Applications of Some Recommended Analytical Methods from Data-Poor Workshop (December 2008) to Department of Fish and Game California Halibut Data Sets

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ABSTRACT

In December 2008 University of California Sea Grant Extension Program and the California Department of Fish and Game (Department) convened a fisheries management workshop in Berkeley, California. The goal of this workshop, "Managing Data-Poor Fisheries: Case Studies, Models and Solutions", was to provide ideas to the Department about ways to manage and assess California fisheries when available data are insufficient. Ideally, fisheries managers need the following long-term (i.e. 30 years or more), **annual** data sets for ecosystem-based management: commercial and recreational catch (including fish released) statistics of targeted species by port, gear, depth, time, and location, including data from logbooks; robust age, weight, length, and sex composition samples for each fishery and management area; fishery-independent surveys to determine relative abundance of all year classes; and size and abundance of associated species in the catch.

In 2011, the first statewide stock assessment for California halibut was completed for the Department by an independent contractor. Subsequent to the release of the stock assessment documents to the Department, in July 2011 the Department's State Finfish Management Project (SFMP) completed a series of tasks which applied some of the analytical techniques recommended at the Data-poor Workshop to the data sets supplied to the stock assessment contractor. These tasks were designed to be relatively straightforward, were conducted within the limits of the relevant available data sets, and did not require modeling expertise. They were done to compare the results with the basic conclusions from the southern California stock assessment and determine if any obvious discrepancies existed.

The tasks completed included the following:

1. The instantaneous coefficient of total mortality Z was calculated from a graph of frequency distribution of female halibut by age. Two independent estimates of 0.53 and 0.36 are near the mid-range of other flatfish estimates and for this reason appear to be reasonable.
2. Telephone interviews were conducted with halibut fishermen who have the greatest historical landings of California halibut in southern California since 1980 to get their perspective of changes in the fishery resource and reasons for those changes. Their observed increase in average size and lack of small halibut in recent years supports the lack of recruitment in southern California as stated in the stock assessment.
3. Length frequency distributions were examined from annual samples from recreational and commercial fisheries by gear type from 1980 to 2010. There was a significant positive trend in mean lengths for halibut sampled from the commercial fisheries and from the private/rental boat mode; this supports the general conclusion that halibut have had poor recruitment in the 2000s.
4. A lower ratio of halibut released to halibut retained by private and rental boat anglers in recent years further supports the idea of relatively low recruitment.
5. The application of several different filters to trawl logbook data yielded variable annual CPUE with no consistent trend. This would appear to substantiate the conclusion in the stock assessment of a fishery that, although heavily exploited, is still above a level that could produce maximum sustainable yield.
6. An optimum size range for harvested fish of 626 to 680 mm was calculated using basic von Bertalanffy parameters and appears to validate the current fishery

management strategy for optimizing harvest size. The present minimum legal size for halibut allows spawning to occur at least once in the lifetime of a fish, and allows the optimum age classes to be fully recruited to the fishery.

In summary, none of the completed tasks produced any results which would significantly differ from the stock assessment's conclusion of a heavily exploited yet sustainable biomass of California halibut in southern California, and the relative scarcity of recruitment during the last decade. Other scientists are encouraged to consult the literature related to the Data-poor Workshop and apply relevant techniques to assess fisheries which are lacking in comprehensive sets of fishery-dependent and fishery-independent data.

BACKGROUND

In December 2008 University of California Sea Grant Extension Program and the California Department of Fish and Game (Department) convened a fisheries management workshop in Berkeley, California. The goal of this workshop, "Managing Data-Poor Fisheries: Case Studies, Models and Solutions", was to provide ideas to the Department about ways to manage California fisheries when available data are insufficient. Ideally, fisheries managers need the following long-term (i.e. 30 years or more), **annual** data sets for ecosystem-based management: commercial and recreational catch (including fish released) statistics of targeted species by port, gear, depth, time, and location, including data from logbooks; robust age, weight, length, and sex composition samples for each fishery and management area; fishery-independent surveys to determine relative abundance of all year classes; and size and abundance of associated species in the catch. The latter includes larval and young-of-the year surveys to relate these to subsequent recruitment to the fisheries. Fisheries, including those for California halibut, which do not have all or most of these long-term data sets are considered "data-poor".

The 100 people who attended the workshop included resource managers, recreational and commercial fishermen, and representatives from academia and non-government organizations. Three members of the State Finfish Management Project (SFMP) attended. The workshop included 36 contributed manuscripts and selected presentations from invited national and international experts in designing techniques and strategies for managing data-poor fisheries. The final workshop report by California Sea Grant, which includes abstracts of the contributed manuscripts, is available through the following link:

http://www.dfg.ca.gov/marine/pdfs/datapoorfisheries.pdf

In 2011, the first statewide stock assessment for California halibut was completed for the Department by an independent contractor, Mark Maunder. Stock assessment documents may be obtained through the following link:

http://www.dfg.ca.gov/marine/sfmp/halibut-assessment.asp

Subsequent to the release of the stock assessment documents to the Department, in July 2011 the SFMP, with assistance from other Department staff, applied some of the analytical techniques recommended at the workshop to the data sets supplied to Maunder for the California halibut stock assessment. These were designed to be relatively straightforward exercises which were conducted within the limits of the relevant available data sets and did not require modeling expertise. They were done to compare the results with the basic conclusions from the southern California stock assessment and determine if any obvious discrepancies existed.

The focus of this exercise was on one of the 21 overarching ideas related to the Workshop themes, specifically idea S12: Develop simple indicators (biological, social, economic) of fishery status. SFMP staff concluded that four workshop papers had potential applications to the assignment. They are listed below along with six corresponding tasks completed by the SFMP; the methods are described first followed by the results. None of these tasks were redundant of those performed by Mark Maunder in the stock assessment.

METHODS

Literature cited: Yamanaka, K.L and G. Logan. Developing British Columbia's inshore rockfish conservation strategy.

Task 1. Calculate instantaneous coefficient of total mortality Z from graph of frequency distribution of female halibut by age. We used data from 1985-1988 from Sunada et al. 1990 (page 311) and 2007-2010 data from Reilly and Tanaka (SFMP) for southern California female halibut sampled from the commercial fishery.

The following explains the calculation of Z. If the number of individuals in each age class is known, mortality can be estimated. This method requires age data from an unbiased sample of a population and involves six steps. The number of animals in each age class is determined.

i. The numbers are natural log (base e) transformed.
ii. The log-transformed numbers are plotted against age.
iii. A linear regression is fitted to the descending limb (right hand side) of the catch curve.
iv. The value of total mortality is calculated as the negative slope of the regression.
v. The error of the estimates is calculated as the error of the slope of the regression.

Literature cited: Petterson, J. and E. Glazier. Fishery Management, Monitoring Systems, and Data Layering in Data-Poor Environments.

Task 2: Interview halibut fishermen who have the greatest historical landings of California halibut in southern California since 1980 to get their perspective of changes in the fishery resource and reasons for those changes. Summarize results using the interview form.

A list for potential interviews of commercial fishermen with extensive historical and/or current participation in the southern halibut fishery was generated using information from the Department's CMASTER database. Total cumulative halibut catch, total number of landings, and port complex of landing from the period of 1987 through 2010 were used as criteria to generate a list of 30 prospective interviewees. The initial data extract was from 1980-2010 but was amended to 1987-2010 due to an extraction error or malfunction in CFIS.

Literature cited: Honey, K.T, J.H. Moxley, and R.M. Fujita. From Rags to Riches: Data-Poor Methods for Fishery Managers. (Use of sequential trend analysis as indicators of trends in catch, landings, or CPUE).

Task 3: Although there are years with data gaps, we used length frequency distribution from annual samples for recreational (private and rental boat fishery) and commercial fisheries by gear with sufficient sample size. We asked if there had been a change in the relative abundance within specified length intervals from 1980 to 2010.

Length frequency histograms were constructed for commercial and recreational halibut samples. The commercial fishery samples were partitioned by year and by gear type for 1983-2010. Hook-and-line samples were excluded due to small sample sizes. Length frequency histograms representing the recreational fishery were constructed using sample data from the private/rental boat (PR) mode from 1980-2010 (excluding 1990-92). Data were separated into early and late periods (before 1990 and after 1992).

For this task and for task 4, a trend analysis was performed using a linear regression. The linear regressions were run, each with the year as the independent variable and the length or number of discards as the dependent variable. For the commercial fishery data, the scope of the regression was all years in the range 1980-2010 with data (based on an annual sample size of 30 or more) for the dependent variable. For recreational variables (which had sufficient data to permit doing so) regressions were run for the 'early' years (1980-1990) and the 'late' years (1991-2010).

Each regression's output included a measure of statistical significance for observed trend in the dependent variable: namely the P-value of the slope coefficient. This value is the probability that, were there truly no trend, an apparent trend - slope coefficient - as large or larger would occur just by chance. The smaller the P-value, the more significant is the evidence for a true nonzero trend. Usual convention takes $P < 0.05$ to be significant evidence for a nonzero trend.

Task 4: Determine if there have been changes in the ratio of halibut released to halibut retained by PR anglers each year. The PR mode is the most important among recreational fishing modes for halibut catch in southern California. Maunder had combined all recreational fishery modes except CPFV in one of his analyses (see Table B.2.10.1 in stock assessment). We asked if there had been a trend in the last ten years of a decreasing ratio. If so, this would be consistent with the basic conclusion of the southern California stock assessment: "There has been a series of low recruitments in recent years."

An analysis was done on the ratio of halibut discarded versus halibut retained by PR mode recreational anglers from 1980-2010 (excluding 1990-92). This trend analysis was separated into early and late periods on either side of the 1990-92 data gap.

Task 5: We re-examined southern California trawl logbook data, applying different filters or using temporal subsets of the data, to determine if there have been changes in catch per unit effort. Maunder's analysis was based on a standardized and more inclusive version of the trawl log data set provided. This data set included tows which had at least one halibut and tows that may have targeted halibut, but did not catch any. Maunder did not use this data set in the model.

Three analyses were completed using subsets of the data base provided to Maunder. Data from 2009 and 2010 were also included and were not available for Maunder's analysis.

1. We analyzed the average CPUE by year for tows with known halibut catch, regardless of target or associated species. Tows with zero halibut catch were excluded.
2. We created a temporal subset of the data to examine those tows that targeted halibut, as evidenced by the use of codes CHLB or UHLB in logbooks. Tows with zero halibut catch were included. This extract covered the period of 1997-2010 and included tows that caught no halibut (Figure 2). Prior to 1997, the target codes CHLB and UHLB were not used or captured in the data.
3. We created a temporal data subset that excludes trawl trips that targeted shrimp or sea cucumber with incidentally-caught halibut. Shrimp trawling activity is to be recorded on the shrimp/ prawn trawl logbook. Fishermen have reported directed sea cucumber

trawling activity in the groundfish trawl log or shrimp/ prawn logbook. However, past shrimp and sea cucumber activity has been incorrectly recorded in the groundfish trawl logs with the target code RPRW (shrimp) and USCU (sea cucumber). In the past few years some trawl fishermen are also using the target code NSM for shrimp, sea cucumber, or finfish trawling. NSM stands for Nearshore Mix. Trips that targeted shrimp (RPRW) or sea cucumbers (USCU) were excluded before analysis of the remaining data. For those remaining trips that did not specify invertebrates (blank, NSM, or CHLB/ UHLB) as the target species, trip totals for shrimp or sea cucumber were compared to the landing weight of halibut caught on those trips. Tanaka consulted with Kristine Barsky (DFG) and Mike McCorkle (southern halibut/ sea cucumber trawl fisherman) for possible parameters for filtering out non-halibut effort and for fishery insight. Based on landing totals, block of catch, length of tow, and fishing depth, trips that appeared to target shrimp or sea cucumber were excluded. Tows with zero halibut catch were also excluded. The temporal parameter for this extract will be 1997-2010 to parallel the second analysis.

Literature cited: Cope, J. and A. Punt. Length-based reference points for data-limited situations: applications and Restrictions.

Task 6: The authors refer to a paper by Froese (2004) which focus on catch length composition. One of the uses of this data is to determine the optimum size range of harvested fish in a fishery, using basic von Bertalanffy parameters.

Froese (2004) defined optimum size L_{opt} as the length where the number of fish in a given year class multiplied with their mean individual weight is maximum and where thus the maximum yield can be obtained. Optimum length is typically a bit larger than length at first maturity, and is calculated as follows:

$L_{opt} = L_\infty \times [3/(3 + M/K]$

L_∞ corresponds to the largest fish in the sample. Values for K (Von Bertalanffy growth parameter) and M (natural mortality) were those used by Maunder in the stock assessment, where K = 0.095 and M = 0.2 for female California halibut.

We used the length composition data from Sunada (1990) and recent data from Reilly and Tanaka to calculate a range of optimum sizes and the corresponding ages. This allowed us to determine in a simplistic fashion if our harvest strategy, dictated by a basic minimum legal size, is appropriate for this species based on the age and length frequency of the sampled commercial catch.

RESULTS

Task 1. **Calculation of Total Instantaneous Mortality Z**

Age composition data from each of the two data sets were combined for all gears (trawl, gill net, commercial hook-and-line, recreational spear, unknown) for two reasons: 1) data from Sunada et al. 1990 were not presented by gear type in the published reference (Fish Bulletin 174) and the original data could not be located in time to complete this assignment; 2) sample size from each gear type from Reilly and Tanaka was too small for a meaningful comparison. However, 90.5% of total commercial landings in southern California from 1985 to 1988 were from gill nets, so it is likely that the majority of aged fish were from this gear. Number of southern California female halibut aged by Reilly and Tanaka came from the following gear types:
Gill net: 45
Trawl: 44
Hook-and-line: 1

Spear: 2
Unknown: 37 (unknown are from carcasses sampled at fish markets)

Since the regressions were truncated to ages 6 and greater, and this age is fully recruited to the fishery and to all gear types sampled, the type of sampling gear should not matter.

Sunada's sample size for fully-recruited ages (6 to 15 years) was significantly greater (N = 718) than that of Reilly and Tanaka (Table 1). Sunada (1990) showed that only 11% of female halibut aged were greater than 8 yr old, and 78% of all fish aged at 6 yr or greater were ages 6 and 7. This may indicate a strong pulse of recruitment, which likely was influenced by the 1982-83 El Niño event. On the other hand, data from Reilly and Tanaka (N = 129 , age range 6 to 19) showed 25% of female halibut aged were greater than 8 yr old, and were characterized by a lower proportion of 6- and 7-yr olds (59%). There were an equal number (50) of halibut aged at 5 yr and 6 yr by Reilly and Tanaka. Although one could make the case that fully recruited ages now range from 5 to 19, the 5-yr old fish were omitted from the calculation of Z to make results more comparable. The lack of one or two relatively strong year classes agrees with Maunder's basic conclusion of lack of recruitment for halibut during the past decade. The age distribution at present is more spread out than it was in the late 1980s.

Only those age class bins with two or more fish were used to calculate total mortality. Estimates of Z were as follows:

0.526 ± 0.103 from Sunada data (ages 6-13)

0.359 ± 0.051 from Reilly and Tanaka data (ages 6-15)

To put this in perspective, a NMFS Annual report on the resources of the continental shelf of Oregon (Demory and Robinson 1972) listed estimates of total instantaneous mortality Z for nine flatfish species. The estimates for females ranged from 0.28 to 0.68 and the average was 0.46. Another report about commercially important groundfish species off the California, Oregon, and Washington coasts (Pikitch and Rogers 1989) listed Z values for female rex sole from 0.43 to 0.51 and for female arrowtooth flounder from 0.16 to 0.42. The values calculated for California halibut in our assignment are near the mid-range of other flatfish estimates and for this reason appear to be reasonable.

