Tab L, No. 4

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MEMORANDUM FOR: Bonnie Ponwith, Ph.D.
Director, Southeast Fisheries Science Center

FROM: Roy E. Crabtree, Ph.D.
Regional Administrator

SUBJECT: Update of Red Drum Sampling Protocols

The Gulf of Mexico Fishery Management Council (Council) is considering development of a scoping document to amend the Red Drum Fishery Management Plan to allow the harvest of red drum (*Sciaenops ocellatus*) in the Gulf of Mexico exclusive economic zone. The Council and I are requesting the Southeast Fisheries Science Center review and update the information on sampling protocols and age composition for red drum presented to the Council in February 2010 as Tab L, Handout 1: "Recommended Age Composition and Mark-Recapture Study Sample Sizes for Gulf of Mexico Red Drum" and Tab L, Handout 2: "Recommended Age Structure and Mark-Recapture Sample Sizes for Gulf Red Drum".

I request this review and updates be provided to me on or before March 31, 2010, if possible. If you have any questions please contact Nick Farmer on my staff at (727) 551-5759.

cc: F/SER2 – Phil Steele
F/SER24 – Steve Branstetter
F/SER29 – Andy Strelcheck
SEFSC – Theo Brainerd, Peter Thompson, Tom Jamir
Gulf Council – Karen Burns

TAB L HANDOUT

RECOMMENDED AGE COMPOSITION AND MARK-RECAPTURE STUDY SAMPLE SIZES FOR GULF OF MEXICO RED DRUM

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Draft Copy

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Introduction

A stock assessment of red drum *Sciaenops ocellatus* in the Gulf of Mexico is scheduled for 2009. The 2009 assessment will build upon the last red drum assessment, which was conducted in 2000 (Porch, 2000) using a modified version of the age-structured population model CATCHEM (Porch and Turner, 1997). The data employed by CATCHEM includes, among other things, the age composition of red drum stocks and estimates of stock abundance.

Age Composition Data

New age composition data, collected from a fishery independent survey, are needed to update the stock assessment model for 2009. Data from three different studies were used to characterize the age structure of red drum stocks in the Gulf of Mexico for the 2000 assessment. A cooperative study between the Alabama Sea Grant Extension Service, Auburn University, and Fishery Information Management Systems collected age composition data from Alabama waters during 1986 (FIMS, 1986). Murphy and Crabtree (1999) collected age composition data from Florida waters during 1996-1998. Several studies by the Coastal Fisheries Institute at Louisiana State University (e.g., Beckman et al., 1988; Wilson et al., 1993) and by the National Marine Fisheries Service (e.g., Nichols, 1988) have collected age composition data from the northern Gulf of Mexico during 1985-1992 and 1997. Fish from all three of these studies were collected using purse seines, which are thought to best represent the adult age structure (Beckman et al., 1988). No fishery independent purse seine surveys have been conducted for red drum in the Gulf of Mexico since the 2000 assessment.

Two questions must be answered before age composition data can be collected for the 2009 assessment. First, what survey sample sizes are needed to adequately characterize the age structure of red drum stocks? Second, what impact will harvesting fish for the survey have on red drum stocks? This second question is important because red drum stocks in the Gulf of Mexico were previously classified as overfished (Porch, 2000). In this study, the first question will be addressed using a bootstrap analysis, while the second question will be addressed using deterministic projection models.

Abundance Estimates

Current estimates of red drum abundance in the Gulf of Mexico would improve the quality of the 2009 stock assessment. Abundance estimates from two mark-recapture studies were used in the 2000 assessment. The first study tagged 15,349 fish and examined 25,489 fish for tags (Nichols, 1988). The second study tagged 9,669 fish and examined 9,550 fish for tags (Mitchell and Henwood, 1999). The smaller sample sizes in the second survey, which were caused by poor weather conditions, led to a high degree of uncertainty in the resulting abundance estimates (Mitchell and Henwood, 1999; Porch, 2000).

