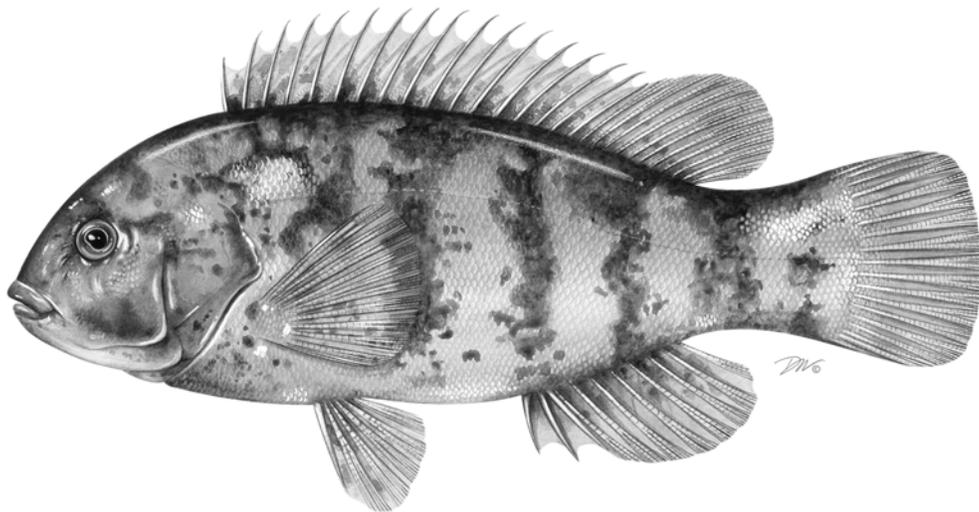Stock Assessment Report No. 06-02 (Supplement)
of the

Atlantic States Marine Fisheries Commission

Tautog Stock Assessment Report for Peer Review

January 2006

*Working towards healthy, self-sustaining populations for all Atlantic coast fish species
or successful restoration well in progress by the year 2015*

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Conducted on
December 7, 2005

ACKNOWLEDGEMENTS

Executive Summary

Status of the stocks

In 2003 tautog experienced fishing mortality rates estimated on a coastwide basis ($F=0.2999$ yr^{-1}) that were marginally above the management target ($F=0.29$ yr^{-1}). Coastwide, catch-weighted Fs had been somewhat higher than 0.29/yr in the four preceding years, which suggests that on average the target fishing mortality rate has been exceeded in recent years. However, the variability in the partial recruitment vector for these fisheries impact the calculation of the 40% SPR target, making precise determination of status difficult.

Individual State reports to the coastwide assessment provided state-specific estimates of status and fishing mortality rates. Because of the potential for substock structure in this species, the Review Panel encourages the continued development and refinement of State-specific assessments to complement the coastwide assessment. Although the approaches used differed among the individual states, the reports indicate that the individual States appear not to be overfishing their components of the population. However, Panel expressed several concerns regarding the comparability of the F estimates developed in the State reports and those developed from the coastwide VPA. Of particular concern to the Panel were the differences between the partial recruitment vectors employed by the different states and the coastwide assessment. The Review Panel recommends that extreme caution be employed when comparing analyses that employ different assumptions regarding the pattern of fishing.

Biological Reference Points

Tautog is currently managed by a coastwide target fishing mortality rate set to ensure at least 40% of the virgin spawning potential ratio is maintained. This is currently estimated to be $F=0.29$ yr^{-1}. No limit reference points or biomass-based reference points have been established.

Coastwide, catch-weighted fishing mortality rates were estimated from the VPA. Fishing mortality rates have been consistently above the target rate in 17 of 24 years for which estimates are available. Catch-weighted fishing mortality rate were considerably higher than the target rate until the mid 1990s when management action to limit recreational harvest lead to a reduction in Fs. The 2003 catch-weighted fishing mortality rate ($F=0.299$ yr^{-1}) was marginally higher than the target. The average of the last three years catch-weighted F was $F=0.389$ yr^{-1}, indicated that overfishing is likely still occurring.

Data

Tautog was assessed via a coastwide VPA analysis. The Review Panel concluded that the coastwide assessment provided the best available scientific foundation for management. The Review Panel noted, however, that there is strong evidence for substock structure which complicates the application of coastwide standards to local fisheries. Additional state-specific assessments were conducted, but were not sufficiently refined at this time to form the basis for management.

Recreational and commercial landings for 1982-2003 were appropriately documented within the report. Recreational landings were the dominant sector in most states in most years, accounting for an average of 92% coastwide landings (Fig. 1). The remainder of the removals was comprised of recreational discard and commercial landings.

Model

The Stock Assessment Team utilized a coastwide Virtual Population Analysis (VPA) to estimate trends in abundance, spawning stock biomass, recruitment and fishing mortality. The Review Panel concluded that, of the assessment work in the Assessment Report, the coastwide assessment provided the best available scientific foundation for management. The VPA estimated population abundances in 11 real age classes and a final plus group. The Review Panel believed that the use of a plus group for ages 12 onward was appropriate. The analysis used aggregate estimates of catches- and weights-at-age for 1982- 2003, and an initial partial recruitment vector. Fifty-one, age-specific tuning indices, derived from the fishery-independent surveys, were used in fitting the VPA model to the available data. A catch-weighted fishing mortality rate (F), based on ages 8-10, was estimated by the VPA.

A retrospective analysis did not indicate any significant issues with VPA sensitivity to recent survey and catch estimates. Although the review Panel accepted the overall VPA, the Panel identified several concerns with the analysis that are listed in full within this report.

Terms of Reference

A. Summarize recreational and commercial landings by region and state from MA to VA.

B. Summarize length composition and available age-length data to the highest level of resolution, based on the accuracy of the data.

C. Summarize all available indices of stock abundance by state.

D. Estimate age composition of recreational and commercial landings and indices using age data from the states MA - VA.

E. Provide estimates of stock status and trends and fishing mortality on a coastwide and regional basis, and if possible for each state.

F. Evaluate biological reference points using appropriate models and updated information.

G. Review stock status and fishing mortality with respect to the biological reference points.

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1.0 Introduction

This stock assessment was requested by Atlantic States Marine Fisheries Commission (ASMFC or Commission) Tautog Management Board and prepared by the ASMFC Tautog Technical Committee, through the Tautog Stock Assessment Subcommittee (SASC), as part of the interstate fisheries management process. The stock was last assessed through a full assessment that was peer reviewed through the National Marine Fisheries Service (NMFS) Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) process in 1999 and updated by the Technical Committee in 2002. Commission benchmark stock assessments are normally updated every four or five years. This assessment was delayed one year to allow incorporation of two years of harvest information since the latest management changes.

1.1 Management Unit Definition

The management unit for tautog includes the territorial waters of Massachusetts to North Carolina and seaward.

1.2 Regulatory History

Prior to the Commission's coastwide Tautog Fishery Management Plan (FMP) individual states managed tautog on a unilateral basis. Some states had minimum size and possession limits and/or effort controls for their commercial and recreational fisheries; however, most did not. An increase in commercial fishing pressure in the mid 1980s through early 1990s and a growing perception of a slow-growing species vulnerable to overfishing stimulated an identification of the need for a coastwide fishery management plan. Accordingly, in 1993 the ASMFC recommended that a plan be developed as part of its Interstate Fisheries Management Program. The states of Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland and Virginia declared an interest in jointly managing this species through the ASMFC. The goal of the FMP was to conserve the resource along the Atlantic Coast and to maximize long-term ecological benefits, while maintaining the social and economic benefits of commercial and recreational utilization.