Recreational fishery data from 1980 through 1987 were used by Helvey and Witzig (1990) to estimate total instantaneous mortality of female California halibut for each of those years. Fish were not aged directly; length frequency distributions were converted to estimated ages using age-at-length data from 1955 to 1966. Total mortality for the female population showed significant fluctuations in the early 1980s and a gradually increasing trend since 1984. Range of calculated Z was 0.12 to 0.46 and the average was 0.27. Helvey and Witzig did not report maximum estimated age, but based on a visual examination of their age distribution graph, very few female halibut greater than age 10 were observed. They stated that the majority of sampled female halibut were estimated to be from 3 to 6 years of age, which may reflect both strong recruitment in those years and a different age distribution for the portion of the stocks harvested by the recreational and commercial fisheries.

Task 2. **Fishermen Interviews**

The three primary commercial gear types were represented (26 gill net or trawl, 4 hook-and-line) by the selected pool of fishermen. Two known active halibut fishermen (trawl) were later added due to their time in the fishery and willingness to participate in the interview. See Appendix 1 for a summary of interview results by question.

Of the 32 attempts to contact fishermen, 11 were successful. The remaining 21 could not be contacted in the time frame allowed for this task for one of the following reasons: phone disconnected; wrong number; no answering machine; phone calls not returned after multiple messages were left.

Several general observations could be made. Fishermen that used gear which is prohibited in certain areas (gill net or trawl) felt their total catch was greatly affected by regulation and management changes. While their total catch was reduced due to gear limitations or area closures, average size of halibut seemed to increase. Hook-and-line fishermen, while not affected by regulation change, also saw an increase in the average size of halibut caught. Two of the three hook-and-line fishermen felt that overall catch varied with no increase or decrease. The observed increase in average size and lack of small halibut in recent years supports the lack of recruitment in southern California as stated in Maunder’s stock assessment.

Temperature and oceanic changes (current direction and strength, El Niño, la Niña) were very influential in locating and catching halibut. All active fishermen noted that 2010 was an extreme cold water year, resulting in poor fishing. By contrast, 2009 had normal water conditions and fishing was rated as good/ excellent. Poor oceanographic conditions are a factor in reducing recruitment.

While two fishermen reported that they were familiar with the perceived issue of a scarcity of halibut in Santa Monica Bay, five other fishermen also contributed comments. These fishermen did not believe that there is a scarcity of halibut in Santa Monica Bay, but the reduced catch was most likely due to oceanic conditions and a lack of knowledge by recreational anglers in understanding the local halibut fishery. Pollution in Santa Monica Bay was also a common concern.

Task 3. **Length Frequency Distribution Analysis**

All length frequency histograms used in the analysis are shown in Appendix 2. For the commercial fishery data, trawl gear consistently caught fish of a smaller mean length than gill nets, which agrees with Maunder’s statements about differences in gear selectivity in the commercial fishery. The results of the trend analysis indicated that the mean lengths of trawl- and gill net-caught fish have significantly increased over the past three decades. This trend may be due to low recruitment events in the past decade, as described by Maunder. The gill net histograms (as well as the trawl histograms to a lesser extent) showed the length distributions in the 1980s as being clumped towards the smaller end of the spectrum, becoming slightly more spread out in the 1990s with more large fish present, and by the 2000s shifting much more towards the larger end of the spectrum and showing a much wider, less clumped, distribution. Figure 1 illustrates the change in mean length by gear type over time (all years with sample sizes less than 30 were excluded).

For the recreational fishery data, the early period (1980-1989) showed no significant trend in mean lengths over time, but the late period (1993-2010) showed a highly significant positive trend (Figure 2). Overall, from 1980-2010, there is a significant positive trend in mean lengths for halibut sampled from the PR mode. Again, this supports the general conclusion that halibut have had poor recruitment in the 2000s.

Task 4. **Ratio of Halibut Discarded by Recreational Private/Rental Boat Anglers**

The early period showed a significant trend in an increasing amount of discarded fish to retained fish from 1980-1989 (Figure 3). More discards presumably means there were more fish being caught that were less than the minimum legal size of 22 inches during that period. The later period did not show a significant trend, but overall from 1980-2009 there was a significant trend in lower discard rates over the past three decades. Since it is assumed that any fish at or above 22 inches is retained by a recreational angler, the lower discard rates in recent years further support the idea of relatively low recruitment in recent years.

Task 5. **Trends in Trawl Logbook Data**

Maunder's analysis determined that the data were unstable and the average annual CPUE results were deemed unreasonable. The data were particularly hampered by a small sample size prior to 1994 which resulted in high variability. Maunder attempted to standardize the information by using a combination of variables to produce consistent records for evaluation. Index of abundance was calculated by dividing total catch (CMASTER data) by total effort (from logs available). Ultimately, the trawl logbook database was considered by Maunder as an unreliable index of abundance and was not used as part of the assessment.

<u>Analysis 1</u>. For the years 1981-1993, there were great fluctuations in average catch and few effort records relative to total catch recorded for those years (Figure 4). Trawl logs from 1981-1993 were entered into the trawl log database at a severely reduced level due to lack of staff. No records were entered for 1984. This may have contributed to the instability in Maunder's analysis. All available logs were entered for 1994-2010.

Except for the two modest peaks in 1996 and 2009, average annual catch per tow from 1997-2008 with at least one halibut per tow was relatively stable. In 2009 there was a sharp increase in average CPUE with a slight drop in 2010. Effort increased from 2008 to 2009 by 14%, but catch increased by 97%. Of interest is that this trend of an increase in CPUE in the two most recent years parallels that of the CPFV logbook data, which were used by Maunder in the stock assessment.

<u>Analysis 2</u>. For those tows that specified that halibut was the target species (1997-2010), average catch per tow by year decreased from 27.5 kg (1997) in 1997 to a low of 10.3 kg per tow in 2003 (Figure 5). Average catch increased from 2004 (10.9 kg) to a period high of 32.7 kg in 2009. The average of the yearly averages is 18.2 kg. The lack of a consistent trend during this shorter period is consistent with Maunder's observation of no trend during the longer period of 1980 to 2010 in the CPFV logbook data. Since analysis 2 was dependent upon a declared target species, compliance and improved log completion may have contributed to the increase from the 2008 to 2009 season (see analysis 3).

<u>Analysis 3</u>. From 1997-2008, the trend was mostly flat but increased slightly (Figure 6). A significant increase in catch occurred in 2009, with a slight drop into the 2010 season. Due to the subjective filtering process, some halibut tows that had shrimp/ sea cucumber incidental catch may have been excluded. These tows may have declared CHLB/ UHLB or NSM as the target. Vessels that targeted shrimp and used the groundfish trawl logbook decreased significantly in 2009. Fishermen that targeted sea cucumber also have become more compliant in reporting their target species since 2009. This is possibly due to LED's enforcement of accurate reporting within the fishery, as well as attention to editing and entry into the database by field staff. This change in reporting increased the accuracy of the data and kept more information in the analysis resulting in an apparent increase in catch.

Overall, the availability of trawl logbook data was poor prior to 1994. The application of several different filters for data subsequent to that year yielded variable annual CPUE with no consistent trend. This would appear to substantiate the conclusion by Maunder of a fishery that, although heavily exploited, is still above a level that could produce maximum sustainable yield.

Task 6. **Calculation of Optimum Harvest Size**

Five estimates were calculated for L_{opt}: four using the largest southern California female halibut sampled by Reilly and Tanaka each year from 2007 to 2010 and one using the largest southern California female halibut sampled by Sunada et al. during 1985-88. These largest fish ranged from 1065 to 1156 mm.

L_{opt} ranged from 626 to 680 mm. This length interval contains the average length for only two ages of female halibut aged by Sunada et al. and Reilly and Tanaka, 6 and 7 years, These ages are the first two age classes which are fully recruited to the fishery, based on age composition data from samples. This length range is that found generally in the right half of the modes of the combined length frequencies for the three primary commercial gear types summarized by Maunder in the stock assessment (Figure B2.8.1, top two and center right graphs). Thus, this simplistic exercise appears to validate the current fishery management strategy for optimizing harvest size. The minimum legal size for halibut allows spawning to occur at least once in the lifetime of a fish, and allows the optimum age classes to be fully recruited to the fishery. Female halibut mature at 4-5 years of age (California's Living Marine Resources: A Status Report 2001).

CONCLUSIONS

The results of this exercise validate the need for long-term fishery-dependent and fishery-independent data sets using standardized protocols in order to make credible conclusions about the status of a fished stock. Quality control of the data and consistent data entry procedures are also critical. This is evident within the trawl log and CMASTER data sets. The stock assessment contractor excluded many of the California halibut data sets provided to him by the Department in his stock synthesis model primarily due to temporal data gaps, changes in sampling methodology, or high variability from small sample sizes. In reviewing the papers from the data poor workshop, the two most valuable data sets required for fishery resource status evaluation are a long-term series of fishery-independent surveys for size and age composition and a long-term series of age composition by sex from the commercial and recreational fisheries (the latter is critically important for a species with different growth rates for males and females).

The stock assessment contractor was only able to incorporate a few of the data sets into the model in determining a biomass estimate for southern California. The six tasks conducted here were simplistic, yet none of them produced any results which would significantly differ from the stock assessment's conclusion of a heavily exploited yet sustainable biomass of California halibut in southern California, and the relative scarcity of recruitment during the last decade. Other scientists are encouraged to consult the literature related to the Data-Poor Workshop and apply relevant techniques to assess fisheries which are lacking in comprehensive sets of fishery-dependent and fishery-independent data.

LITERATURE CITED

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Table 1. Southern California female California halibut age composition data used to calculate total instantaneous mortality Z

Data from Sunada et al. 1990			Data from Reilly and Tanaka	
Age (years)	Number aged	ln number aged	Number Aged	ln number aged
3	8		10	
4	21		19	
5	175		50	
6	325	5.789	50	3.912
7	235	5.459	26	3.258
8	80	4.382	21	3.045
9	30	3.401	9	2.197
10	11	2.398	11	2.398
11	16	2.773	3	1.099
12	11	2.398	5	1.609
13	8	2.079		
14	1		1	
15	1		2	0.693
16				
17				
18				
19			1	
	Z = 0.526 ± 0.103		Z = 0.359 ± 0.051	

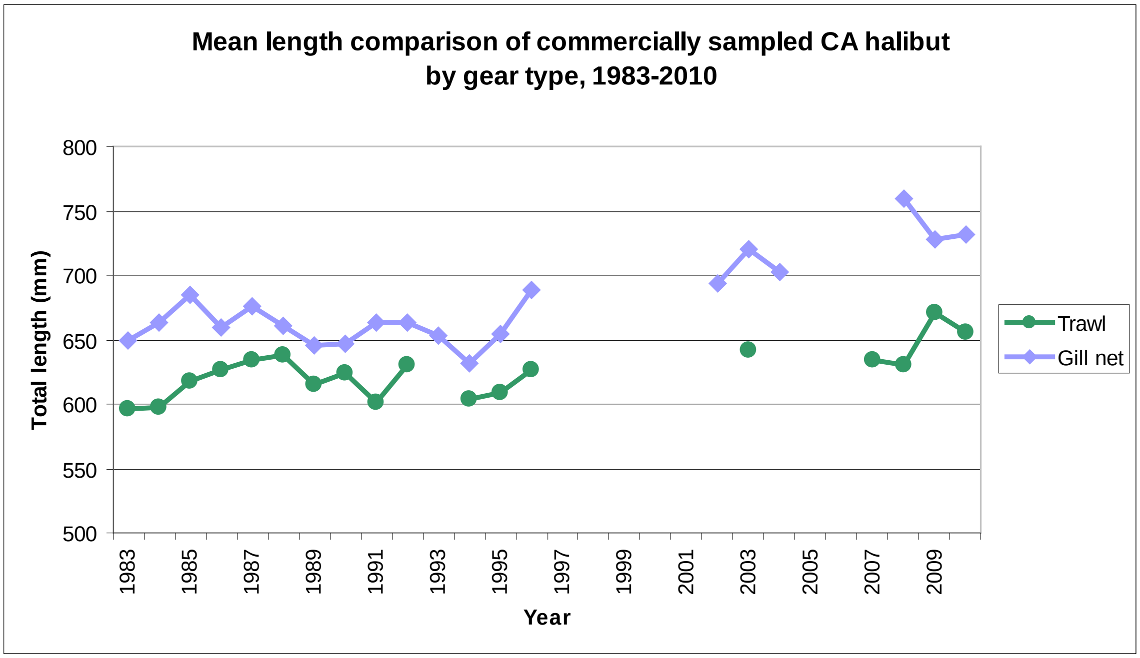


Figure 1. Mean length of California halibut from southern California commercial fishery samples by gear type, 1983 to 2010.

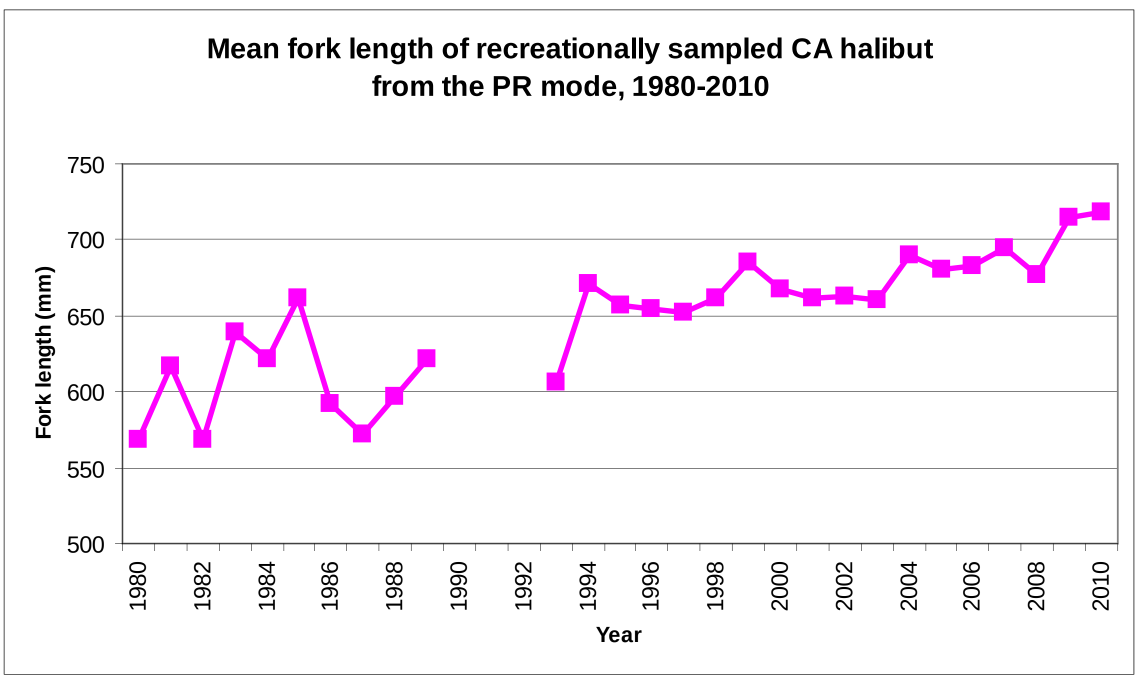


Figure 2. Mean length of California halibut from southern California recreational fishery samples, 1980 to 2010.