Two questions must be answered before another mark-recapture experiment can be conducted. First, how many fish must be tagged and examined for tags to estimate the abundance of red drum stocks? Second, what impact will tagging mortality from a mark-recapture study have on red drum stocks? The first question was addressed in the design of the first red drum mark-recapture study (RSD, 1986). The second question will be addressed in this study using deterministic projection models.

Methods

Age Composition Sample Sizes

Red drum age compositions are reported as the proportions of catch-at-age from the fishery independent survey. These proportions-at-age are assumed to follow a multinomial distribution (Porch, 2000). When selecting sample sizes for a simple random sample to be drawn from a multinomial population, the smallest sample size which meets the following condition is selected:

(1) $$\Pr\left\{\bigcap_{i=1}^{k}\left|p_i - \pi_i\right| \le d_i\right\} \ge 1-\alpha ,$$

where the probability will be at least 1 - α that all of the predicted proportions p_i will simultaneously be within distance d_i of the true population proportions π_i for all k categories (i.e., age classes) (Thompson, 1987). In the case where $d_i = d$ for $i = 1, \ldots, k$, the smallest necessary sample size can be solved for analytically for any value of α (Thompson, 1987). Red drum stocks in the Gulf of Mexico demonstrate a high degree of age stratification among schools (Porch, 2000), which means that fish collected by the surveys do not represent simple random samples of the population. In practical terms, the effective sample sizes of the surveys are less than the actual number of fish collected. Therefore, another method is needed to calculate sample sizes for red drum surveys.

A bootstrap analysis was used to determine sample sizes for the red drum surveys empirically. The fishery independent survey data used to construct the age compositions for the 2000 stock assessment were used in this analysis. The survey data consisted of daily catches-at-age for a total of 118 sampling days. A single red drum school was assumed to be sampled each sampling day. The "true" age composition was assumed to be the proportions of catch-at-age for the combined set of 118 sampling days.

Survey sample size n was based on the number of schools sampled s and the number of fish collected per school f, so that $n = sf$. The number of schools sampled by the survey is just as important as the number of fish collected, because of the age stratification among schools. The number of schools was sequentially varied from 1 to 100 by increments of one. For each value of s, the number of fish collected per school was sequentially varied from 1 to 200 by increments of one. The subsequent procedure was followed for each combination of values for s and f:

1) A set of s daily survey catch-at-age records were drawn randomly with replacement from the full set of 118 sampling days.
2) A set of f fish were drawn randomly with replacement from each of the daily survey catch-at-age records.
3) The ages associated with the resulting n fish were used to calculate the predicted proportions of catch-at-age for the survey. Ages were assumed to be estimated without error.
4) Steps 1 through 3 were repeated until 500 replicates of the survey were generated.

Equation 1 was used to determine which of the different s-f combinations produced adequate sample sizes. A given sample size was considered adequate if the probability was at least 0.9 that all of the predicted proportions were simultaneously within 0.05 of the true population proportions (i.e., $d = 0.05$, $\alpha = 0.1$). In other words, if all of the predicted proportions for a given s-f combination were within 0.05 of the true proportions for 450 or more of the 500 replicates (450/500 = 0.9), then the resulting sample size was considered adequate. The smallest adequate sample size n^* was selected for each value of s. As a sensitivity analysis, the process of selecting n^* was repeated so that the probability was at least 0.8 that all of the predicted proportions were simultaneously within 0.05 of the true population proportions (i.e., $d = 0.05$, $\alpha = 0.2$).