Since the first stock assessment and adoption of the FMP all cooperating states have implemented various restrictive management measures to reduce fishing mortality. In general states have enacted low possession/catch limits and/or restrictive closed seasons for their recreational fisheries, and seasonal closures and possession limits for their commercial fisheries. States also adopted higher minimum size limits consistent with the FMP minimum of 14", while some states maintained their existing more restrictive size limits. A compilation of current management measures is contained in Table 1.

1.3 Assessment History

The first tautog assessment was performed in 1995. A coastwide VPA (ADAPT) was performed but rejected during the SAW/SARC peer review. Nonetheless an F estimate from that assessment was incorporated into the initial FMP (ASMFC 1996). At that time it was estimated that the coastwide stock of tautog was overfished and that overfishing was occurring. In response state management measures were adjusted to realize a 50% cut in the fishing mortality rate. A second benchmark coastwide assessment, performed in 1999 and based upon a VPA run and corroborative tag based survival estimates, was peer reviewed and accepted through the SAW/SARC process. The 1999 assessment determined that the terminal year F value had dropped to 0.29, close to the interim FMP target of 0.24, but well above the final plan target (F=M= 0.15).

A stock assessment update, performed in 2002, found that recreational catch rates had returned to levels prior to the minimum size increase and that F had increased above the overfishing definition (0.41). This required reductions in recreational harvest only, starting in 2003, in an attempt to return F to the FMP target value. The target had been revised to $F_{SSB\ 40\%}$ (0.29) by Addendum III (ASMFC 2002), based upon updated recruitment and weight at age parameters and a desire to adopt a target with more management flexibility. In 2003 and 2004, states operated under the new suite of regulations and this assessment was scheduled to determine if those regulations achieved the desired result of reducing recreational catch and lowering F back to or below target levels.

In the past, analytical assessments of individual state or regional tautog populations were hindered by a lack of age data, fisheries independent surveys south of New Jersey, and unresolved questions concerning appropriate stock units. Accordingly more recent stock assessments were divided into Northern and Southern Regions, consisting of Massachusetts to New York and New Jersey to Virginia respectively. The regional approach was used for data consolidation, application of age keys, and preliminary VPA runs, but the assessments derived coastwide estimates of F, spawning stock biomass and recruitment, since regional VPAs produced unreliable results for the Southern Region's stock.

Since that time additional tagging studies in both regions have confirmed the more localized nature of tautog stocks (Lynch 1999, Lucy et al 2001, Arendt et al 2001, Caruso 2004). In addition, states have pressed for more unilateral control over what are assumed to be local populations and managers have requested more localized stock status information. Accordingly this assessment provides separate stock condition and fisheries trends for individual states to the level appropriate, given the available data. In most cases the nature and magnitude of the fishery is such that states cannot justify the expense of large-scale data acquisition programs for this species alone in support of analytical assessments at the state level, so the available information allows only qualitative assessment advice.

Many of the compliance elements of the coastwide FMP have served well to increase the knowledge base regarding this species and the importance of having a coastwide plan is still high, since the influences of the recreational and commercial fisheries on the stocks affect the species over broad geographic areas, even if the stocks are locally discrete. Thus a coastwide VPA was performed in keeping with the methodology of the two prior assessments. This should allow comparison to past assessment results, and assist with implementation of the FMP.

2.0 Life History

Tautog *(Tautogis onitis)*, is one of over 630 species composing the wrasse or labrid family and is often known by the common name "blackfish" in the Northeastern United States (U.S.), in reference to its common overall coloration. Tautog are also known locally by several other common names such as "white chinner", slippery, or tog. Most labrids are inhabitants of tropical waters, making tautog, and its close relative the cunner (*Tautogis adsperis*) exceptions to the general rule. Tautog range along the western Atlantic coast from Nova Scotia to South Carolina (Bigelow and Schroeder 1953), however, they are most abundant from the southern Gulf of Maine (lower Massachusetts Bay and southern Cape Cod Bay) to Chesapeake Bay.

Although tautog share a preference for temperate waters with the cunner, tautog can easily be distinguished by its stouter more robust profile and lack of scales on the gill covers. Tautog also grow to much larger sizes, up to 11.36 kg with an estimated age of 30 years. Cunner rarely exceed 2.5 kg in weight and a 7.5 kg specimen would be an exceptional catch.

Throughout most of the range adult tautog migrate inshore in the spring from offshore and nearshore wintering sites to spawn and feed. The reverse migration occurs in late fall as water temperatures drop. Southern Region populations may undergo shorter distance seasonal migrations and in the southern most part of the range localized populations may not undertake seasonal movements at all (Olla and Samet 1977, Ecklund and Targett 1990, Hosteter and Munroe 1993, White 1996, Arendt et al 2001). Spawning occurs primarily at or near the mouth of estuaries in nearshore marine waters (Cooper 1967, Stolgitis 1970). In Narragansett Bay, Rhode Island mature tautog returned to the same spawning site each year but dispersed throughout the bay after spawning (Cooper 1967). Similar patterns of site fidelity have been observed in the nearshore waters of Massachusetts (Caruso 2004). However, Olla and Samet (1977) found that tautog did not always return to the same spawning site in the south and that some mixing of the populations occurred on the spawning grounds.

2.1 Maturity

Tautog are thought to reach sexual maturity at ages 3 to 4 (Chenoweth 1963, White 1996). Mature tautog can often be sexed from external characteristics (sexual dimorphism) with males having a pronounced lower mandible and more steeply sloping forehead. Females exhibit a more midline mouth position and a more ovoid body shape. Coloration varies by habitat and sex, with males most often grayish in color with a white midline saddle mark common on breeding males. Juveniles and females more often exhibit a mottled and brown toned appearance.

2.2 Age and Growth

Age and growth studies indicate a relatively slow growing, long-lived fish with individuals over 30 years reported in Rhode Island, Connecticut, and Virginia. Males exhibit faster growth and attain larger sizes (length) than females (Cooper 1967). Evidence suggests females reach senescence at an earlier age than males, consistent with their smaller maximum size.

Growth rates from the southern part of the range are similar to those in the north, until about age-15 (Cooper 1967), after which growth rates decrease more rapidly in northern waters (Hostetter and Munroe 1993). This work was reevaluated in 1996 using growth equations developed by White (1996). Differences noted between these studies were attributed to a difference in aging techniques and revealed more similar growth rates at both ends of the range (Cooper 1967, Hostetter and Munroe 1993). More recent work suggests that growth rates maybe higher in the far southern end of the range but that work has yet to be peer reviewed.

2.3 Reproduction

The spawning peak was assumed to occur coastwide on June 1 based on observed spawning peaks throughout the range (Cooper 1967, White 1996), although White noted batch spawning with repeated spawning events extending over sixty days. The proportion of natural mortality (M) occurring before spawning was estimated at 0.42 (153/365 days). The proportion of fishing mortality (F) before spawning (0.15) was estimated as the proportion of landings from January - May vs. total landings.

2.4 Stock Definitions

For this assessment discrete populations were assumed for most states. Exceptions were Long Island Sound, shared by both New York and Connecticut, the northern end of the Mid-Atlantic Bight shared by New York and New Jersey, and in the Chesapeake Bay, shared by Maryland and Virginia. However, the coastwide VPA was based upon past assessment work and the desire to compare current fisheries and population parameters to past estimates. Coastwide recruitment

trends were examined at the last peer review and like cunner appear consistent on a more regional and coastwide basis, lending some additional justification for a coastwide assessment approach. In addition, regional fisheries differences and state management concerns mandate some compromise in the adoption of stock units somewhere between a coastwide or regional unit and state specific units in some areas.

