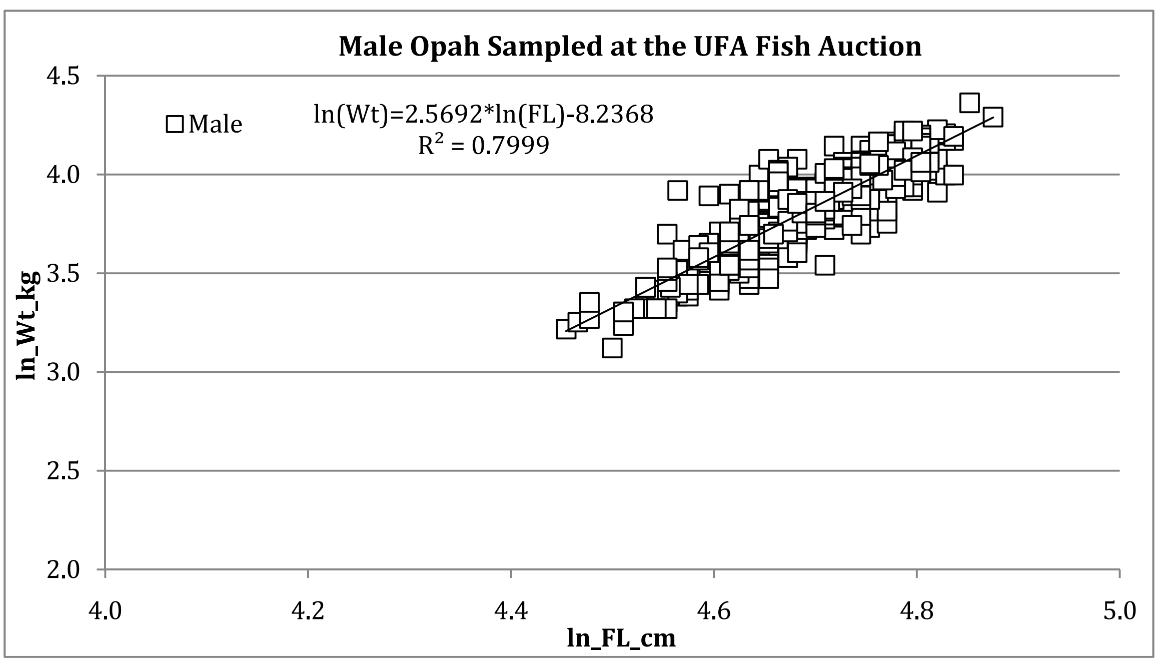

Figure 47.—All male opah (both *Lampris* spp. bigeye and smalleye) sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=689). Weight is of whole animal; specimens were not eviscerated at sea.

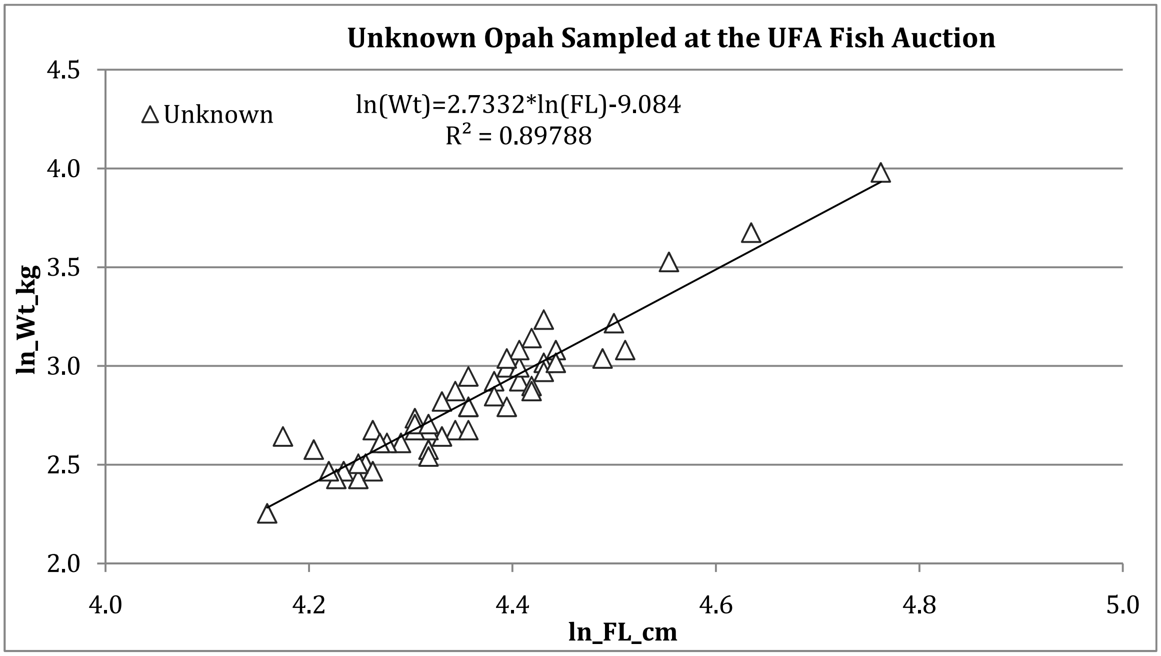

Figure 48.—All opah with unknown sex (both *Lampris* spp. bigeye and smalleye) sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 (n=52). Weight is of whole animal; specimens were not eviscerated at sea.