Risk Assessment

A deterministic projection model was used to evaluate the impact of harvest by the survey on red drum stocks in the Gulf of Mexico. The projection model used in the 2000 assessment was modified for this purpose (Porch, 2000). Two survey scenarios were examined in this study. The first survey scenario had a onetime survey being conducted in 2008. The second survey scenario had an annual survey, which was started in 2008. A scenario with no survey was included as a control. Three fishing mortality levels were used to project red drum stocks into the future for each of the survey scenarios. The first mortality level assumed no fishing ($F = 0\ yr^{-1}$), other than the survey. The second mortality level assumed fishing occurred at the level that achieved a 30% spawning potential ratio ($F = 0.47\ yr^{-1}$). The third mortality level assumed fishing continued at recent levels ($F = 1.18\ yr^{-1}$). Projected spawning stock fecundity was examined to determine what impact survey harvest had on red drum stocks.

Survey harvest in the projection model was set equal to the highest value of n^* from across all values of s. Therefore, the survey scenarios evaluated the highest possible impact of the surveys on red drum stocks. Survey harvest was distributed among age classes using the "true" age composition from the bootstrap analysis.

Results

Age Composition Sample Sizes

The smallest adequate number of fish collected per school decreased as the number of schools sampled increased (Figure 1; Table 1). A minimum number of 32 schools had to be sampled, with 155 fish being collected from each school. Below that number of schools, the age composition could not be determined with the specified degree of precision given the study's maximum limit of 200 fish collected per school. The number of fish collected per school decreased to 18 when the number of schools sampled increased to 40. The inverse relationship between *s* and *f* became less significant after about 70 schools were sampled, leveling out around 6 fish per school.

The smallest adequate sample size values decreased as the number of schools sampled increased (Figure 2; Table 1). Sampling 32 schools required 4,960 fish to be collected. The smallest adequate sample size dropped to 720 fish when the number of schools sampled increased to 40. The smallest adequate sample sizes leveled out around 500 fish after the number of schools sampled reached about 70.

Decreasing the survey's precision ($\alpha = 0.2$) led to decreases in the smallest adequate sample sizes, due to reductions in the necessary numbers of fish collected per school (Table 2). The trends seen in sample sizes for the less precise survey were similar to those reported for the more precise survey ($\alpha = 0.1$). The number of fish collected per school and total number of fish collected decreased as the number of schools sampled increased. On average, the smallest adequate sample sizes with α of 0.2 were half that of the sample sizes when α was 0.1. The decreases in sample size between α of 0.2 and 0.1 were greater when small numbers of schools were sampled, and less when large numbers of schools were sampled.

Mark-Recapture Sample Sizes

In preparation for the first mark-recapture study, it was determined that tagging 20,000 fish and examining 50,000 fish for tags provided reasonably precise abundance estimates for population sizes between 1 and 10 million fish (e.g., CV of 10% for population estimate of 10 million fish) (RSD, 1986). The precision of abundance estimates would still be adequate (e.g., CV of 14% for estimate of 10 million fish) if only 10,000 tagged fish were still at large during the recapture phase of the study (RSD, 1986). The precision of abundance estimates likely would be inadequate (e.g., CV of 22% for estimate of 10 million fish) if the number of fish examined for tags was reduced to 20,000 (RSD, 1986).

Risk Assessment

Survey harvest was set equal to 5,616 fish, which was obtained by sampling 36 schools with 156 fish collected per school (Table 1). There was no discernable impact of either the onetime or annual survey on the spawning stock fecundity at this harvest level (Figure 3). This result is not unexpected given the predicted abundance of red drum stocks in the Gulf of Mexico. The average annual abundance of red drum from 1979 to 1996 was approximately 17 million fish according to the 2000 assessment (Porch, 2000). Deaths due to natural and fishing mortality, which are already acting on red drum stocks, far exceed even the highest potential harvest by the survey.

A mark-recapture study could impact red drum stocks due to tagging mortality. Nichols (1988) reported no tagging mortality for dart tagged red drum, but 3% of belly tagged red drum experienced tagging mortality. If the recommended number of 20,000 fish were marked with belly tags, then 600 fish would be expected to die due to tagging mortality. The loss of 600 fish in a mark-recapture study would have even less impact on red drum stocks than the age composition survey.