2.5 Genetic Information

Genetic studies suggest one coastwide population but acknowledge that stocks may have not had sufficient time to evolve genetically on a coastal scale (Orbacz and Gaffney 2000).

2.6 Natural Mortality

A natural mortality rate of 0.15 was selected for past assessments as well as this one. Previous mortality estimates were based on the Hoenig length based method. That value was corroborated by Simpson (1989) who used Pauly's temperature based method to estimate M at 0.152. In addition the chosen value is similar to other long-lived slow growing species, such as redfish (M=0.10) and the frequently used ICES convention of $3/T_{max}$, which yields a value of 0.1 for a maximum age of 30 years.

3.0 Fishery Description

3.1 Overview of Fisheries

The coastwide commercial fisheries for tautog could best be described as diverse in nature, while those of the recreational fisheries could best be described as similar in nature. Recreational harvest far exceeds the commercial harvest in all states, ranging from approximately seventy six percent in Rhode Island to almost one hundred percent in Delaware, and averaging ninety two percent for all states for the 1982 - 2004 time series.

Commercial gear types that account for the majority of landings are fish pot, lobster pot, otter trawl, gillnet and hook and line. A small but active spear fishery is located in Rhode Island. Both commercial and recreational landings are generally highest in the spring and fall months when tautog are grouped in spawning and pre-migratory schools and thus most vulnerable to capture. Because the landings take place within relatively short time periods, year-to-year catch variance can be high, since those months are periods of highly variable weather and most recreational and commercial fishing boats targeting tautog are smaller vessels which are most affected by weather conditions.

The recreational fisheries for tautog are quite similar up and down the coast, most landings coming from the private boat and for hire modes fishing with bait on structured bottom. Most recreational landings, an average of seventy percent, come from directed fishing effort for the species since the bait, hook types and locations fished are specific to this species. Few fish are landed during the course of fishing for other more frequently caught species such as bluefish or striped bass. For this reason tautog could be looked at as an infrequently encountered species and thus landings data from traditional survey methods is thought to be much less reliable for this species than for other more commonly caught species, like striped bass or scup.

3.2 Current Fisheries Status

After a period of moderate landings in the early 1980s, with a mean total coastwide harvest of 2,946 mt, the harvest rose to an average of 4,314 mt from 1986 to 1993. Peak landings were reached in 1986 with 8,093 mt. From 1994 to 2002 landings have declined to an annual average

of 1,560 mt, commensurate with stock declines and management actions in the mid 1990s. Landings rose slightly from that average in 2002 when it is assumed that the effect of the increase in the minimum size diminished as fish grew into the new size limit, and thus became vulnerable to harvest. Some states experienced a drop in landings in 2003 and 2004, possibly in response to additional restrictions on recreational catch. Exceptions were: Rhode Island, Connecticut, New York and Virginia. Both Rhode Island and Virginia were allowed to retain their existing recreational regulations because they produced local stock and fisheries information that indicated they were below the fishing mortality rate target.

4.0 Habitat Description

Tautog are found in association with specific structured habitats throughout their life, and these habitats are important to its survival. Structured locations such as boulder habitat, ship wrecks or wharf pilings provide the tautog shelter during nightly dormant periods and deeper water structure provides an over wintering location when the fish are inactive and in a torpor like state. The preference of adults for highly structured habitats may be one possible explanation for the domed shaped recruitment pattern evident in past assessments, since larger and older fish may be less vulnerable to capture from hook and line, gillnet and trawl gear. Juvenile tautog also require shelter from predators and for feeding and are often found in shallow nearshore vegetated areas such as eelgrass beds or algae beds. Little is known about habitat needs critical to recruitment levels, but given the small percentage of structured habitat, relative to the over all marine habitats along theNorthern Atlantic coast, one could safely assume that carrying capacity is bounded to some degree by available habitat. This may be especially true in the region south of Long Island, New York were relatively little natural rock habitat exists compared to the structure rich northeastern states (Flint 1971).

5.0 Data

5.1 Commercial Fishery

5.1.1 Data Collection Methods

Commercial catch data used for this assessment is gathered by the NMFS dealer canvass system. In some cases that data is augmented by state obtained data from dealers that may not hold federal permits, since federal requirements do not necessitate the licensing of dealers of tautog. Catch data is gathered annually as pounds landed.
Bycatch estimates are unavailable for the commercial fishery since there is limited sea sampling of the directed fisheries that land tautog.

Since tautog is not a federally managed species few commercial tautog lengths are taken through the NMFS dealer sampling program. Some states have limited and sporadic sampling of commercial landings, but the sampling intensity is too low, is clustered by gear type, and samples are too widely dispersed geographically for use in recreating commercial catch at length data. Length sampling intensity is thus presented as a proportion of the total combined harvest for both recreational and commercial fishery sectors.

The total harvest by state was treated with the coastal recreational harvest mean weight (A type catch only), to attain commercial numbers at length, as in the last three analytical assessments.

5.1.2 Biases

In some cases the NMFS recorded landings are obtained from the individual states while in other cases the data is obtained directly from NMFS licensed dealers. In the latter case, total state

tautog landings may under represent actual landings since there are no federal requirements for dealer licensing of tautog buyers. In addition since tautog are often marketed for the live trade and command a relatively high ex-vessel price the chances that there are unreported landings are believed to be higher than for other species.

Commercial length data may not reflect the actual commercial catch-at-age, since the commercial catch-at-length was estimated using recreational catch length frequency data at the annual state level. This is especially true in fisheries where grading for higher value fish may occur (i.e., for the more valuable live market). However, since the commercial harvest is on average only eight percent of the entire harvest this bias may not be problematic. Additionally, because hook and line is a significant component of the commercial harvest and the commercial fishery is not separated in space and time from the recreational fishery, catch lengths and ages should be similar to the recreational fishery.

5.1.3 Biological Sampling

Some age samples come from the commercial fishery, however, at this time sampling intensity is low and sampling is not stratified by fishery or gear type. See biological sampling in the recreational section (5.2.5).

5.1.4 Ageing methods

Whole opercula are obtained at random from commercial and recreational catches and fisheries independent surveys. Approximately 200 individual samples per state per year have been obtained since 1996. Opercula are most often taken in pairs from each fish, along with a total length and sometimes weight. Opercula are boiled for a short period of time, cleaned of all flesh, air-dried and read in their whole form. Annular marks are usually quite distinct, with the exception of the first annuli, which may be obscured by the thick bone growth in the region of the focus in older fish. January 1 aging conventions are used and fall aged fish are treated as an age plus group.

Age and growth workshops were held prior to earlier assessments but none have been held recently. Most available state age data were used to create regional age length keys with obvious outliers excluded. An exception was made for the last two years of Virginia data since aging methodology has changed and could not be verified in time for this assessment. Keys created for the early years of the time series were combined over years and within regions to yield adequate sample sizes, as was done in the past two assessments. Since FMP implementation almost all states have started sampling tautog for age and growth as per compliance criteria in the most recent plan addendum. Accordingly, keys from 1998 on represent single year keys for the Northern Region and biannual keys from 1996 on for the Southern Region. Key structure and sample sizes are presented in Table 2.