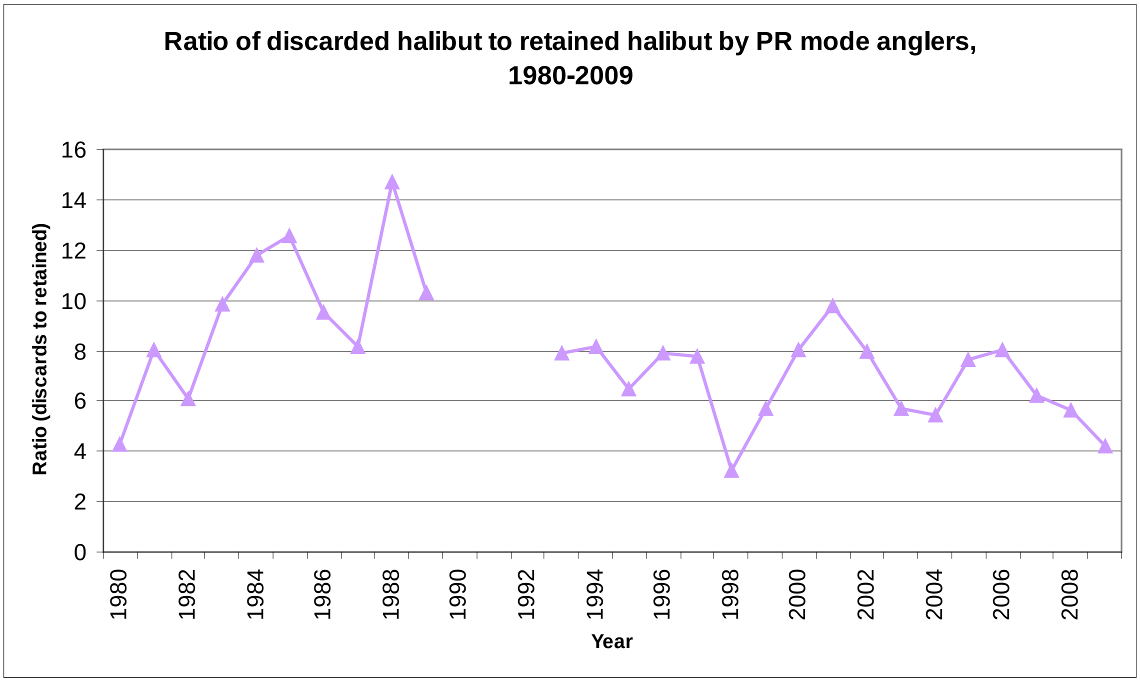
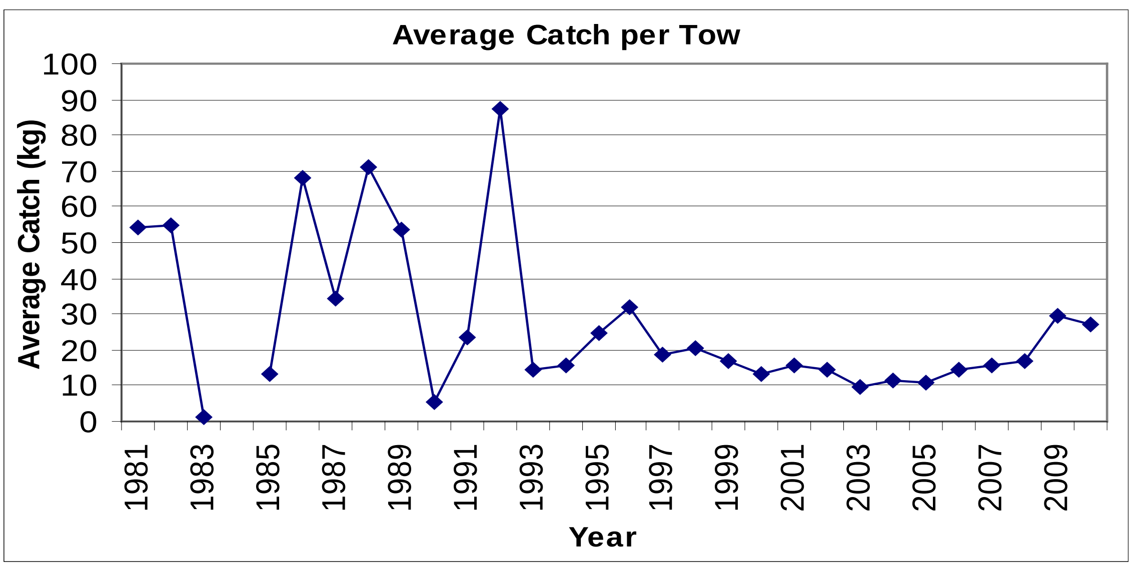
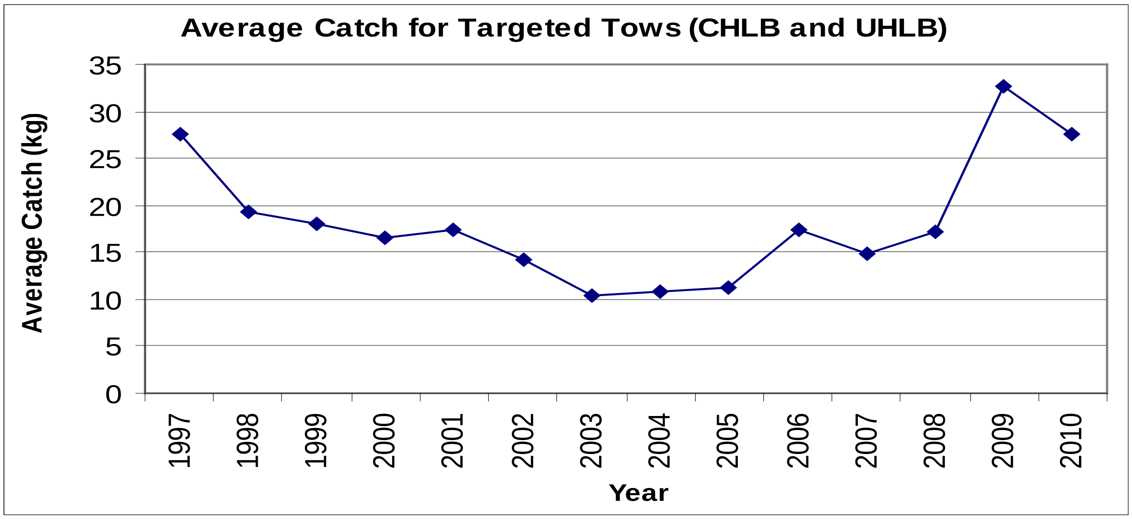


Figure 3. Ratio of discarded to retained California halibut by private and rental boat recreational anglers from 1980 to 2009.



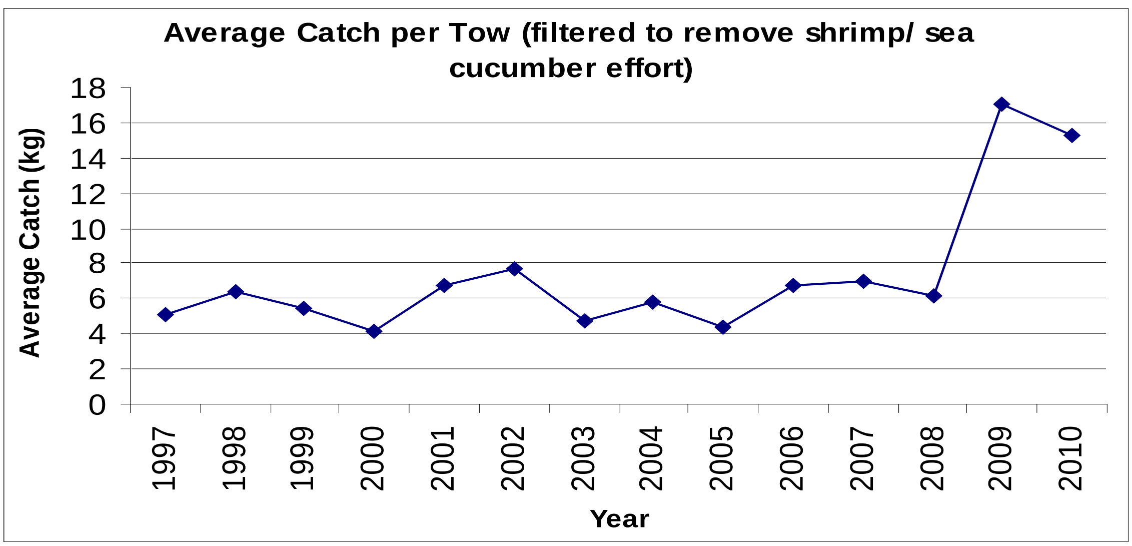
(source:CDFG trawl logs)

Figure 4. Average catch per tow (kg) for all southern California commercial trawl tows that had at least one halibut regardless of target species.



(source:CDFG trawl logs)

Figure 5. Average catch per tow (kg) for all southern California commercial trawl tows that targeted (CHLB or UHLB). Includes tows that did not catch halibut.



(source:CDFG trawl logs)

Figure 6. Average catch per southern California commercial trawl tow (kg) filtered to remove directed shrimp or sea cucumber effort. The reporting habits of shrimp trawlers changed in 2009.

Appendix 1. Interview form for experienced southern California halibut commercial fishermen with summarized responses

Fisherman name:____

Date of interview:____________________

My name is Travis Tanaka and I am a marine biologist with the Department of Fish and Game. Through the Department's commercial fish landings database, you have been identified as a fishermen with significant landings from the commercial halibut fishery in southern California.

In the near future the Department will be releasing to the public the first stock assessment for California halibut. A stock assessment basically describes the status and history of the resource. It will be separated into components north and south of Point Conception. Shortly after the documents are released we will be conducting a series of public workshops in southern California to discuss the southern California stock assessment with fishermen and interested members of the public. Before we release the documents we would like to ask you a few questions about your experience in the fishery during the past decades. Your responses will remain confidential, and they will help us evaluate the southern California assessment and explain it to the public. Do you have a few minutes to answer some questions?

(Results are in *italics*)

1. How many years have you commercially fished for California halibut in southern California?

The 11 fishermen collectively had 304 years of halibut fishing experience in southern California

2. How important is the commercial halibut fishery to you as a source of income?
   a. Less than 25% of total income; *2 fishermen*
   b. 25-50% of total income; *5 fishermen*
   c. Greater than 50% of total income. *4 fishermen*

3. What gear type(s) have you used during this time (list years for each gear if more than one gear) *Gill net only= 3 fishermen (100.5 y); Trawl only= 3 fishermen (53 y); Hook-and-Line only= 2 fishermen (42 y); Gill Net and Trawl= 2 fishermen (27 y-gill net and 54.5 y- trawl); Gill Net and Hook-and-Line= 1 fisherman (10 y-gill net, 15 y-h&l)*

4. What locations in general in southern California have you fished for halibut?
   a. Point Conception to Point Dume *9 fishermen*
   b. Point Dume to Palos Verdes Peninsula *4 fishermen*
   c. Palos Verdes Peninsula to Dana Point *4 fishermen*
   d. Dana Point to Mexico border *4 fishermen*
   e. Santa Barbara Channel Islands *3 fishermen*
   f. Santa Catalina or San Clemente Island *3 fishermen*

(If more than one gear used, ask all questions for each gear)

We realize that the fishery has experienced some regulation changes over the years, such as gill net closures and changes in regulations within the California Halibut Trawl Grounds.

5. Do you think these changes in regulations have affected your catch rates or the average size of fish you catch?

(If yes, ask the following two questions):

All gill net and three trawl fishermen answered "yes"

5b. Have your catch rates:

a. Generally increased *Gill Net=0; Trawl=0*

b. Generally decreased *Gill Net=4; Trawl=1*

c. Varied each year with no general increase or decrease *Gill Net=1; Trawl=2*

5c. Has the average size of California halibut you have caught:

a. Generally increased *Gill Net=4; Trawl=1*

b. Generally decreased *Gill Net=0; Trawl=0*

c. Varied each year with no general increase or decrease *Gill Net=1; Trawl=2*

If no, ask the following:

Two trawl fisherman and all hook-and-line fishermen answered "no".

5d. During your years of fishing, have your catch rates of California halibut:

a. Stayed the same *Trawl=1; H/L=0*

b. Generally increased *Trawl=0; H/L=0*

c. Generally decreased *Trawl=0; H/L=1*

d. Varied each year with no general increase or decrease *Trawl=1; H/L=2*

e. None of the above (explain) *Trawl=0; H/L=0*

5e. During your years of fishing, has the average size of California halibut you have caught:

1. Stayed the same *Trawl=1; H/L=0*
2. Generally increased *Trawl=1; H/L=3*
3. Generally decreased *Trawl=0; H/L=0*
4. Varied each year with no general increase or decrease *Trawl=0; H/L=0*
5. None of the above (explain) *Trawl=0; H/L=0*

6. Are their any species associated with California halibut that you have seen increase significantly over the years in your catch?

Black seabass, California scorpionfish, ling cod, soupfin shark, fantail sole, thornback ray, box crab, starry flounder, english sole.

Four fishermen answered that they have not observed any associated species increase.

7. Are their any species associated with California halibut that you have seen decrease significantly over the years in your catch?

Various rockfish species (1980's), spiny dogfish, thornback ray, blue shark, bat ray, angel shark. Six fishermen answered that they have not observed any associated species decrease.

8. Have you observed any significant changes in ocean conditions during your years of fishing for halibut? If yes, what changes and approximately when?

2010 was a very cold water year. Major El Nino events resulted in poor catch.

9. During your years of fishing, have you observed any changes in the interactions of marine mammals such as California sea lions and harbors seals with your fishing gear?

If yes, please describe the changes:
All fishermen except for those who use hook-and-line indicated that marine mammals contributed to loss to catch. It was agreed by all that the marine mammal population is increasing and becoming more problematic.

During your years of fishing, do you think the amount of fishing by recreational boats has:
1. Stayed the same *1*
2. Generally increased *7*
3. Generally decreased *2*
4. Varied each year with no general increase or decrease *1*
The main observation regarded the increase in the skiff fleet. Some fishermen thought CPFVs are not changing in number; others thought they were decreasing in number.

Recreational fishermen have expressed concerns regarding a decrease in the population in halibut in Santa Monica Bay, such that an annual fishing derby was canceled in 2010. Are you aware of this? If so, do you believe that there is a local scarcity of halibut within Santa Monica Bay?

Two of the 11 fishermen knew about the situation in Santa Monica Bay. Seven of the 11 had comments. Comments include: no scarcity of halibut, amateur fishermen don't know how to fish, fishing in the wrong spots, pollution, cold water in 2010 made fish move elsewhere, low derby enrollment- use population decrease as a reason to cancel, using wrong type of bait, derby conditions poor, treble hooks kill small halibut, SMB is closed to commercial yet the recreational fleet complains that no fishing-commercial closures do not work,

One hook-and-line fisherman fished in SMB this year and landed 25 halibut in 3 trips.