Discussion

Age Composition Data

There is a wide range of survey sample sizes, depending on the number of schools sampled and the number of fish collected per school, which can characterize adequately the age structure of red drum stocks in the Gulf of Mexico. The choice of which sample size value to select comes down to a cost-benefit analysis. Time, effort, and resources are required both to collect fish and to estimate the ages of the fish that are collected. Sampling from more schools (increased sampling costs) means the ages of fewer fish must be estimated (decreased processing costs). An optimal sample size could be determined analytically, if the costs of collecting and processing samples could be quantified. Lacking that information, sampling somewhere between 40 and 60 schools seems reasonable, and would result in sample sizes ranging from 580 fish to 1,591 fish. This range follows the sharp decline in numbers of fish per school that must be collected and before the benefits of sampling additional schools becomes negligible. It should be noted that more samples will need to be collected if regional differences are to be modeled. For example, if the Northern Gulf of Mexico and Florida are treated as having distinct stocks with potentially different age structures.

Though a onetime survey is all that is needed for the 2009 red drum stock assessment, a long term survey program would improve the quality of future assessments. Changes in the age structure of red drum stocks can be better followed through time, and the dynamics driving those changes can be better understood the more frequently age composition data is collected. Conducting the survey every five or six years likely would be sufficient for tracking changes in the age structure of red drum stocks given the lifespan of the species in the Gulf of Mexico (i.e., 30+ years). If the goal is to assess red drum on a five year SEDAR cycle, then it would make sense to conduct the survey more frequently (e.g., every three years or so).

Abundance Estimates

For a mark-recapture study, there is no reason not to adopt the targets of tagging 20,000 fish and examining 50,000 fish for tags (RSD, 1986). The high degree of uncertainty in abundance estimates from Mitchell and Henwood's (1999) study appears to support these recommended sample sizes. Mitchell and Henwood (1999) managed to tag 9,669 fish, which could produce reasonably precise abundance estimates (RSD, 1986). Unfortunately, they were only able to examine 9,550 fish for tags, which was well short of both the 50,000 fish target and the 20,000 fish level that had been deemed inadequate (RSD, 1986).

Another question to be considered is whether or not a mark-recapture study can be conducted in time for the 2009 red drum stock assessment? One of the assumptions of a mark-recapture experiment is that, during the recapture period, random samples of fish are being drawn from the total population (i.e., of marked and unmarked fish). Therefore, time must be given after the marking period for marked and unmarked fish to mix with each other. This mixing period is in addition to the time already required to mark and recapture fish. Nichols' (1988) study included a 9 week marking period, an 11 week mixing period, a second 18 week marking period, a second 8 week mixing period, and a 14 week recapture period for a total of 60 weeks. Mitchell and Henwood's (1999) study included a 15 week marking period, a 39 week mixing period, and a 17 week recapture period for a total of 71 weeks. If the 2009 red drum assessment is scheduled early in the year, then it would be impossible to conduct a 60 to 70 week long mark-recapture study in time for the assessment. If the 2009 red drum assessment is scheduled later in the year, then it might be possible to conduct a mark-recapture study in time for the assessment.