5.1.5 Development of Estimates

Annual numbers of harvested fish by state from the commercial fishery were derived using the annual recreational fishery coastwide mean weights and were characterized by length into one cm length intervals using recreational length frequency harvest proportions. Past assessments were conducted using length data pooled into one-inch increments. This change in methods was based upon a recommendation of the last SARC panel. The catch-at-age matrix from this assessment was very similar to the historical catch-at-age from the past two assessments for the overlapping years.

5.1.6 Commercial Landings Trends

Coastwide commercial landings were on the order of 200 mt at the beginning of the time series, rising rapidly in the mid 1980s to a peak of 535 mt in 1987. Landings remained high until 1994 but by 1999 had dropped to approx 94 metric tons. Commercial landings have since risen slightly to an average of 150 mt (2001-2003 average; Table 3 and Figure 1). Individual state landings have generally followed the coastwide trend, with the exception of Delaware, Maryland and Virginia, which peaked later, in the mid 1990s. State trends are examined more closely in the state-by-state status report Section 9.

Regarding the importance of the commercial fishery in individual states, the proportion of commercial landings to recreational landings ranges from a high of twenty five percent in Rhode Island to a low of less than one percent in Delaware. The states of Rhode Island, Massachusetts, and New York harvest the most tautog in their commercial fisheries, in descending order of coastwide rank.

5.1.7 Commercial Discards/By-catch

As in previous assessments, no discard estimates were available for the commercial catch so none were assumed. Since most commercial gears targeting tautog are used in shallow water, with relatively benign gear types, and the over all contribution to the harvest from the commercial fishery is less than ten percent, discard mortality rates and numbers from the commercial fishery are assumed to be negligible.

5.1.8 Commercial Catch Rates (CPUE)

No commercial CPUE data were available for this species since. Except for handful of small regional directed fisheries, tautog landings in most states represent by-catch from other commercial fisheries.

5.2 Recreational Fishery

5.2.1 Data Collection Methods

The recreational catch estimates, retained and discarded numbers of fish and mean weights, were obtained from the NMFS Marine Recreational Fisheries Statistical Survey (MRFSS) web site. Directed recreational effort data was obtained from NMFS personnel in Silver Spring, MD. State and mode specific recreational catch, harvest and B2 length data were obtained directly from MRFSS SAS files. Additional harvest length frequency data, by year and mode, were obtained directly from the New York DEC Open Boat Survey (Weber, personal communication) for the Northern Region, and the New Jersey DEP (Brust, personal communication), Delaware DNREC (Wong, personal communication), Virginia Gamefish Tagging Program (Lucy, personal communication) and the Virginia Tautog Mortality Study (White, personal communication) for the Southern Region. Released length data from the American Littoral Society (Shepherd, personal communication) were supplemented with data from the New York open boat survey for the Northern Region, and the New Jersey party boat survey and the Virginia tagging study for the Southern Region. Data from these studies were used to augment the limited MRFSS release data set.

5.2.2 Survey Methods

The MRFSS survey is a two-part survey. Telephone intercepts are made within states using random digit dialing of coastal households within coastal counties producing effort estimates by wave (two month sampling time periods), mode and area fished. Effort estimates are combined with intercept data from interviews with anglers at fishing sites and treated by correction factors to produce a catch per trip (angler day), within each state, wave, mode, county sampling cell.

5.2.3 Sampling Intensity

Recreational length sampling intensity information is presented in Table 4. In general recreational length sampling was poor early in the times series, rose in the 1990s and has since declined with declining landings.

5.2.4 Biases

Proportional Standard Error (PSE) estimates are generally poor at the state level (>20%) for harvest estimates in the beginning of the time series but have improved over the years. However, they are still not at acceptable levels in most states for most years. This is largely thought to occur as a result of the infrequent nature of intercepts of tautog in most states due to the seasonality and specialized nature of the fishery. Wave 1 is also not covered by the survey, which would underestimate harvest, particularly in the Southern Region. Nonetheless, it is the same data used in past assessments and the only available complete harvest and catch data set for the time series.

5.2.5   Biological Sampling

Length, weight and age samples are infrequently collected from the recreational fishery. Exceptions have been dedicated short-term sampling programs for specific fisheries in New York (head boat mode), New Jersey (head boat and shore mode), and Virginia (a directed fishing mortality study) and in some states that have a significant head boat or shore mode component to their recreational tautog catch. Most state's age samples come from a combination of recreational, commercial and fisheries independent surveys. See Table 2 for age sample sizes and sample sources.

5.2.6   Ageing methods

See the commercial age section above (5.1.4).

5.2.7   Development of Estimates

Proportions of catch-at-length for each state and year were determined and applied to the numbers harvested by state by year to yield numbers at length and were summed for each region. A discard mortality rate of 2.5% was applied to the total released numbers (MRFSS B2 catch) characterized by length by state and was summed within regions to account for release mortality (Simpson and Gates 1999). Individual state harvested lengths and B2 catch at length by region were added to the commercial catch at lengths by region to yield the total catch at length by region and aged using the appropriate region and time series age keys. The combined fishery regional catch-at-age was summed for the annual coastwide catch-at-age estimates.

5.2.8 Recreational Landings Trends

Coastwide trends are generally similar to those of the commercial harvest (Table 5 and Figure 2). Catches in the early to mid 1980s averaged 2.5 million fish, rose rapidly to a peak of 7 million fish in 1986, and returned to more moderate levels, averaging 2.7 million fish from 1987 to 1993. Harvest over the past ten years has averaged just below 1 million fish. Landings in 2004 were estimated at just over 1 million fish, a slight increase over 2003 (700,000 fish). The time series low was reached in 1998 with an estimated 300,000 fish. State by state trends follow similar patterns with the exception of Delaware that is without trend, Maryland with peak landings in the mid 1990s, and Virginia, without trend until the past few years and most recently rising slightly. Individual state trends are described in more detail in the state stock status report sections.

The importance of the recreational fishery relative to the commercial fishery reveals that Rhode Island has the smallest recreational landings proportion (seventy-five percent), as opposed to Delaware and Virginia, where most all landings come from the recreational fishery. By rank New Jersey, New York and Massachusetts have been the leading states in recreational landings over the time series with twenty-nine, twenty-four, and fifteen percent of the total coastwide harvest respectively. In more recent years (post FMP implementation) that ranking has changed to New Jersey, New York, and Delaware in descending order.

5.2.9 Recreational Discards

Recreational discards have increased steadily over the time series, from a low of 290 thousand fish to an average of 2.3 million fish over the last three years. Those trends are consistent with imposition of increasing minimum possession sizes and the release of undersized fish and more restrictive daily possession limits. However, estimated losses from released tautog are still a minor component of the over all recreational and total losses compared to other popular recreational species, due in large part to the assumed low discard mortality rate (2.5%) and the fact that tautog are not a popular catch and release target species, Table 5 and Figure 3.

5.2.10 Recreational Catch Rates (CPUE)

Since most tautog are caught by directed fishing methods a coastwide recreational CPUE was derived as the harvest from directed trips divided by the total number of directed trips. Directed trips are defined as a MRFSS preferred species, either prime 1 or 2. There is no trend over the coastwide time series (Figure 4). Most states' trends exhibit a similar pattern with the possible exception of Rhode Island. State-by-state trends are depicted and discussed in further detail in the respective states status reports, Section 9.

5.2.11 Recreational length frequency distributions

Recreational harvest length frequency distributions from the Northern Region reveal a loss of smaller fish over time from the range of 20 cm to 30 cm, commensurate with minimum size increases (Figure 5). On the larger end of the size range, fish as large as 65 cm are noted in the early years of the time series. Since 1998 few fish larger than 60 cm are evident in the landings.