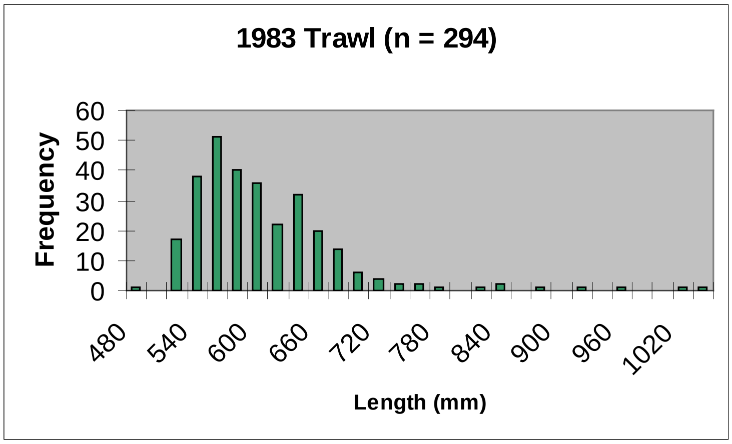
Thank you for your time. Do you have any questions?
When is the Department going to have an FMP for halibut?

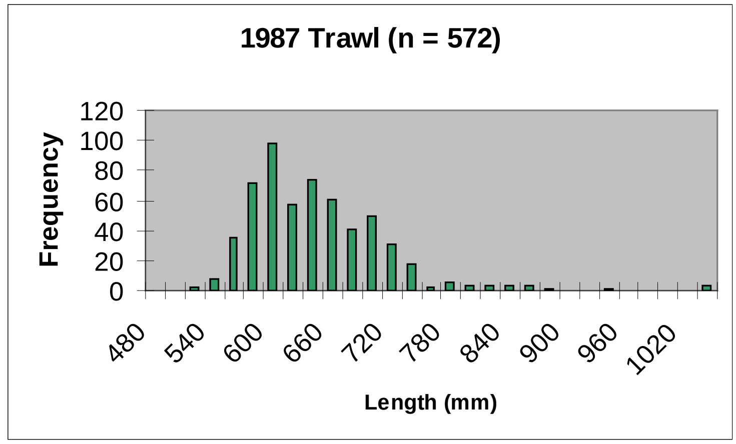
Additional Comments:

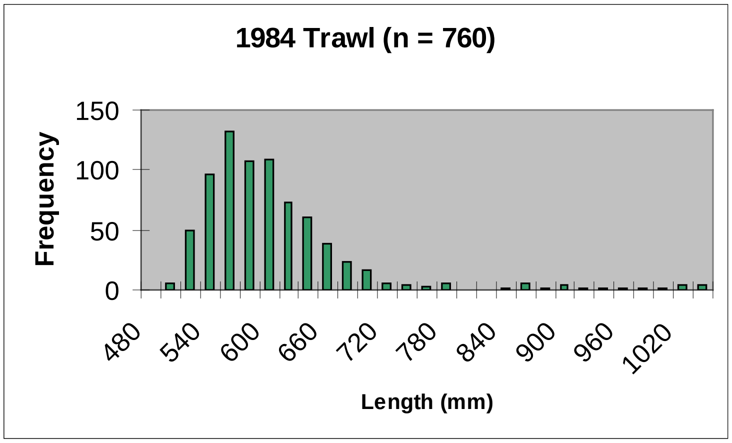
Imported Korean halibut has reduced demand for locally-caught California halibut.
Marine closures force fishermen into the fewer, shared locations resulting in heavy pressure on local stocks.
Fish will move when conditions are wrong within their present location.
Halibut have a 20-year cycle and a lot of fish "on the beach" results in possible good spawning.
Knowledge is important in catching halibut.
There have been a lot of males in the 2011 catch.
The Monterey Bay trawl closure hurt the halibut market.
Halibut are found everywhere but we can only fish 10% of grounds due to closures.
Gill netters have learned to fish smaller nets and small areas-they have become more efficient.

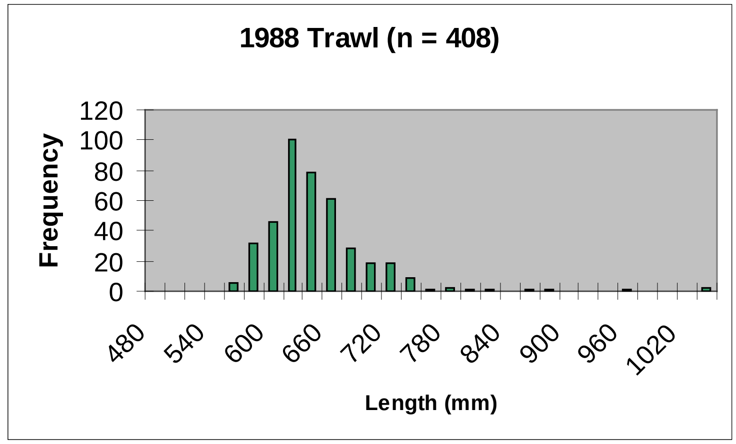
Maintained fishing gear results in better catch.
Fishermen are catching less fish but are getting a higher price.
Halibut are prolific.

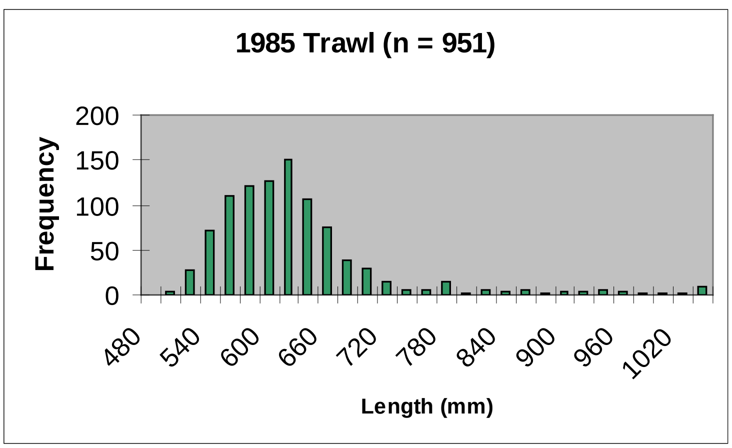
Appendix 2: Length frequency histograms

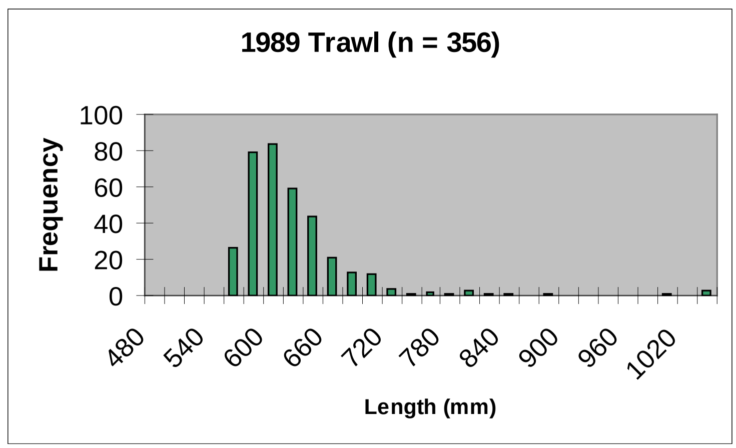


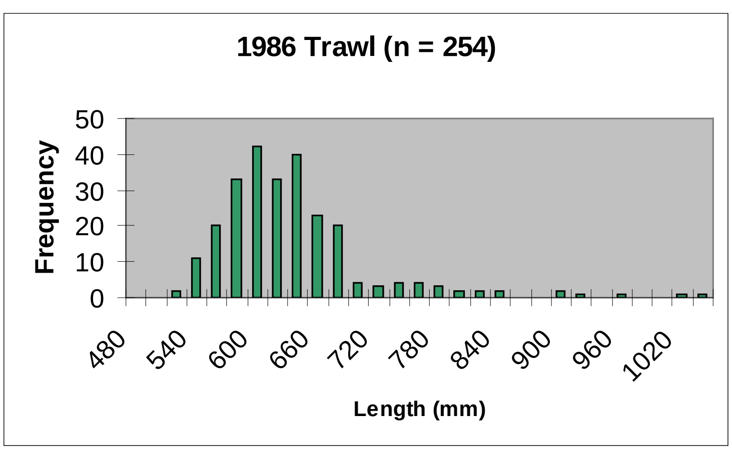


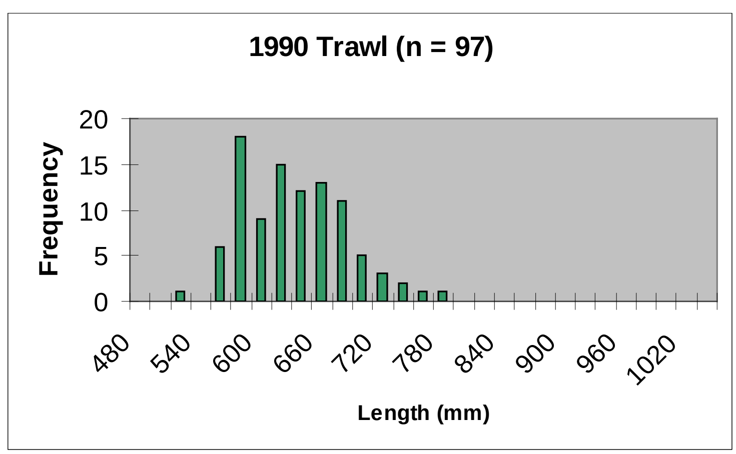


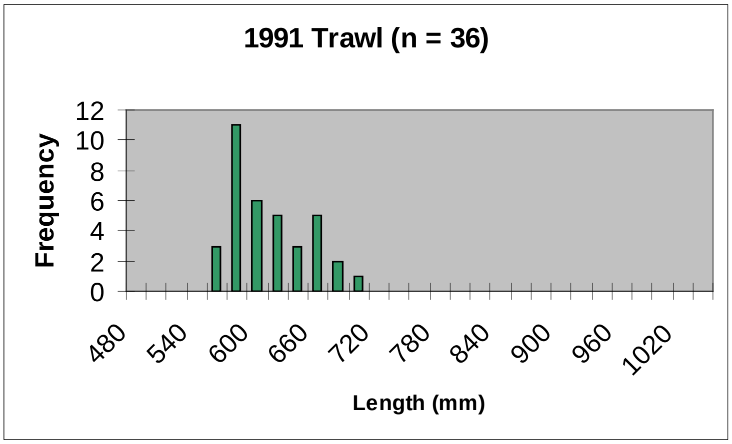











1991 Trawl (n = 36)
Frequency
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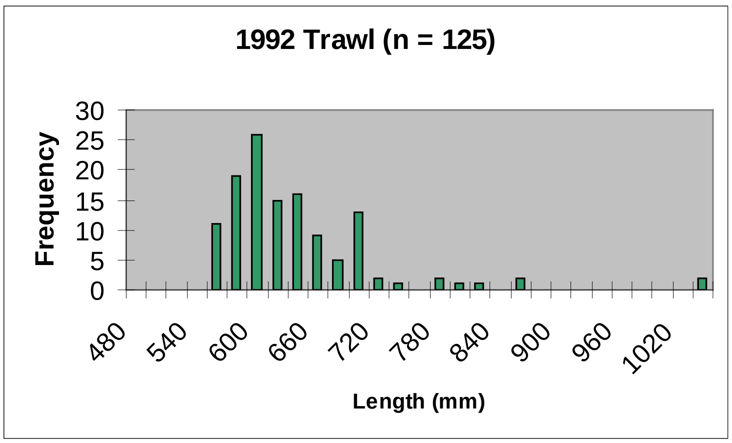
480 540 600 660 720 780 840 900 960 1020
Length (mm)


1992 Trawl (n = 125)
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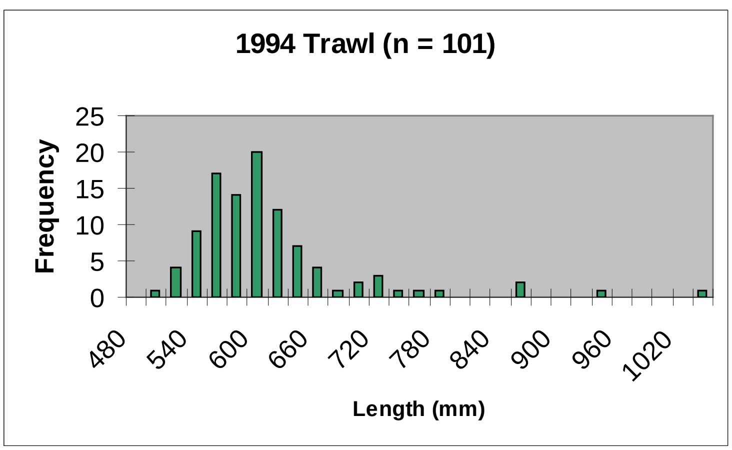
480 540 600 660 720 780 840 900 960 1020
Length (mm)


1994 Trawl (n = 101)
Frequency
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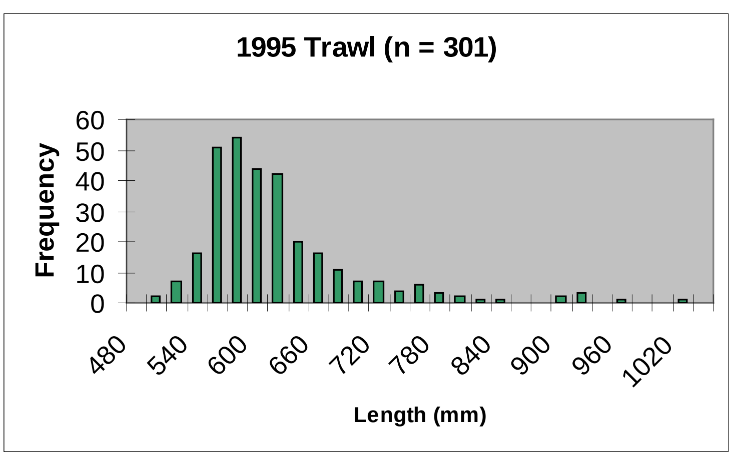
480 540 600 660 720 780 840 900 960 1020
Length (mm)


1995 Trawl (n = 301)
Frequency
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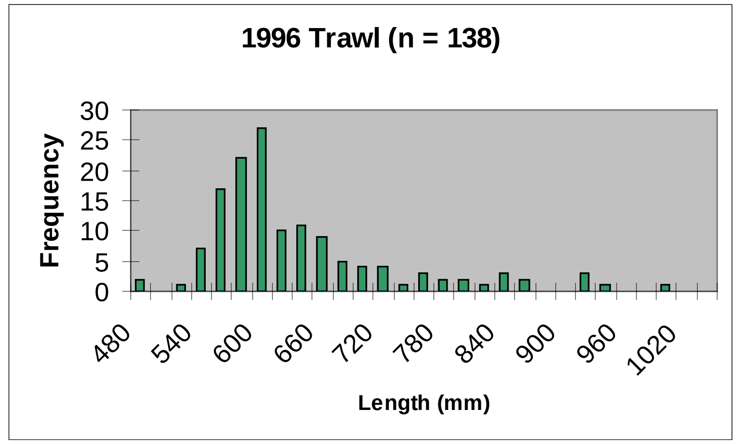
Length (mm)


1996 Trawl (n = 138)
Frequency
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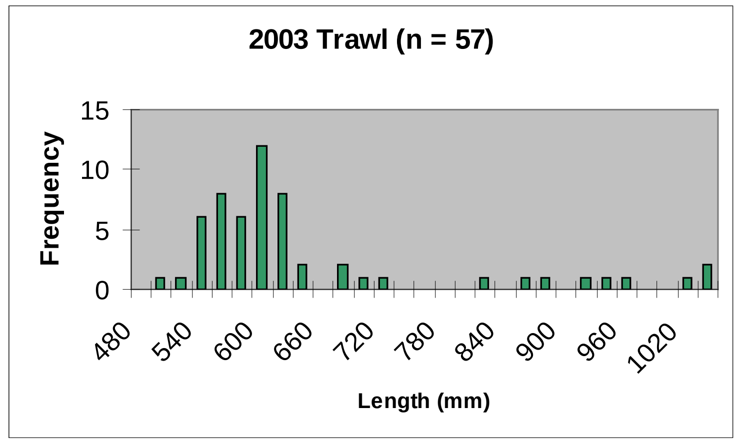
Length (mm)