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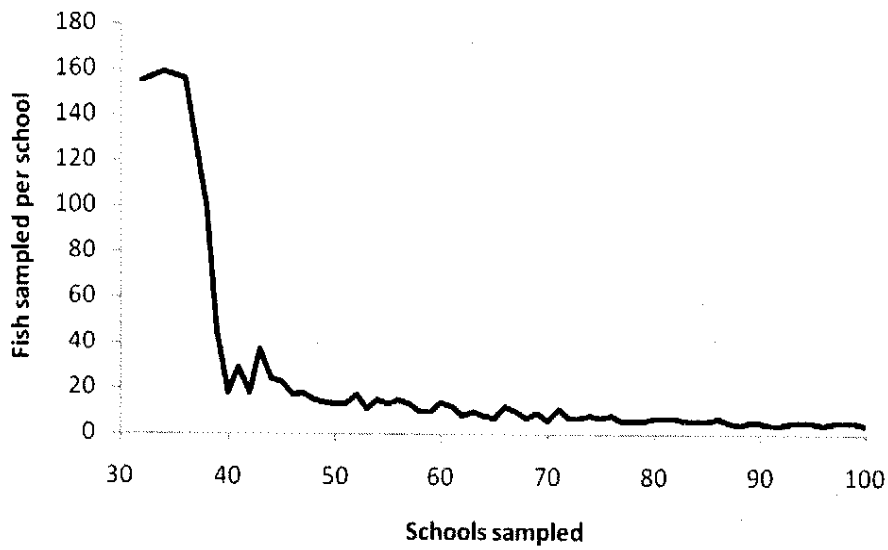


Figure 1. Minimum number of fish sampled per school for a given number of schools sampled to determine age compositions of red drum in the Gulf of Mexico.

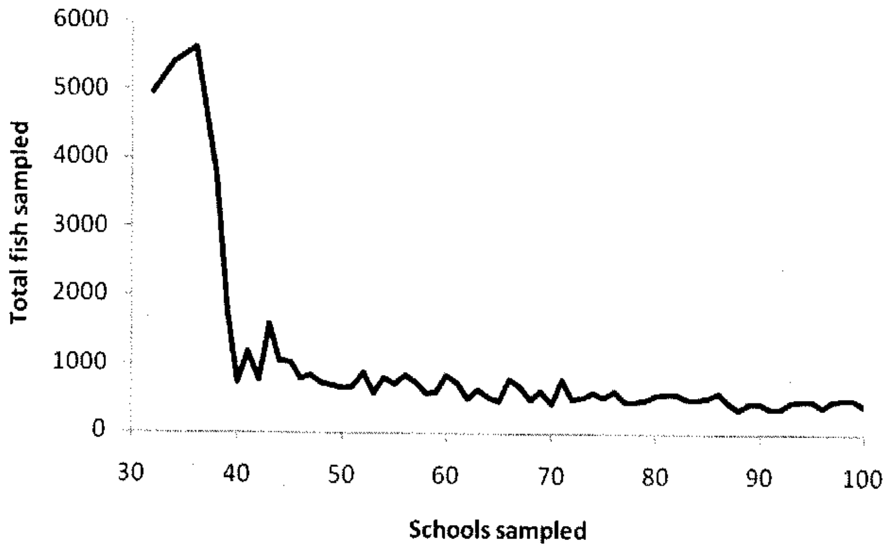


Figure 2. Smallest adequate sample size for a given number of schools sampled to determine age compositions of red drum in the Gulf of Mexico.