For the Southern Region, fish are noted in the harvest as small as 10 cm up to the mid 1990s (Figure 6). Since the imposition of restrictive minimum size limits, fish smaller than 26 cm are uncommon in the harvest length frequency distributions from that region. Southern Region recreational harvest does not appear to exhibit the same loss of larger and older fish evident in Northern Region harvests.

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5.3 Fisheries Independent Survey Data

5.3.1 Data Collection Methods

Individual state survey data sets were obtained directly from each state's lead species biologists as numbers per tow, stratified mean numbers per tow or geometric mean number per tow, as in past assessments.

5.3.2 Survey Methods

Additional information is provided on state surveys in the individual state stock status section Appendices B - I. A brief descriptor for each survey is provided below.

The Massachusetts Division of Marine Fisheries runs a synoptic coastal trawl survey performed in two seasonal legs, one in May and the other in September. Sampling station numbers are stratified at random by depth within an eco/geographic region. The survey performs twenty minute tows with a 36 foot whiting net, with a small mesh liner and cookie sweep. Tautog indices are from the spring leg and regions 1-3 only (south of Cape Cod) and represent the weighted stratified mean number per tow of adult fish. Too few age-0 fish are captured for a reliable young-of-year index.

The Rhode Island Division of Fish and Wildlife, Marine Fisheries Section also performs a trawl survey in state waters. They have both a seasonal and monthly survey with both fixed and random stations. The index for tautog is from all month's surveys with non-duplicated tows from the two surveys combined and represents the number of adult tautog per tow. Juveniles are too infrequently encountered in the trawl survey to derive a reliable index of abundance. Past assessments have used a local seine survey index of tautog for age-0 fish but this assessment did not since the survey data was determined to contain age one fish as well.

The Connecticut Department of Environmental Conservation, Marine Fisheries Division runs a monthly trawl survey in Long Island Sound. The index for tautog represents a geometric mean number per tow of adult fish. Like most other northern state's trawl surveys too few juveniles are captured by this gear to allow an accurate index for age-0 fish.

The New York Department of Environmental Conservation performs a seasonal trawl survey in Peconic Bay. The survey is performed with a small "skiff" trawl in shallow waters and so captures primarily age-0 and age-1 fish with some occasional adults. For this assessment, only the geometric mean number of age-1 fish was used since the correlation of age-0 to age one fish the following season was weak and negative implying incomplete recruitment to the gear.

The New Jersey Bureau of Marine Fisheries runs a seasonal monthly trawl survey of coastal waters using an otter trawl in a random depth stratified experimental design. The survey takes place in January/February, April, June, August, and October. The index represents the stratified mean number per tow by age. Few age zero fish are captured in this survey.

5.3.3 Biases

Potential biases in the individual state surveys largely concern use of the gear type, an otter trawl, to sample what is primarily a reef fish. Highly habitat associated, tautog may not be sampled proportional to the population size over time. Changes in behavior, such when tautog are found off structured habitat (e.g., severe weather events, spawning activity, and pre-migratory schooling), may strongly influence encounters with the gear. Similarly, surveys may yield high numbers when the population expands and more fish are available on marginally suitable habitats

and more vulnerable to capture by this gear type. Surveys that cover more time and area are less susceptible to the biases associated with short-term availability events. Addressing the bias associated with contracted spatial distribution inside of core habitats below a threshold population size may require the use of alternate gear types, such as fish pots, to properly assess population strength at lower abundance.

5.3.4   Biological Sampling

Limited age, growth, sex and some maturity data are taken on most state surveys. However the total numbers captured by most states are low, meaning the data becomes supplemental to other collections and is not sufficient by itself to characterize survey catch-at-age, with few exceptions.

5.3.5 Ageing methods

See the commercial fisheries ageing section for a descriptor of ageing methods (5.1.4).

5.3.6 Development of Estimates

For all states but Connecticut and New York the combined recreational-commercial-survey age length keys were applied to the catch numbers at length. Connecticut used their own survey age/length keys and the New York survey catch was aged into three age classes, young-of-the-year, age-1, and adults, based on past local aging work.

5.3.7 Catch Rates

In general tautog catches are low for most all states when compared to many other species. The highest catch rates occur in Rhode Island and Connecticut waters where trawl survey methodology increases the chances of encounters with the gear and there is more tautog habitat in proportion to the area covered by the survey.

5.3.8 Length/Weight

Separate survey length-weight equations were not developed for this assessment.

5.3.9 Abundance Indices

Figure 7 depicts the combined plot of all available age aggregated survey indices over time, standardized (Z-scores) for comparison on the same scale. In general age aggregated survey index trends are similar for most states. Levels were moderate to high in the early part of the time series dropping to low levels since the mid 1990s. A slight upward trend is noticeable at the end of the time series in the Rhode Island and New York indices. Closer scrutiny of individual indices-at-age reveals those increases are attributable to increased abundance of younger age classes. The recently obtained 2005 Massachusetts index value is not depicted but also shows an increase at the end of the time series.

5.4 Uncertainty and Measures of Precision

See the VPA output files for more information concerning the fit of certain indices relative to the model outputs. In general, certain year classes and states contributed more relative variance to the model fit. In particular the states clustered in the Northern Region (Massachusetts - Connecticut) contribute a well-correlated and strong signal to the model that in turn makes several of the New Jersey indices contribute the most variance to model fit. Since it was the committee's desire to make the assessment provide the best available information for the range of

the assessment, and New Jersey was the southernmost state with a usable fisheries independent survey index, those indices were left in the final model run. This appropriately balanced the desire for increased precision versus increased spatial coverage since the model outputs did not change appreciably in either configuration. In addition, the VPA model accommodates catch error in the surveys. Exceptions were made for indices of age-0 fish for Rhode Island and New York, which did not correlate well with age-1 indices the following year. This was assumed to occur due to the relative availability of the smaller fish to the sampling gear, and so those indices were dropped from the final model run configuration.

6.0 Assessment

6.1 Qualitative Assessment

In general most states were at high levels of total losses in the mid to late 1980s and early 1990s. Combined fisheries losses have since dropped to far more moderate levels, and declined even further since the latest round of recreational harvest restrictions were applied. Notable state exceptions to that trend were Rhode Island, Connecticut, New York and Virginia. Both Rhode Island and Virginia were exempted from the last round of harvest reductions.

Regarding fisheries independent survey indices and abundance, most adjoining states exhibit similar trends (Figure 7). Age aggregated indices for Massachusetts, Rhode Island and Connecticut show high abundance in the mid to late 1980s falling to lower levels in the early 1990s with a recent upswing in the late 1990s, with the exception of Massachusetts. However, 2005 indices have recently been obtained for Massachusetts and show a similar increase. Both New Jersey and New York's indices reveal higher levels at the series start, in the early 1990s, declining immediately thereafter and returning to higher levels in the early 2000s. Age disaggregated indices reveal the recent increases coming mostly from younger aged fish. See the state stock status sections for more qualitative information and exploitation trends.

6.2 Analytical Models

The ADAPT VPA, Version 2.3.1, from the New England Fisheries Science Center NFT toolbox was used as the analytical model for this assessment. This model is similar to those used in the past assessments, but is a newer version providing better diagnostic tools. The toolbox Yield Per Recruit (YPR) model was used to update the yield per recruit and spawning stock biomass per recruit reference points with the updated VPA selectivity information.