2003 Trawl (n = 57)
Frequency
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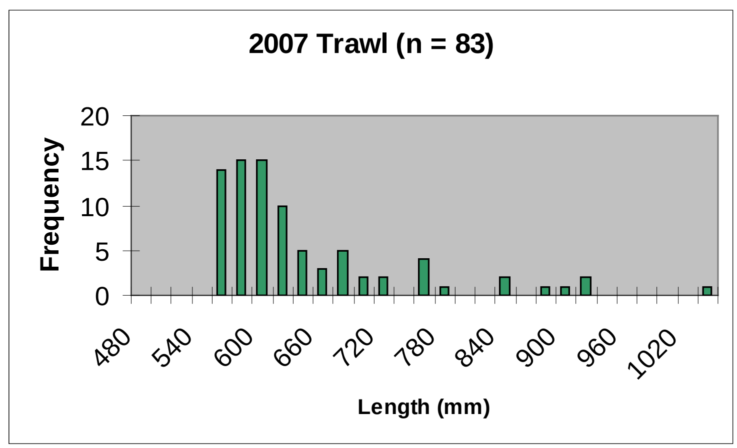
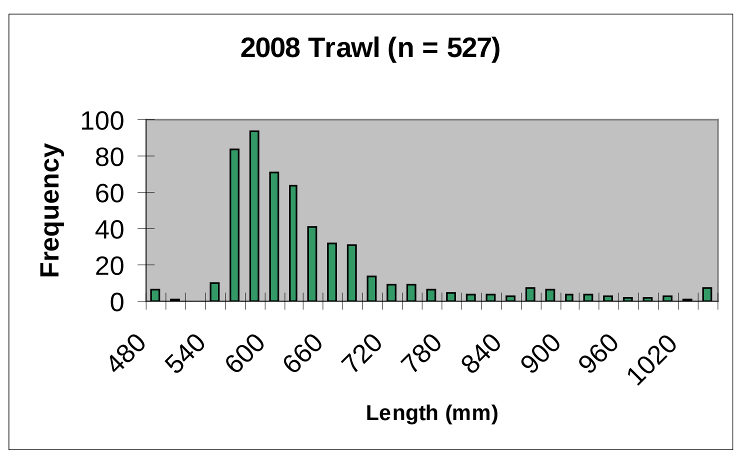
Length (mm)


2007 Trawl (n = 83)
Frequency
0 5 10 15 20
480 540 600 660 720 780 840 900 960 1020
Length (mm)


2008 Trawl (n = 527)
Frequency
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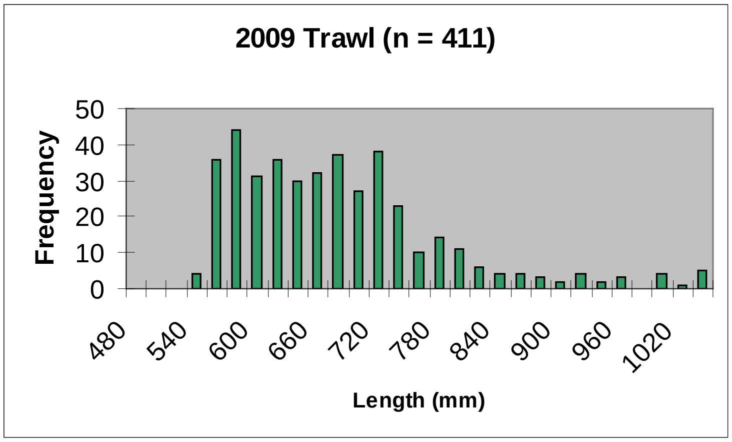
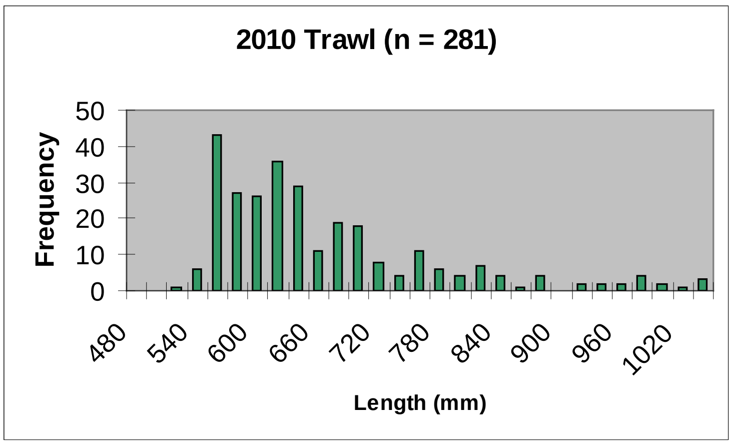
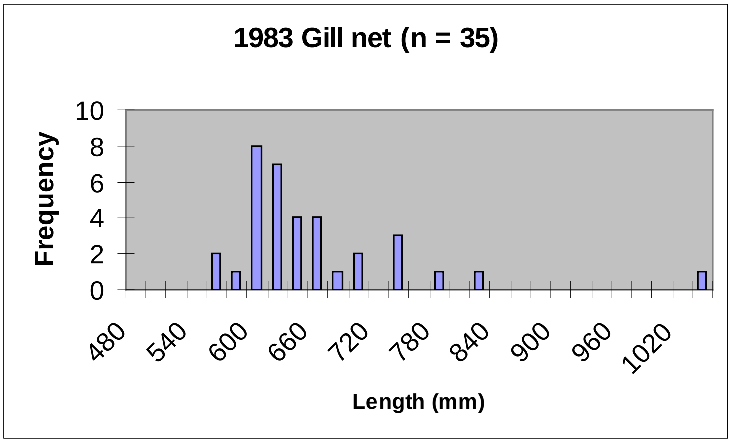
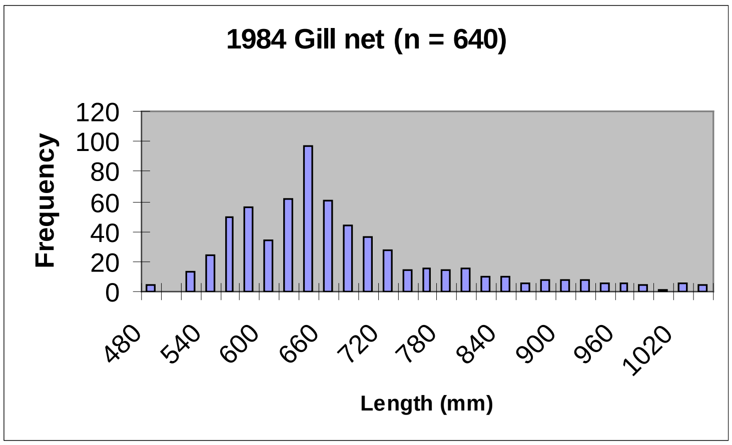
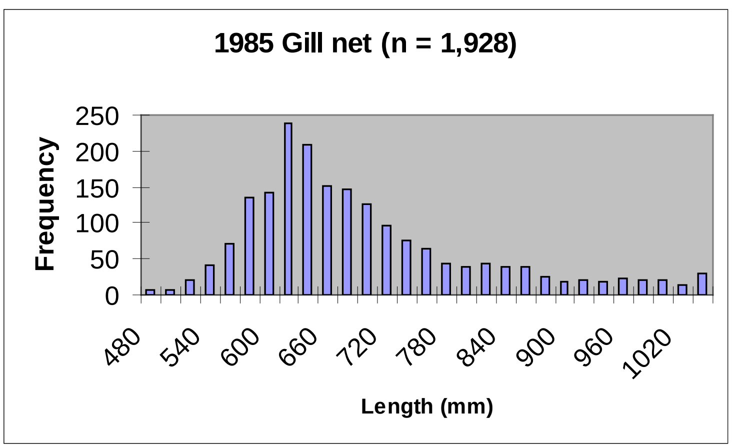
Length (mm)

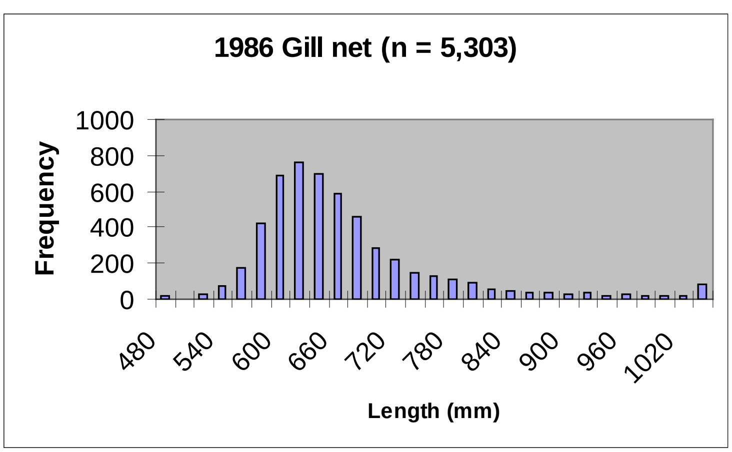

2009 Trawl (n = 411)
Frequency
50
40
30
20
10
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)

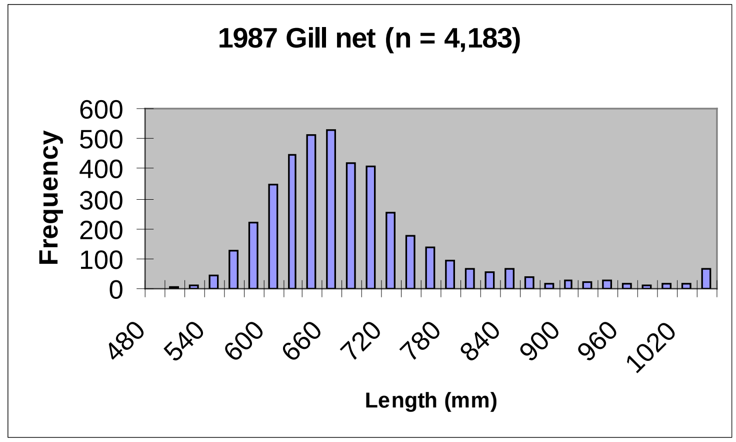

2010 Trawl (n = 281)
Frequency
50
40
30
20
10
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)

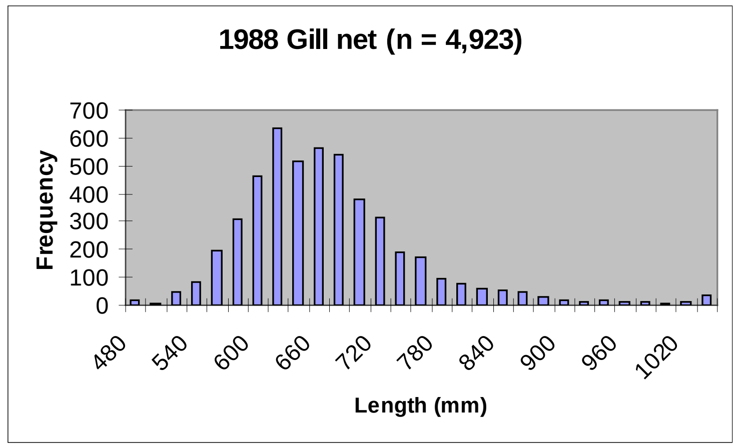

1983 Gill net (n = 35)
Frequency
10
8
6
4
2
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1984 Gill net (n = 640)
Frequency
120
100
80
60
40
20
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1985 Gill net (n = 1,928)
Frequency
250
200
150
100
50
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1986 Gill net (n = 5,303)
Frequency
1000
800
600
400
200
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1987 Gill net (n = 4,183)
Frequency
600
500
400
300
200
100
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1988 Gill net (n = 4,923)
Frequency
700
600
500
400
300
200
100
0
480
540
600
660
720
780
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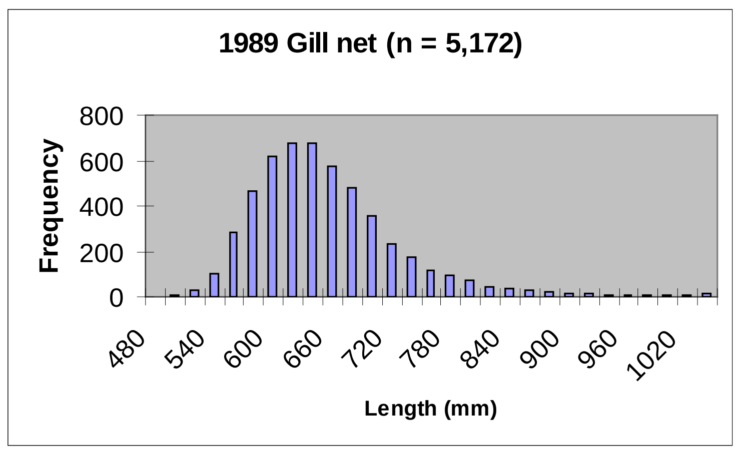
900
960
1020
Length (mm)


1989 Gill net (n = 5,172)
Frequency
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600
400
200
0
480
540
600
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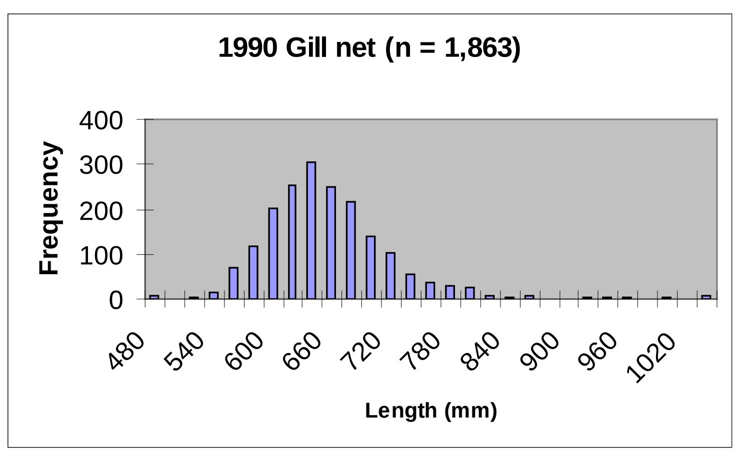
720
780
840
900
960
1020
Length (mm)