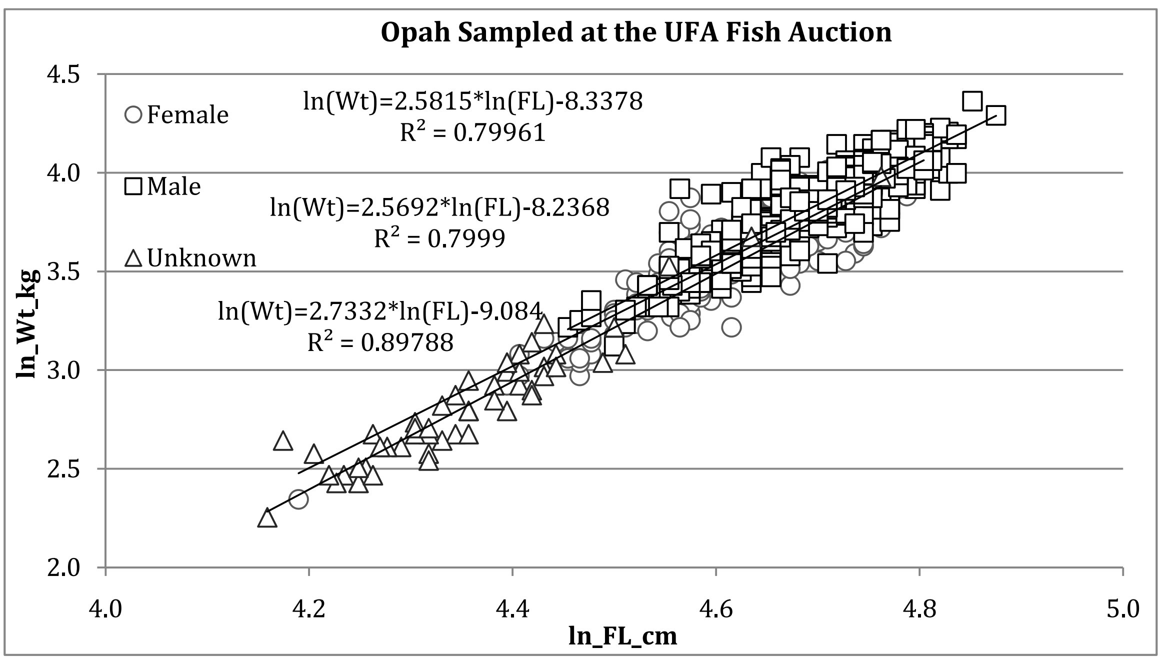

Figure 49.—All opah (both *Lampris* spp. bigeye and smalleye) sampled at the UFA fish auction with fork length and weight collected October 2007-December 2009 separated by sex (Female n=384, Male n=689, Unknown n=52). Weight is of whole animal; specimens were not eviscerated at sea.

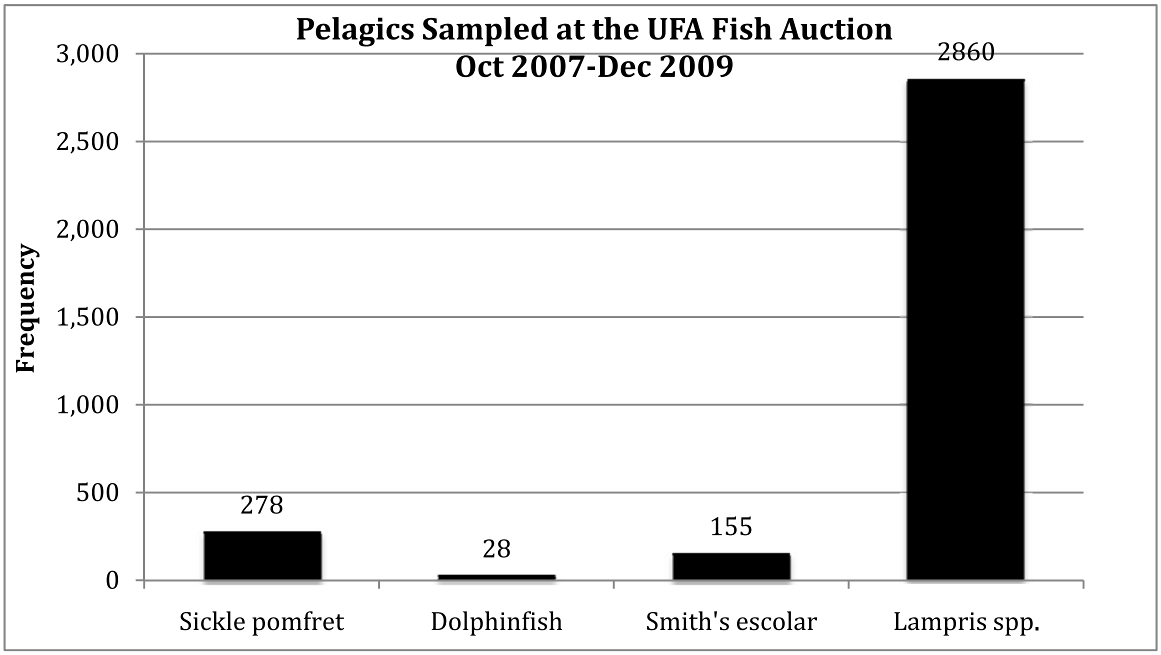

Figure 50.—Pelagic species sampled at the UFA fish auction October 2007-December 2009. Total number reflects all fish encountered. For some specimens, the only data collected was UFA recorded weight.