6.2.1 Model Calibration

6.2.1.1 Tuning Indices

All available state indices-at-age were used for the initial VPA model runs. In the final runs the age zero indices from Rhode Isalnd and New York were deleted as mentioned above. The majority of the available indices came from states in the Northern Region that are geographically clustered and showed high pair-wise correlations, as might be expected. Since New York's survey location is separated geographically from the other states it showed different trends from the Northern Region but exhibited a trend similar to adjoining New Jersey's. The following indices were used in the final model run: Massachusetts indices at ages 1-12+, 1982- 2004; Rhode Island indices at ages 1-12+, 1982-2004; Connecticut indices at ages 1-12+, 1984 - 2004; New York index age-1 -1987-2004; New Jersey indices at ages 1-12+, 1988 -2004. State indices for 2005 were not available for this assessment.

6.2.1.2 Input Parameters and Specification

See the catch-at-age matrix for both regions combined (Table 6). See the spawning stock biomass weights at age and mean weights-at-age (Table 7). See the January 1 weights at age, Rivard calculated, (Table 8).

Natural mortality was assumed at 0.15 for all ages, 1-12+. Maturity inputs were 10% at age-2, 50% at age-3, 75% at age-4, 100% for ages 5 -12+, as in the past VPAs. Initial partial recruitment vectors were set at 0.27 for age-2, 0.215 for age-3, 0.328 for age-4, 0.519 for age-5, 0.679 for age-6, 0.827 for age-7, 0.921 for age-8, and 1.0 for ages 9-12+, based on the average estimated recruitment values of the past 5 years from initial VPA runs.

The F oldest calculation in years prior to terminal years uses F for ages 8-10.
Previous assessments used ages 7-11, but age-7 fish are not fully recruited and age-11 is the year prior to the plus group and not appropriate for calculation using this method.

The full catch weighted F was calculated using the classic method, backward projection, with auto estimated catchability coefficients.

7.0 Output/Results

7.1 Parameter Estimates

7.1.1 Exploitation Rates

Terminal year F estimates are depicted in Figure 8. Model output terminal F estimates reveal a similar pattern and similar values as in past assessments and updates. F estimates declined rather rapidly post FMP implementation to a low point in 1998. Fishing mortality rates then rose sharply in 1999, which was noted in the last assessment update and assumed attributable to recruitment of fish into the new size limit and recoupment effects in the recreational fishery. Catches again rose in 2002 before additional reductions were imposed on the recreational fisheries. Since that time the F has declined close to the existing F target value of 0.28. The bootstrapped estimate of F_{2003} is 0.30, which is slightly above the overfishing definition.

Preliminary terminal F estimates from a VPA run with the 2004 catch included were higher than estimated for 2003 but were not included in this assessment since 2005 index values are desired to reliably predict the 2004 fishing mortality rate and are unavailable at this time.

7.1.2 Abundance Estimates

The plot of estimated January 1 population numbers (Figure 9), reveals a steady increase in population numbers beginning in 1996, however, a plot of January 1 biomass (Figure 10), reveals little change in biomass since the mid 1990s, implying that the increase in numbers is the result of younger age classes that is not yet reflected by growth into higher biomass.

Similarly, the spawning stock biomass trend (Figure 11) reveals a steady decline in spawning potential from a high in the mid 1980s to low levels from 1994 to the present. Coastwide, spawning stock biomass is currently at about one-third of the level of the peak levels observed in the early to mid 1980s. Estimated recruitment, as measured by estimated age-1 population numbers reveals a steady decline from the early 1980s, with the lowest levels reached in 1996. Since that time recruitment has improved peaking in 2003 at a level last seen in 1983 (Figure 12).

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7.2 Precision of Parameter Estimates

Bootstrap estimates of fishing mortality reveal a mean catch weighted F of 0.30 with the 90% confidence interval estimates ranging from 0.24 to 0.38 (Figure 13). The January 1 biomass mean value was estimated at 11,422 mt with a 90 % confidence interval from 9,721 mt to 13,273 mt. The spawning stock biomass bootstrap mean estimate was 10,260 mt with the 90 % confidence interval running from 8,993 mt to 11,184 mt.

7.3 Sensitivity Analysis

7.3.1 Sensitivity to Input Data

Output terminal F estimates do not appear highly sensitive to individual index choices but the fit does change. Since the committee desired to keep most of the indices for management purposes the model fit is not as good as would normally be desired. The lack of 2005 survey indices yields unstable estimates of F, biomass and stock numbers based on the retrospective patterns when the 2004 catch-at-age is included. Accordingly those results are not presented here.

7.4 Retrospective Analysis

The historical pattern is depicted in Figure 14. In general the pattern of retrospective F estimates shows little difference in values between assessments with the exception of the last few years of the 1999 VPA and the 2002 update.

8.0 Biological Reference Points

8.1 Overfishing Definition

The most recent FMP addendum (III) defines overfishing as a fishing mortality rate exceeding the F target of $F_{40\%SSB}$, which was estimated in the previous assessment update at 0.29. This assessment updates the $F_{40\%SSB}$ value to 0.28 using the VPA estimated partial recruitment values and input mean weights.

8.2 Stock Recruitment Analysis

VPA estimated age-1 stock recruit numbers were plotted against the previous years spawning stock biomass (Figure 15). Spawning success appears non-compensatory at levels of spawning stock biomass noted in this assessment. Visual analysis suggests that on average median recruitment would be reached when spawning stock biomass is two and one half times the current level. Recent estimated recruitment patterns appear as an exception, suggesting favorable environmental conditions in some of the more recent years.

8.3 Yield and SSB per Recruit

The yield curve for tautog is not well defined (Figure 16), typified by a slowly sloping asymptotic limb. While the estimated F_{max} value is 0.6, a similar yield could be reached at a more conservative F of 0.35. As mentioned above the value of SSB $_{40\%}$ was re-estimated at 0.28 using the updated VPA estimated recruitment values. $F_{0.1}$ is a commonly used conservative biological reference point set where the slope of the yield per recruit curve is equal to 10% of the slope at the origin. $F_{0.1}$ was estimated at 0.20.

9.0 Summary of state status reports

State by state status reports are contained in Appendices B-I. Summaries of those reports are presented here while figures and tables from the main document are referenced in this section. The state reports in the appendices contain additional tables and figures that are not referenced here for clarity.

9.1 Massachusetts

9.1.1 Management History

In 1992 Massachusetts implemented a 12" minimum possession size for both recreational and commercial fisheries. In 1994 the minimum possession size was amended to 16". A recreational possession limit was set at 6 fish and a commercial daily limit was set at 50 fish in 1996. In response to a needed coastwide reduction in fishing mortality an annual closed commercial season from November 1 - April 15 and May 16 - July 10 to was implemented in 1998. In response to another plan required reduction in fishing mortality (Addendum III) the recreational fishery possession limit was decreased to 3 fish per angler per day in 2003.

9.1.2 Fisheries Dependent Data

Commercial harvest trends are landings averaging 38 mt during the 1982 to 1985 time period, rising to a peak harvest in the mid to late 1980s (121.5 mt), commensurate with development of a live fish wholesale market and high ex-vessel values (Table 3, Figure 17 A). Harvest declined in the mid 1990s, to an average of 35 mt, coincident with the imposition of commercial regulations. A slight increase over the past few years can probably be attributed to increased effort, as tautog is one of the few remaining species not controlled by quota management or limited entry in Massachusetts.