1990 Gill net (n = 1,863)
Frequency
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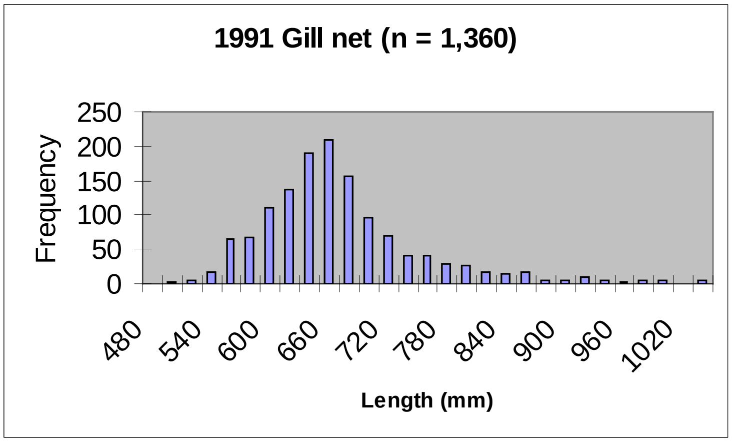
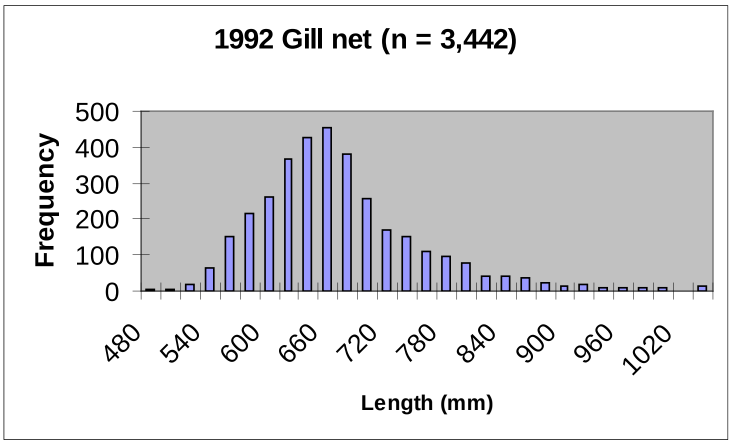
300
200
100
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1991 Gill net (n = 1,360)
Frequency
250
200
150
100
50
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1992 Gill net (n = 3,442)
Frequency
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200
100
0
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540
600
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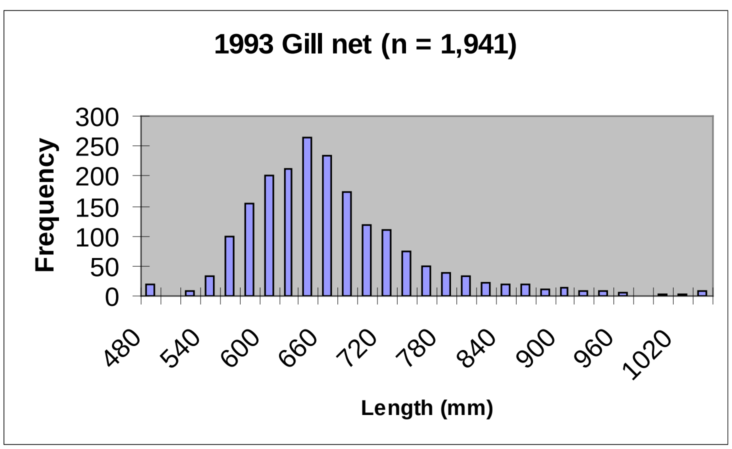
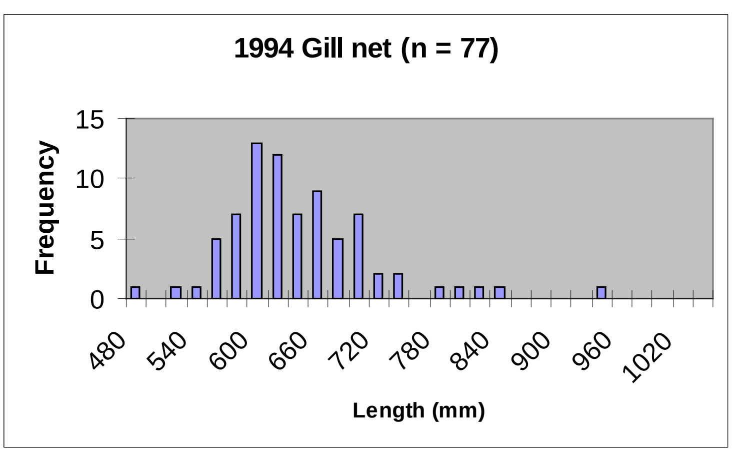
780
840
900
960
1020
Length (mm)


1993 Gill net (n = 1,941)
Frequency
300
250
200
150
100
50
0
480
540
600
660
720
780
840
900
960
1020
Length (mm)


1994 Gill net (n = 77)
Frequency
15
10
5
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540
600
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720
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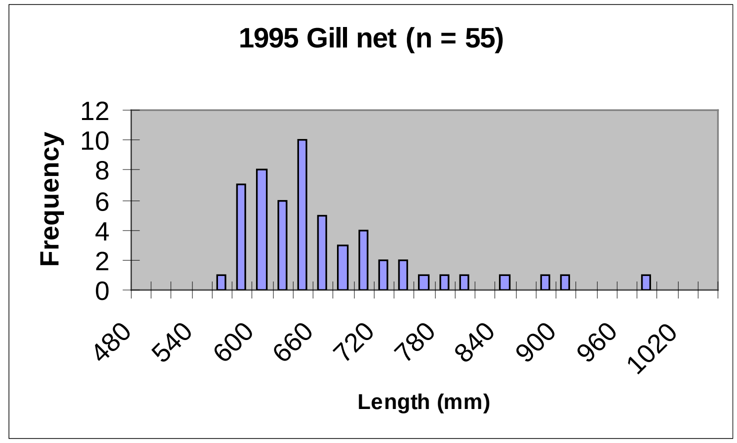
840
900
960
1020
Length (mm)


1995 Gill net (n = 55)
Frequency
12
10
8
6
4
2
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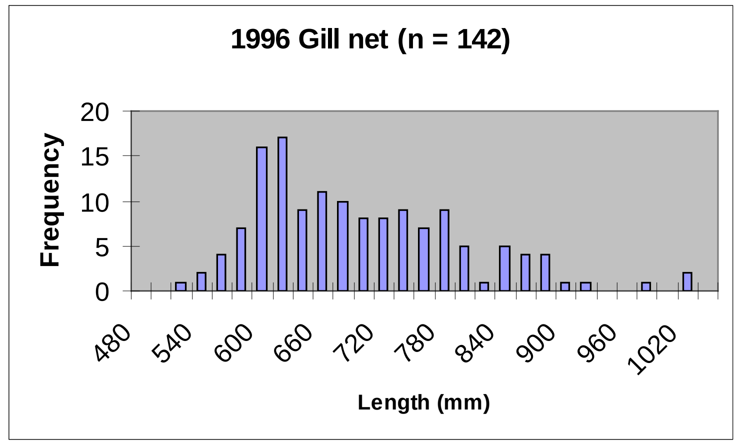
540
600
660
720
780
840
900
960
1020
Length (mm)


1996 Gill net (n = 142)
Frequency
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15
10
5
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780
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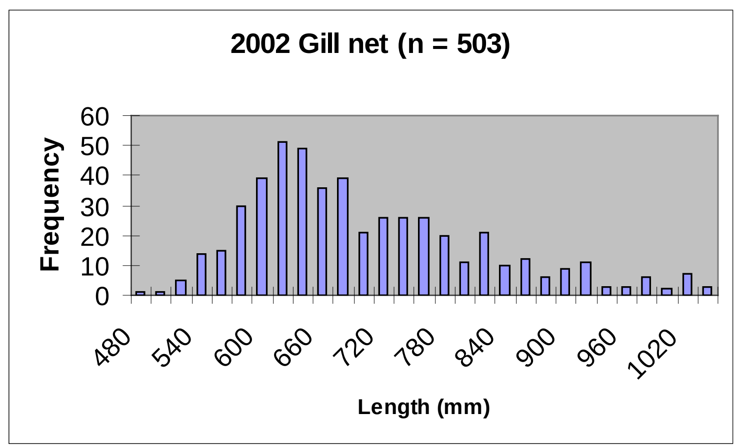
900
960
1020
Length (mm)


2002 Gill net (n = 503)
Frequency
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40
30
20
10
0
480
540
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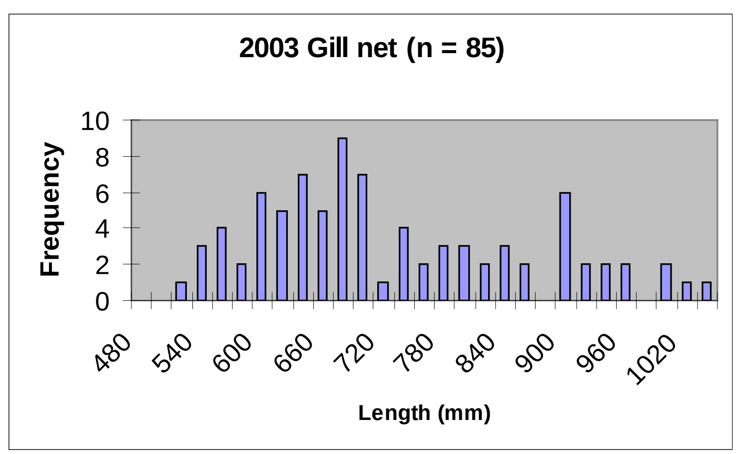
660
720
780
840
900
960
1020
Length (mm)


2003 Gill net (n = 85)
Frequency
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6
4
2
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720
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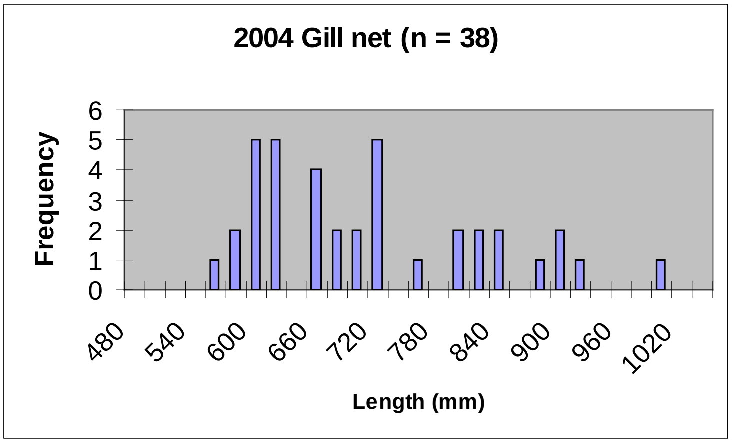
1020
Length (mm)


2004 Gill net (n = 38)
Frequency
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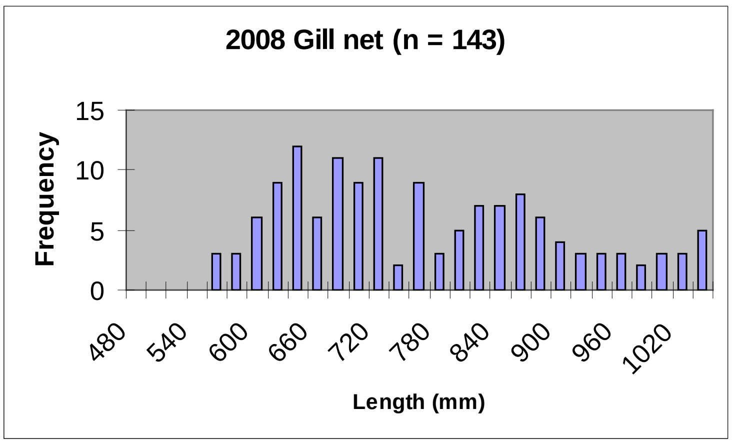
900
960
1020
Length (mm)


2008 Gill net (n = 143)
Frequency
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600
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720
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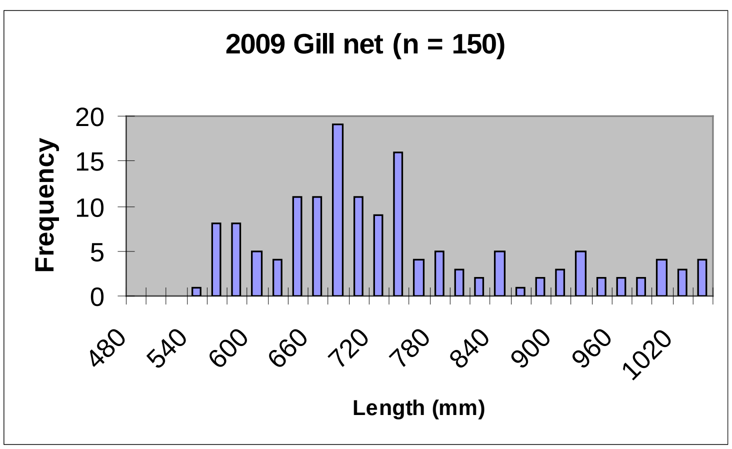
840
900
960
1020
Length (mm)


2009 Gill net (n = 150)
Frequency
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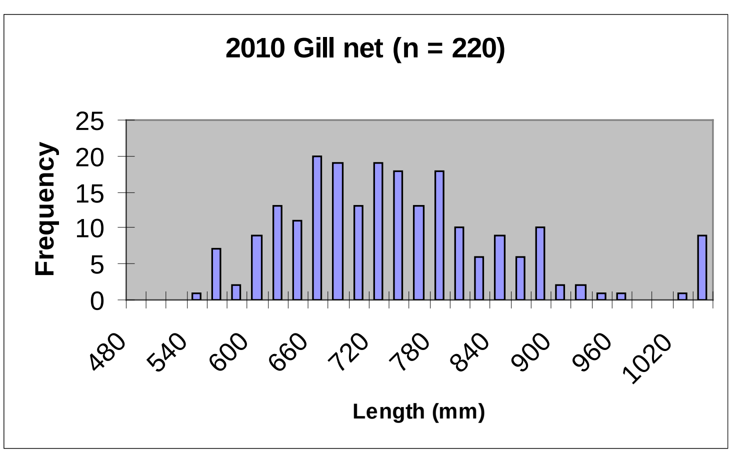
5
10
15
20
480
540
600
660
720
780
840
900
960
1020
Length (mm)