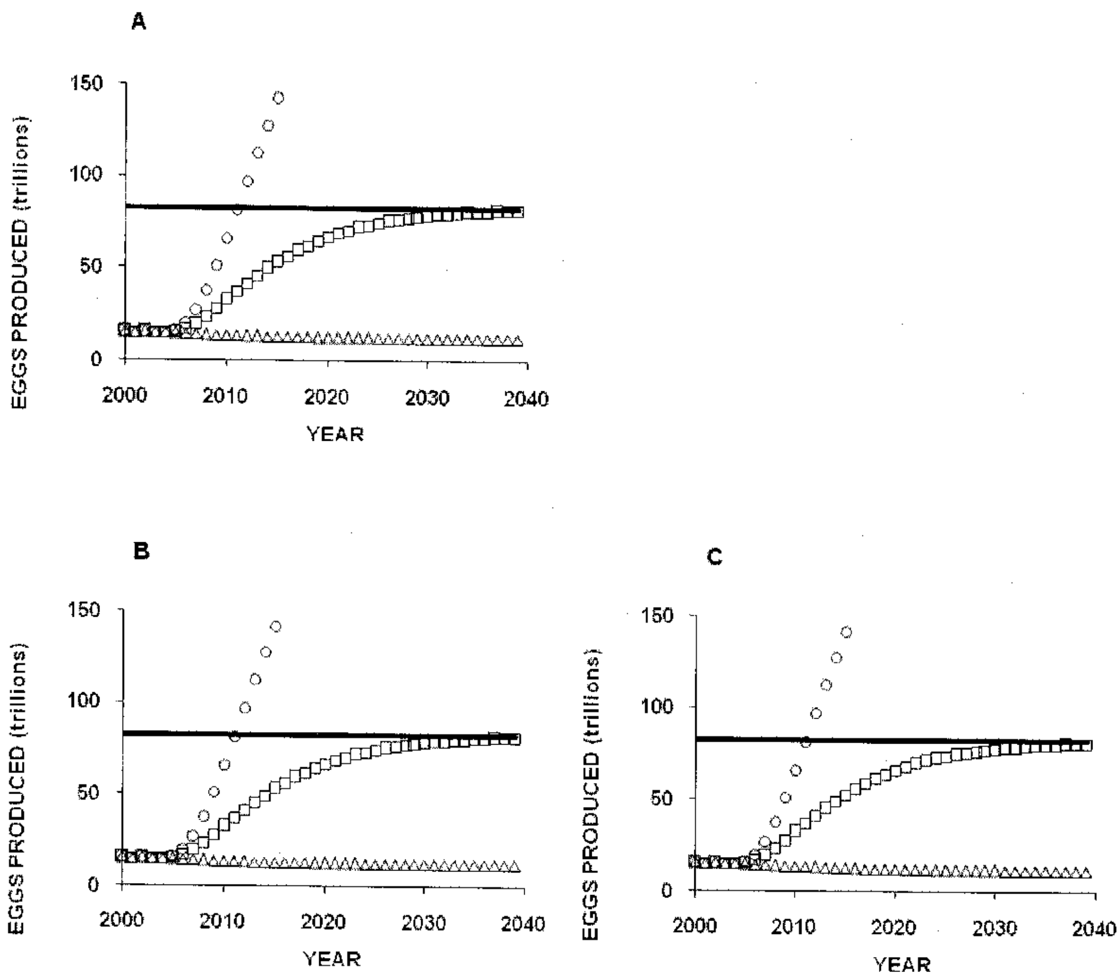


Figure 3. Projected spawning stock fecundity of red drum in the Gulf of Mexico with A) no survey, B) a onetime survey in 2008, and C) an annual survey starting in 2008. Projected fishing mortality levels are set at F = 0 (circles), F = 0.47 (squares), and F = 1.18 (triangles).

Table 1. Number of schools sampled s, number of fish collected per school f, and smallest adequate sample size n^* for red drum surveys from bootstrap analysis with $d = 0.05$ and $\alpha = 0.1$.

s	f	n^*	s	f	n^*
32	155	4960	68	7	476
34	159	5406	69	9	621
36	156	5616	70	6	420
38	99	3762	71	11	781
39	45	1755	72	7	504
40	18	720	73	7	511
41	29	1189	74	8	592
42	18	756	75	7	525
43	37	1591	76	8	608
44	24	1056	77	6	462
45	23	1035	78	6	468
46	17	782	79	6	474
47	18	846	80	7	560
48	15	720	81	7	567
49	14	686	82	7	574
50	13	650	83	6	498
51	13	663	84	6	504
52	17	884	85	6	510
53	11	583	86	7	602
54	15	810	87	5	435
55	13	715	88	4	352
56	15	840	89	5	445
57	13	741	90	5	450
58	10	580	91	4	364
59	10	590	92	4	368
60	14	840	93	5	465
61	12	732	94	5	470
62	8	496	95	5	475
63	10	630	96	4	384
64	8	512	97	5	485
65	7	455	98	5	490
66	12	792	99	5	495
67	10	670	100	4	400