Recreational harvests (MRFSS A+B1 catch), from 1982 to the present range from a high of 2 million fish in 1986 to a low of 20,000 fish in 2004, averaging 317,000 fish over the time series (Table 5, Figure 18 A). Catches have averaged only 68,000 fish annually since restrictive recreational fisheries management was implemented in 1994 (16 inch minimum size limit). Since 1996 only 65,000 fish have been harvested on average. Additional and more restrictive recreational fisheries regulations were adopted in 2003 (3 fish bag limit) and recreational catches have since dropped to 46,000 and 20,000 fish in 2003 and 2004, respectively.

Since 1996 the released alive proportion of the catch (MRFSS B2 catch) has risen from 18.5% (1982 - 1993 mean) to 71% (1994 to 2004 mean). Estimated total recreational removals (harvest plus 2.5% of the B2 catch representing an estimate of release mortality) follow a trend similar to the recreational harvest, since the contribution of release mortality to total mortality is still relatively small.

Recreational CPUE was determined as the harvest numbers from directed trips divided by the number of directed trips, where directed trips are identified when anglers stated tautog as the preferred primary or secondary species sought. Since 71% of the total recreational catch is from directed trips one might expect a poor correlation between CPUE and local abundance. Indeed, the directed CPUE is without trend over the time series, and the correlation to estimated abundance is weak and negative (Figure 19 A). The total recreational harvest trends more closely resembles local abundance as measured by local survey indices, with a correlation coefficient value of 0.67.

Trends in overall fisheries removals closely track the recreational harvest and total recreational removal patterns since, as in the coastwide fisheries, the recreational catch dominates, making up an average 80% of local harvest over the time series.

9.1.3 Fisheries Independent Data

Survey indices are from the Massachusetts Biannual Coastal Trawl Survey and represent the stratified mean weight per tow and stratified mean number per tow from the spring survey leg in all regions south of Cape Cod. Survey indices averaged 5 fish per tow in the early 1980s, rising to a peak of 10.7 fish per tow in the mid 1980s (Figure 20 A). Survey indices declined in the late eighties to 1.7 fish per tow (1987 to 2004 mean), and the 2004 index (0.6) approached the time series low of 2000 (0.2). The 2005 index (2.86) returned to levels not seen since 1989.

Sampling for local age and growth parameters has remained at approximately the 200 fish level for the last ten years. That level is insufficient to create a viable local age length key. For that reason survey catch was aged using the Northern Region age-length keys pooled by year and state. The resulting catch-at-age matrix indicates a loss of older aged fish from the survey catch over time. In 1978 fish were routinely captured up to age-31. Beginning in 1993 few fish were caught older than age-21. In most recent years few fish were caught older than age-18.

9.1.4 Stock status

Plots of total losses over abundance indices (relative exploitation) reveal exploitation peaking in the mid 1980s through the mid 1990s, spiking up again in 2000 and dropping to moderate levels over the past four years (Figure 21 A). Recent exploitation levels are about one half of those in the peak years, before implementation of the FMP.

A local VPA or age-based analytical model run could not be performed since recreational and commercial catch frequency data is insufficient in recent years to expand catch numbers to length and age. A Biomass Dynamic Model run could not be performed because the available catch data has no contrast between the catch and indices (the "one way trip") within the recreational catch data time series (1981-present).

For an indication of fishing mortality trends localized Z estimates were made using within cohort (longitudinal) catch curves from the aged survey indices. Estimates of F were derived as Z-M where M = 0.15. All fully recruited ages were used, generally age-3 or 4 and older. Age classes since 1993 contain too few fully recruited age groups to estimate Z or F by this method. In addition the value of F calculated by this method is not comparable to mortality rates estimated from harvested catch since the data series contain fish that are recruited to the survey gear but not the fishery. Mortality rates for year classes recruiting to the fishery before local harvest restrictions averaged 0.25 (1988-1993). Since local management the average F (recruitment years 1994-2001) has dropped to 0.15.

Given the limited available data discussed above local stock status is uncertain. Survey catch-at-age patterns reveal age truncation over time indicative of past over fishing. However, local survey indices suggest that stock levels are steady at about one third of observed levels before fisheries expansion. There is some indication that 2002 may have been a favorable year for production based on age-1 survey index values and increased 2005 age-disaggregated indices. Survey cohort catch curves reveal F levels dropping on cohorts that recruited to the fishery post management. Relative exploitation patterns for recent years also appear moderate compared to peak levels in the mid 1980s. However, recreational fishery catches, and subsequent total removal patterns suggest that total removals may be more closely tied to local abundance than regulatory changes, with the exception of the past two years when the most recent cuts took

effect. Steadily increasing commercial harvests, though moderate, are cause for some concern given current resource levels and declining recreational harvest proportions.

9.2 Rhode Island

9.2.1 Management History

A 12" minimum size limit was implemented in 1988 for both fisheries. In 1994 the minimum size was increased to 16 inches. In 1995 commercial seasons and a recreational bag limit (8 fish) were imposed. The recreational possession limits were adjusted to 2 fish for the party and charter boat fishermen and 5 fish per private boat and shore fishermen in 1996. A commercial quota of 21 mt (47,000 pounds) was implemented the same year. In 1997 the commercial quota was adjusted downward to 16.8 mt (37,000) pounds and a daily possession limit of 40 fish was established. Party and charter boat possession limits were adjusted to allow an increased possession limit of 12 fish from October 15- December 31. In 1998 the recreational possession limit was decreased to 4 fish for private modes and to 1 fish for party/charter modes during the 2 fish possession season, and the commercial possession limit was adjusted to 20 fish. 2000 saw a readjustment in annual seasons and possession limits for recreational fishermen to 3 fish from May 1 - October 14 and 10 fish from October 15 to December 31. The commercial possession limit was adjusted to 10 fish per day in 2003.

9.2.2 Fisheries Dependent Data

Commercial harvest trends reveal moderate landings of about 52 mt per year at the beginning of the time series rising to an average of 145 mt from 1984 - 1993 (Table 3, Figure 17 B). Like neighboring Massachusetts these trends are commensurate with development of a live fish wholesale market and high ex-vessel values. Harvest declined in the mid 1990s, to an average of 20 mt (1996-2004), commensurate with imposition of commercial regulations, including an annual harvest quota that has held harvest in check independent of effort.

Recreational harvests (MRFSS A+B1 catch), from 1982 to the present range from a high of 672,000 fish in 1986 to a low of 54,000 fish in 1995, averaging 163,000 fish over the time series (Table 5, Figure 18 B). Landings have averaged only 54,000 fish annually since restrictive recreational fisheries management was implemented in 1995 (16 inch minimum size limit), exclusive of the past two seasons when catches rose to 120,000 and 165,000 fish. Catches probably rose in the last two seasons in response favorable weather and availability of fish during the portion of the season when higher bag limits are in effect.

Since 1996 the released alive proportion of the catch (MRFSS B2 catch) has risen from 23% (1982 - 1995 mean) to 60% (1996 to 2004 mean). Estimated total recreational removals (harvest plus 2.5% of the B2 catch representing an estimate of release mortality) follow trends similar to the recreational harvest, since the contribution of release mortality to total mortality is relatively small.

Recreational CPUE trends are variable from 1982 to 1992, averaging 1.8 fish per angler trip dropping to the time series low in 1993 (0.86) (Figure 19 B). From 1994 onward the CPUE indicates improving angler success, rising to the time series high of 3.1 in 2003.

Trends in overall fisheries removals closely track the recreational harvest and total recreational removal patterns, since, as in the coastwide fisheries, the recreational catch predominates, making up an average 71% of local losses over the time series.