2010 Gill net (n = 220)
Frequency
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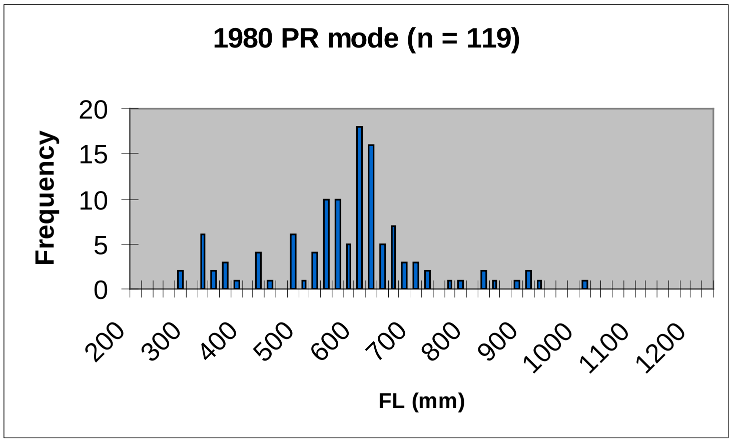
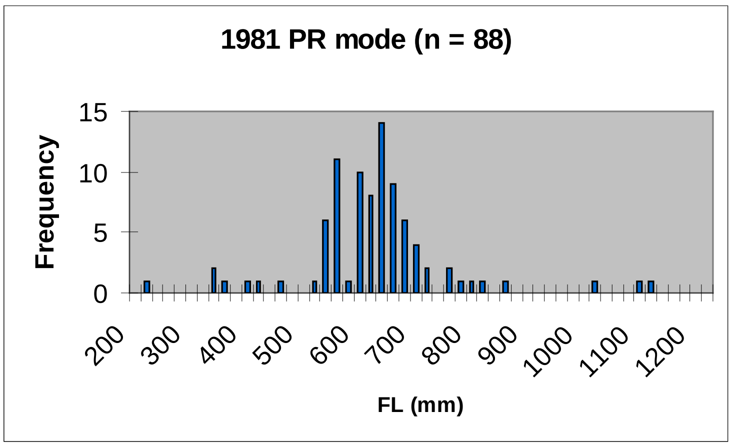
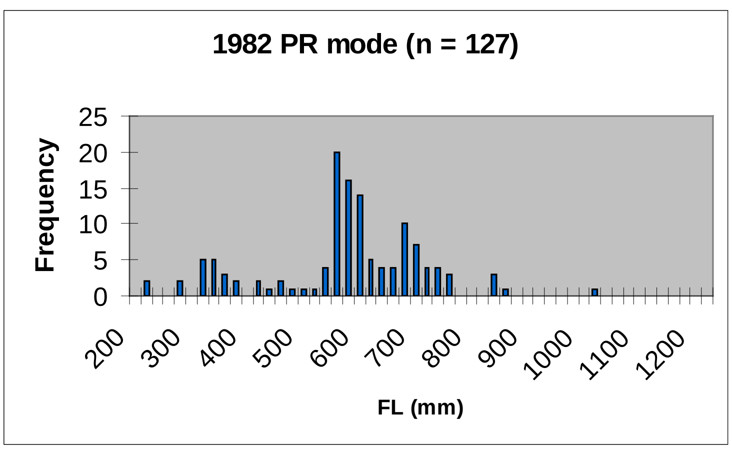
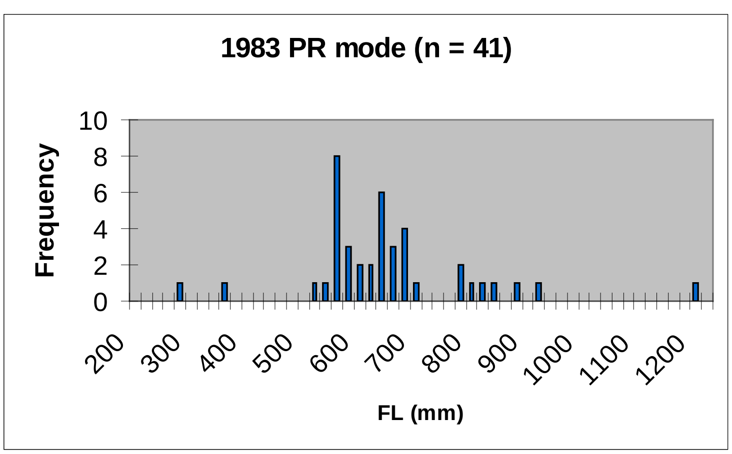
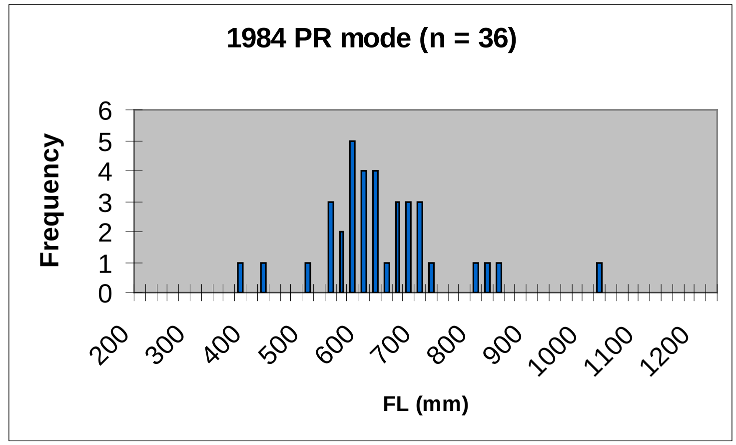
10
15
20
25
480
540
600
660
720
780
840
900
960
1020
Length (mm)