Table 2. Number of schools sampled *s*, number of fish collected per school *f*, and smallest adequate sample size n^* for red drum surveys from bootstrap analysis with $d = 0.05$ and $\alpha = 0.2$.

s	*f*	n^*	*s*	*f*	n^*
24	44	1056	63	5	315
25	79	1975	64	4	256
26	34	884	65	4	260
27	32	864	66	5	330
28	28	784	67	5	335
29	25	725	68	4	272
30	18	540	69	4	276
31	21	651	70	4	280
32	15	480	71	4	284
33	15	495	72	4	288
34	14	476	73	4	292
35	13	455	74	4	296
36	16	576	75	4	300
37	16	592	76	4	304
38	13	494	77	4	308
39	13	507	78	4	312
40	9	360	79	4	316
41	9	369	80	3	240
42	7	294	81	3	243
43	10	430	82	4	328
44	8	352	83	4	332
45	7	315	84	4	336
46	8	368	85	3	255
47	8	376	86	3	258
48	7	336	87	3	261
49	6	294	88	3	264
50	7	350	89	3	267
51	7	357	90	3	270
52	6	312	91	3	273
53	5	265	92	3	276
54	7	378	93	3	279
55	6	330	94	3	282
56	5	280	95	4	380
57	6	342	96	3	288
58	5	290	97	3	291
59	5	295	98	3	294
60	7	420	99	3	297

61	5	305	100	3	300
62	5	310			

TAB L HANDOUT

Recommended age structure and mark-recapture sample sizes for Gulf red drum

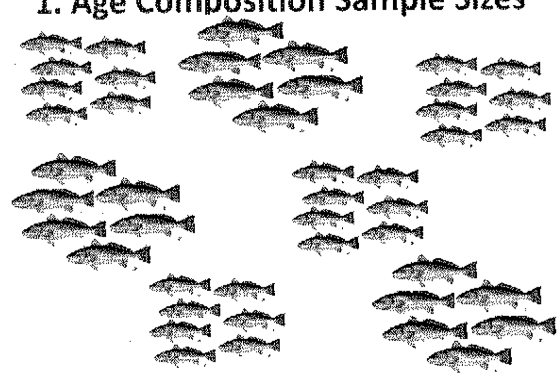
Introduction

- Last red drum assessment was in 1999
- Next red drum assessment in 2009
- Recommendations from 1999 assessment included:
  - Collect age composition data for offshore region by fishery independent surveys
  - Estimate abundance via mark-recapture experiments

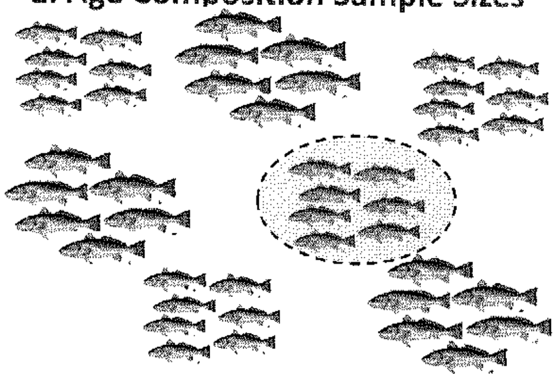
GMFMC Research Questions

1. How many fish must be collected to characterize the offshore age structure?
- How many fish must be tagged in order to achieve different levels of precision in the estimates of stock size?
- What are the risks to the Gulf of Mexico red drum stock from carrying out the activities in (1) and (2) above

1. Age Composition Sample Sizes



1. Age Composition Sample Sizes

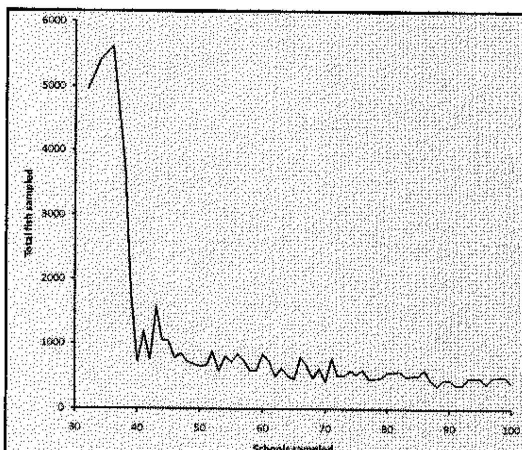


1. Age Composition Sample Sizes

- Apply bootstrapping approach (assumes variability in past surveys similar to now)
  - Draw *S* "schools" randomly w/ replacement
  - Draw *N* individual fish randomly w/replacement from each selected "school"
- 500 replicates for each combination of N & S
- Find number of replicates where each age class was adequately represented

  sample *P(age)* = True *P(age)* +/- 0.05

  for all ages in 90% of bootstrap samples



2. Mark-Recapture Sample Sizes

Fish Marked	Fish Examined	CV
20,000	50,000	10%
10,000	50,000	14%
10,000	20,000	22%

(Resource Surveys Division, 1986)

2. Mark-Recapture Sample Sizes

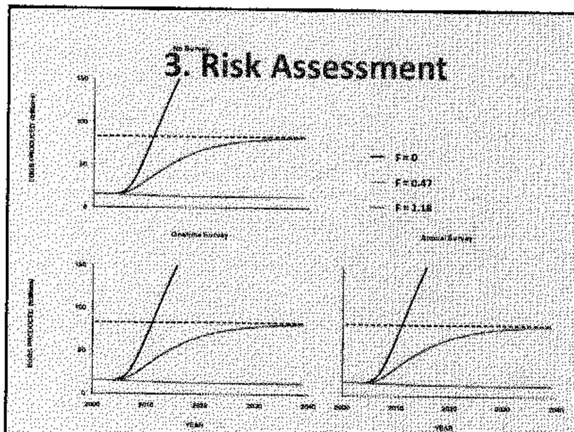
Fish Marked	Fish Examined	CV
20,000	50,000	10%
10,000	50,000	14%
10,000	20,000	22%

- 3% tagged fish died due to tagging (Nichols, 1988)
- 600 fish would die in study, if 20,000 fish marked w/ belly tags

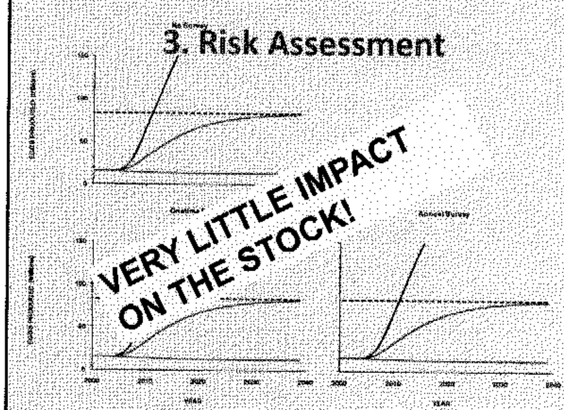
3. Risk Assessment

- **Used projection model from 1999 assessment**
- **Set survey harvest to maximum adequate sample size (5,000 fish)**
- **Examined 3 survey scenarios**
  - **No survey (baseline case)**
  - **One-time survey**
  - **Annual survey**
- **Applied 3 projected mortality rates**
  - **No fishing (F = 0)**
  - **F30% (F = 0.47)**
  - **Current levels (F = 1.18)**

3. Risk Assessment



3. Risk Assessment



Recommendations

- Age composition data
  - –Sample 40 to 60 schools
  - –Sample 10 to 20 fish per school
  - –Conduct survey every 3 yrs
- Mark-recapture abundance estimates
  - –Mark 20,000 fish, examine 50,000 fish
  - –May not be possible to conduct mark-recapture study before 2009