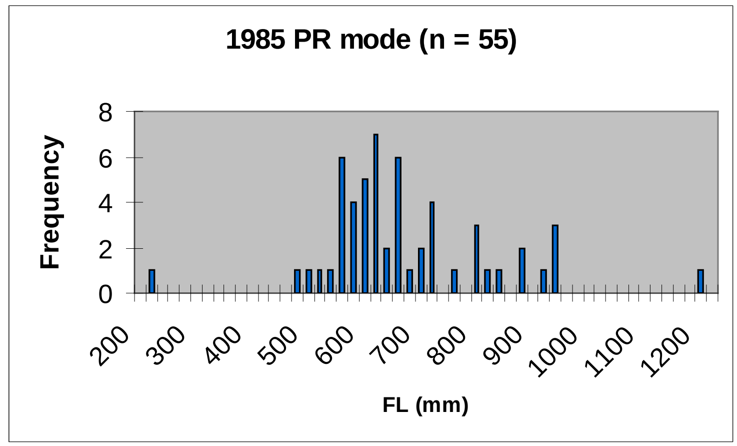

1980 PR mode (n = 119)
Frequency
0
5
10
15
20
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

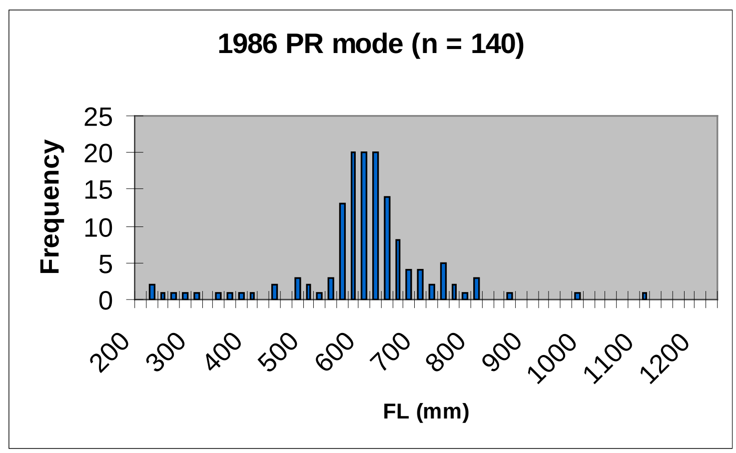

1981 PR mode (n = 88)
Frequency
0
5
10
15
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

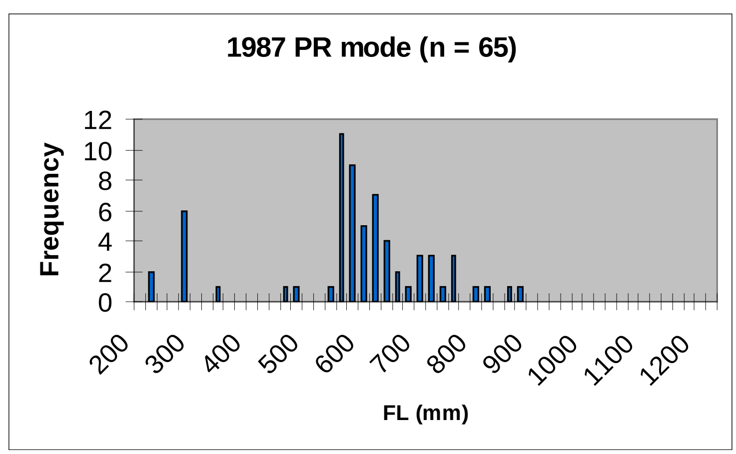

1982 PR mode (n = 127)
Frequency
0
5
10
15
20
25
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

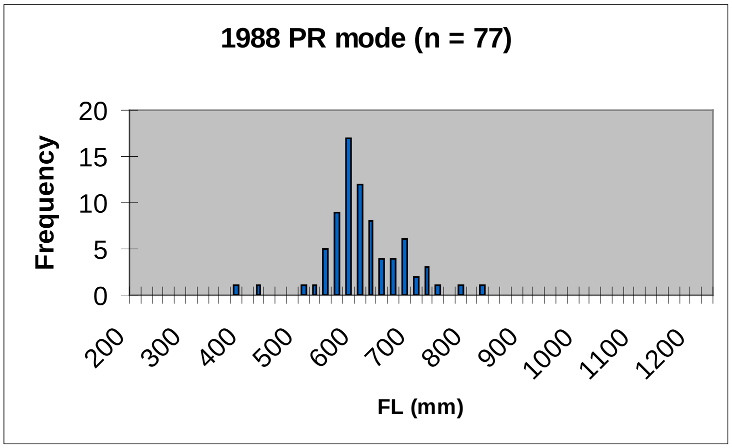

1983 PR mode (n = 41)
Frequency
0
2
4
6
8
10
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

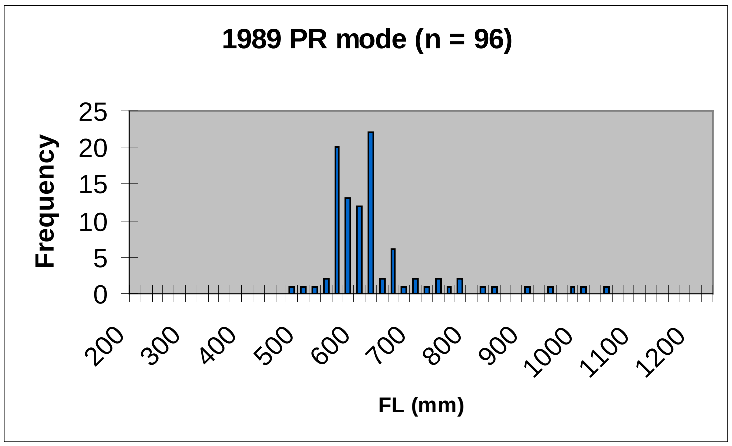

1984 PR mode (n = 36)
Frequency
0
1
2
3
4
5
6
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

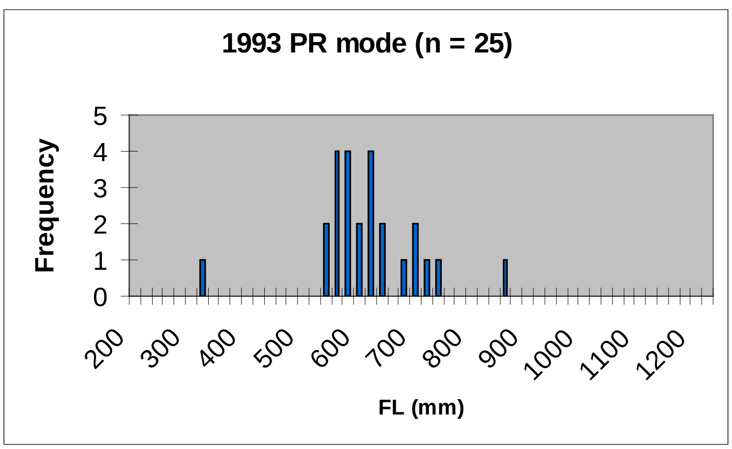

1985 PR mode (n = 55)
Frequency
0
2
4
6
8
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

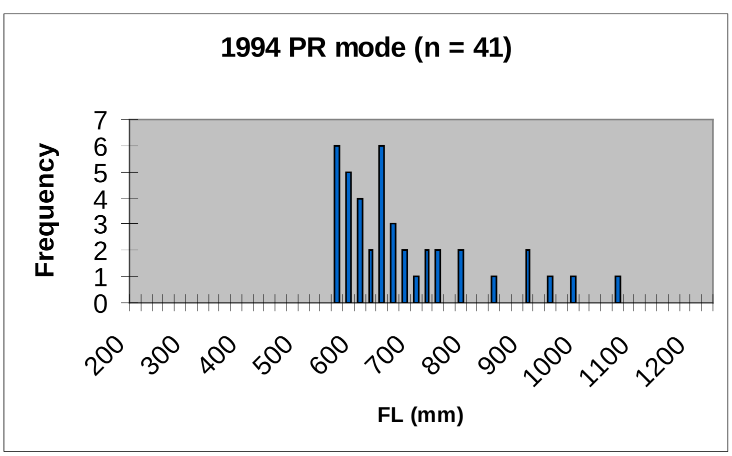

1986 PR mode (n = 140)
Frequency
0
5
10
15
20
25
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

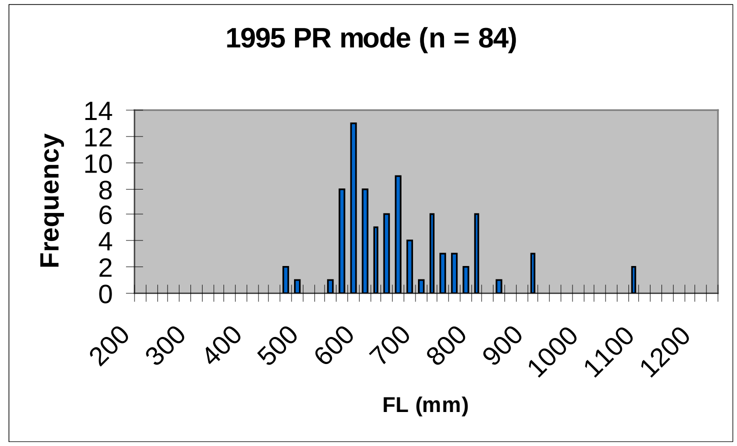

1987 PR mode (n = 65)
Frequency
0
2
4
6
8
10
12
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

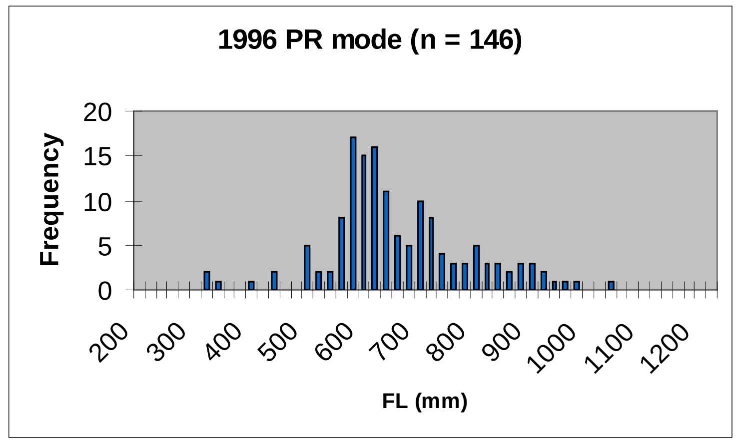

1988 PR mode (n = 77)
Frequency
0
5
10
15
20
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

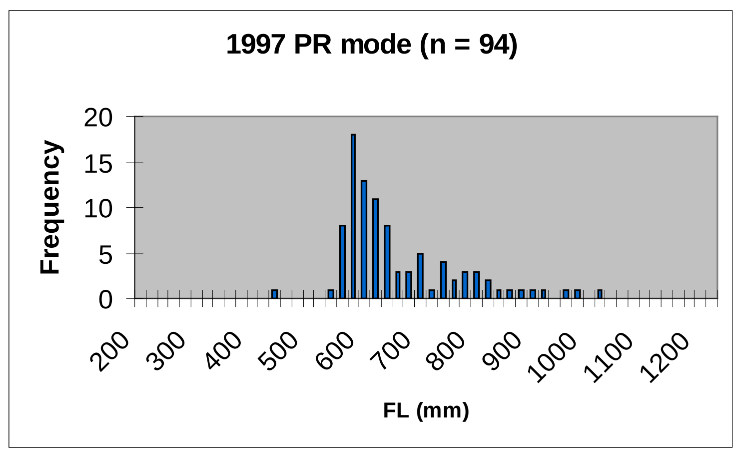

1989 PR mode (n = 96)
Frequency
0
5
10
15
20
25
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

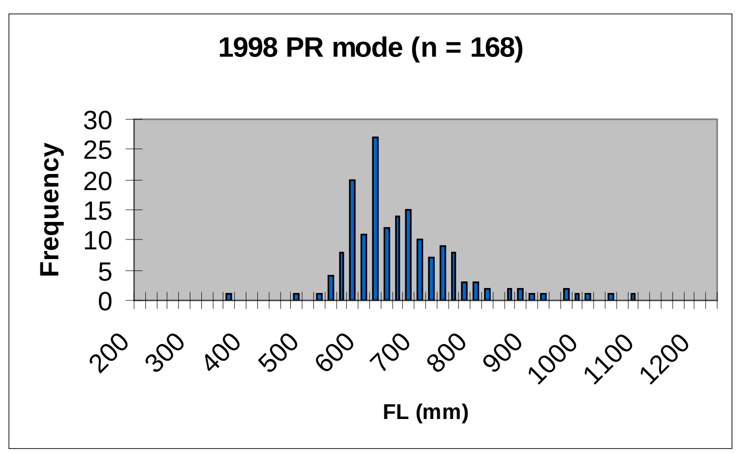

1993 PR mode (n = 25)
Frequency
0
1
2
3
4
5
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

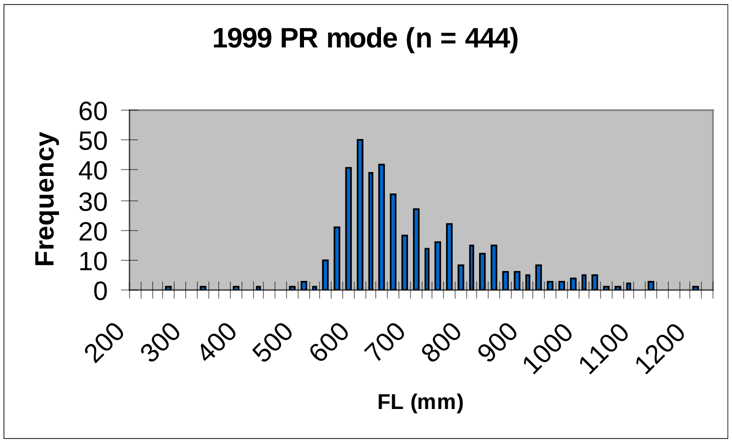

1994 PR mode (n = 41)
Frequency
0
1
2
3
4
5
6
7
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

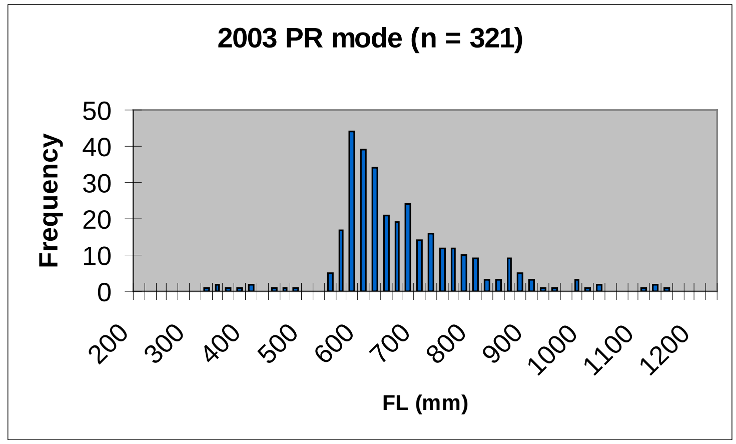

1995 PR mode (n = 84)
Frequency
0
2
4
6
8
10
12
14
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

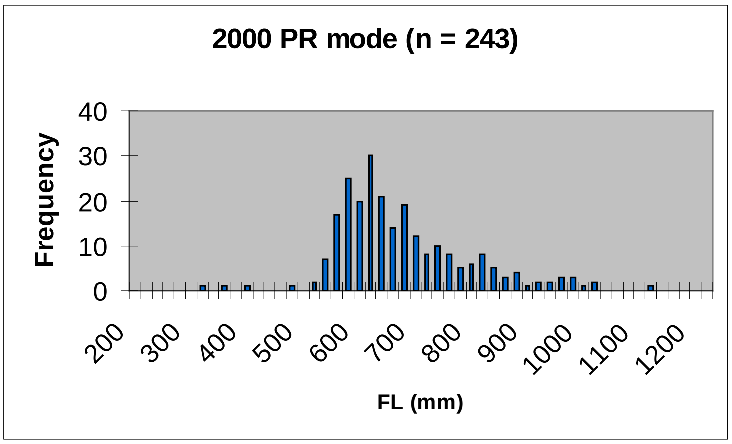

1996 PR mode (n = 146)
Frequency
0
5
10
15
20
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

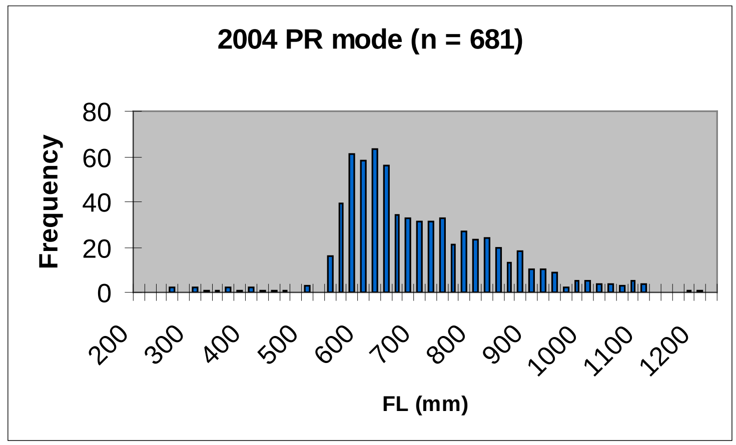

1997 PR mode (n = 94)
Frequency
0
5
10
15
20
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

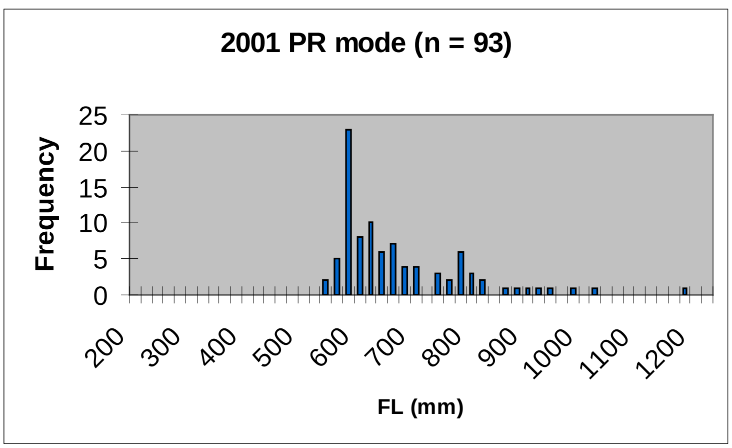

1998 PR mode (n = 168)
Frequency
0
5
10
15
20
25
30
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)

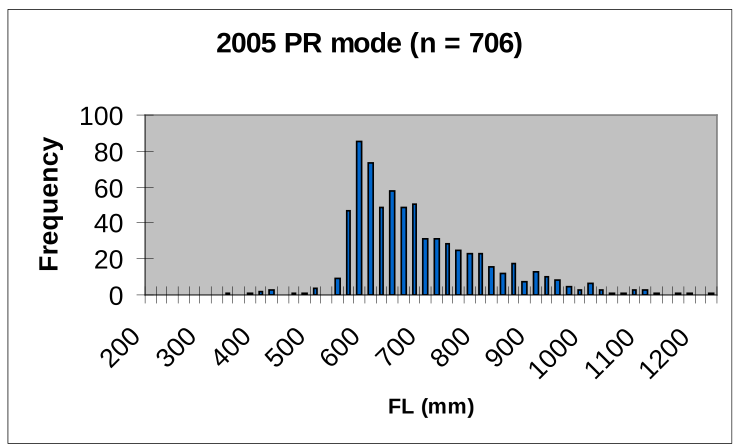

1999 PR mode (n = 444)
Frequency
FL (mm)

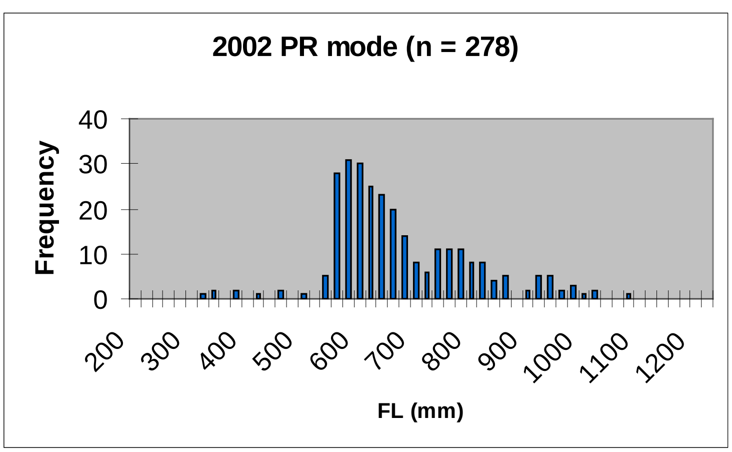

2003 PR mode (n = 321)
Frequency
FL (mm)

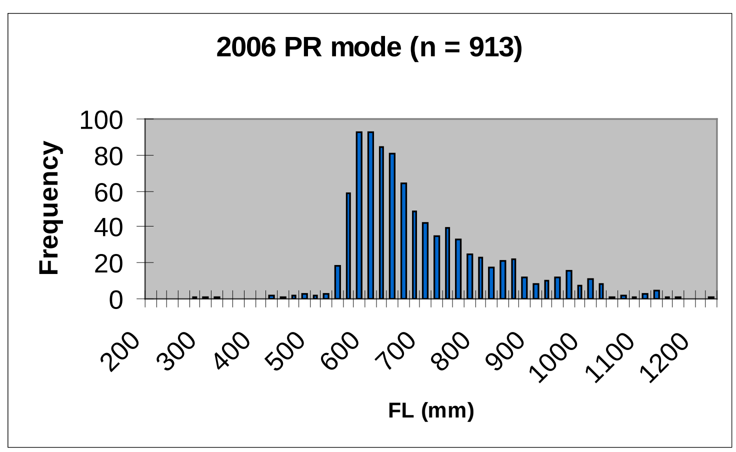

2000 PR mode (n = 243)
Frequency
FL (mm)

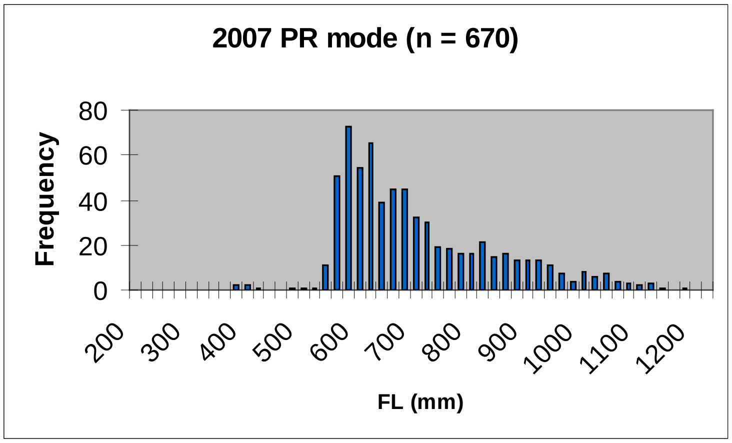

2004 PR mode (n = 681)
Frequency
FL (mm)

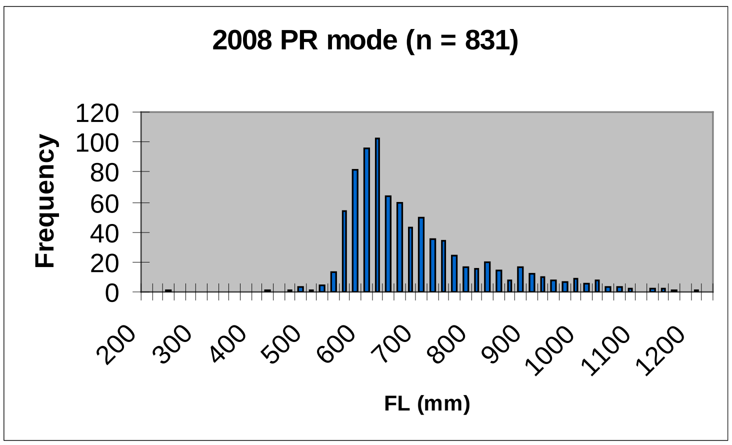

2001 PR mode (n = 93)
Frequency
FL (mm)

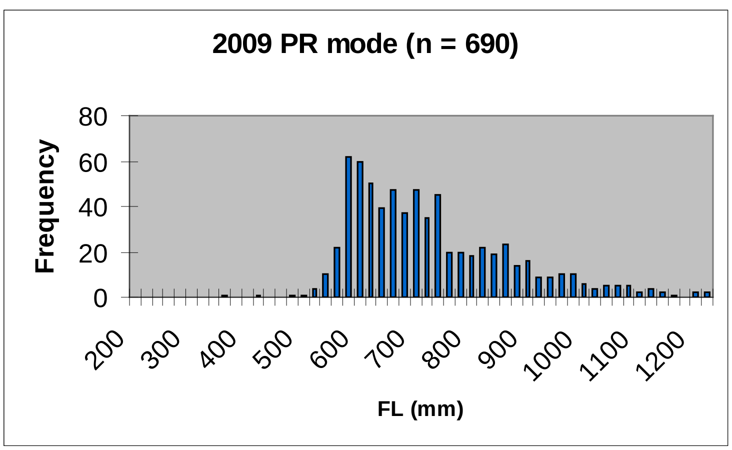

2005 PR mode (n = 706)
Frequency
FL (mm)

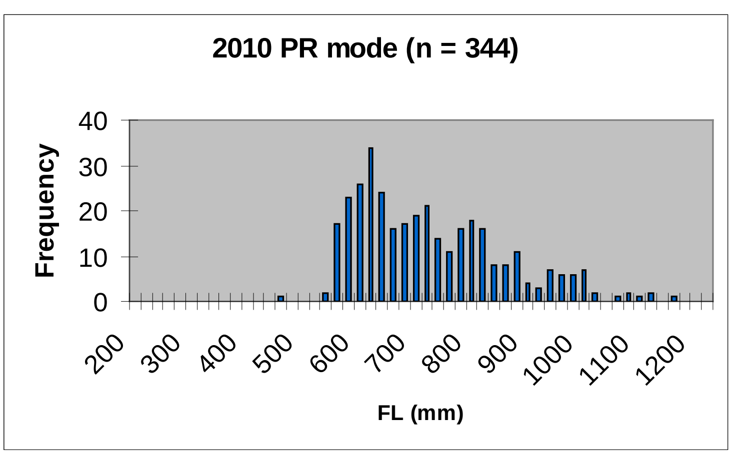

2002 PR mode (n = 278)
Frequency
FL (mm)


2006 PR mode (n = 913)
Frequency
FL (mm)


2007 PR mode (n = 670)
Frequency
80
60
40
20
0
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)


2008 PR mode (n = 831)
Frequency
120
100
80
60
40
20
0
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)


2009 PR mode (n = 690)
Frequency
80
60
40
20
0
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)


2010 PR mode (n = 344)
Frequency
40
30
20
10
0
200
300
400
500
600
700
800
900
1000
1100
1200
FL (mm)