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9.2.3 Fisheries Independent Data

Aggregate survey indices are from the Rhode Island monthly and seasonal surveys with duplicate tows removed and represent the mean catch per tow. Survey indices averaged 0.43 fish per tow in the early 1980s, rising to an average of 0.89 fish per tow in the mid 1980s - early 1990s (Figure 20 B). Survey indices then declined during the period 1994 -1998 to low levels, averaging 0.26 and have since rebounded to 0.57 during the 1999-2004 time frame. The index from 2004 is approximately equal to levels last seen in 1991 and is about 65% of levels noted during the 1984 - 1993 time period.

The age composition of the survey catch indicates some truncation over time. Fish out to age-30, where captured in the survey in the early part of the series. Fish older than age-23 are absent from the series after 1991. By 2002 few fish older than 18 are present in survey catches. Younger aged fish (ages 0 - ten) are increasing in the survey indices since 1999, but the trend implies some increased availability to the gear vs. stock rebuilding since the indices increase for all ages during the same years vs. improved recruitment being tracked over subsequent years.

9.2.4 Stock status

Plots of total losses over abundance indices reveal relative exploitation at high levels at the beginning of the time series, at moderate levels from 1983 - 1995, and dropping to levels about half of that since 1998 (Figure 21 B).

A Biomass Dynamic Model was run and is presented in Appendix C. Results depict exploitation at very low levels from 1959 - 1977 (biomass F = 0.1) rising to high levels from 1991-1992 (estimated biomass F = 0.8), commensurate with increased harvest and decreased abundance. Since management restrictions, F has dropped to moderate levels (averaging 0.3 for 1997 - 2003) and current exploitation levels appear low (biomass F=0.19). These results are consistent with relative exploitation patterns.

Given the data discussed above local stock status appears to be improving. There is some indication that 2002 may have been a favorable year for production based on age-0 - 2 survey index values, implying that biomass will continue to increase in the future. Exploitation patterns for recent years also appear moderate compared to intermediate levels in the mid 1980s and high levels in the early 1980s, suggesting that local management is helping to control exploitation to some degree. Commercial harvests appear well capped by the existing local quota, however recent years recreational catches are increasing and are of some concern given desired biomass levels.

9.3 Connecticut (Long Island Sound)

9.3.1 Management History

Prior to 1995 Connecticut had a 12-inch size limit, which was increased in 1995 to 14 inches. In 1996 Connecticut enacted possession limits of 4 fish in the recreational fishery and various gear specific possession limits in the commercial fisheries. Also a seasonal closure of May 1 to June 14 was implemented for both fisheries at that time. In response to Addendum III the recreational fishery closed period was extended to include the time of November 24 - December 31 in 2003, which was amended to September 8 - 21 and December 14 - December 31 during 2004.

9.3.2 Fisheries Dependent Data

Like many of the Northern Region states, commercial harvests of tautog were relatively low until the mid 1980s, when landings peaked at 72 mt (Table 3, Figure 17 C). From then until 1998 a declining trend is noted, reaching the low of 3 mt and remaining at low levels since management was imposed. The annual post management (1997 - 2004) average is 8 mt.

Recreational harvest in number varied without trend from 1982 to 1992, averaging 216,ooo fish, declining over the period 1993 to 1997, with 1996 representing the first year of truly restrictive management (Table 5, Figure 18 C). Post management the harvest averaged 28,000, fish but has since increased to an average of 127,000 fish over the past three years.

Recreational CPUE is without trend over most of the time series but has been increasing steadily over the past three years (Figure 19 C).

9.3.3 Fisheries Independent Data

Similar to other northern region states survey trends, indices are relatively high at the beginning of the time series, averaging about 2 fish per tow in the early to mid 1980s, declining rapidly in the late 1980s (Figure 20 C). Since that time indices have averaged 0.8 fish per tow. Survey indices dropped below that mean from 1993 to 2000 and rose above it for 2001-2003. Survey indices dipped slightly below that mean again in 2004. YOY survey indices from a local seine survey are variable but indicate an increasing trend in local production over the time series.

Trawl survey age and length data exhibit truncation over time. From 1984-1994 20-30 percent of fish were age-10 or older, from 1995-2004 only 10% of the fish were age-10 or older.

9.3.4 Stock status

Relative exploitation patterns reveal a high level of exploitation from 1986 to 1995, declining sharply in 1996, when minimum size regulations were first imposed (Figure 21 C). Since that time relative exploitation has declined even further to very low levels during the 1999 - 2001 time period. Exploitation has returned to moderate levels in the past four years, commensurate with the noted increased recreational harvest. Survey age distributions reveal age truncation indicative of past overfishing.

In general, based on survey indices, the Long Island Sound stock appears to be increasing slowly from the time series lows in the mid 1990s, and local recruitment appears on the increase. However, recreational harvest may not be adequately constrained by existing regulations and exploitation levels are on the short term increase. On the whole however, exploitation rates are about one third of those noted in the peak fisheries years.

9.4 New York

New York is in a unique geographic situation sharing Long Island Sound (LIS) waters with Connecticut, and northern Mid-Atlantic Bight waters with New Jersey. Harvest trends reported as a state are described here. For stock status see Connecticut for the LIS stock. See the New Jersey stock status section for the New York south coast stock status.

9.4.1 Management History

Prior to 1991 New York had a minimum size of 7 inches. In 1991 a 12-inch minimum size was enacted for the commercial fishery and the recreational size limit was adjusted to 10 inches. By 1994 both the recreational and commercial minimum sizes were raised to 12 inches. In 1995 the recreational size limit was increased to 13 inches and a daily possession limit of 10 fish was put

into place. Similarly, the commercial minimum size was increased to 14 inches and a 50 fish daily limit was implemented. The commercial minimum size was increased again in 1996 to 16 inches. 1997 saw a reduction in the commercial trip limit to 25 fish per vessel and prohibited the use of gill and trammel nets.

In response to adoption of Addendum I of the ASMFC FMP New York increased the recreational size limit to 14 inches and revised the recreational bag limit to 10 fish during the October 7 - May 30 time period and 1 fish the remainder of the year and the commercial size limit was lowered to 14 inches with a March 1 - April 8 seasonal closure. In response to adoption of Addendum III the recreational possession limit was adjusted to 10 fish with a seasonal closure of June 1 through September 30.

9.4.2 Fisheries Dependent Data

Commercial harvest trends depict landings averaging 41.5 mt during the 1982 to 1985 time period, rising to a peak harvest in the late 1980s, 129 mt in 1989 (Table 3, Figure 17 D). Harvest declined in the early 1990s, to an average of 32 mt.

Recreational harvests from 1982 to the present range from a high of 1.2 million fish in 1986 to a low of 46,000 fish in 2001, averaging 0.5 million fish over the time series (Table 5, Figure 18 D). Catches have averaged 189,000 fish annually since restrictive recreational fisheries management was implemented in 1994 (14 inch minimum size limit). Since 1996 the released alive proportion of the catch has risen from 46% (1982 - 1995 mean) to 75% (1996 to 2004 mean). Estimated total recreational removals follow trends similar to the recreational harvest, since the contribution of release mortality to total mortality is still relatively small. The recreational CPUE for New York appears without trend over the time series (Figure 19 D).

Trends in overall fisheries removals closely track the recreational harvest and total recreational removal patterns since, as in the coastwide fisheries, the recreational catch predominates, making up an average 80% of local harvest over the time series.

9.4.3 Fisheries Independent Data

Survey indices are from the New York Peconic Bay Trawl Survey and represent the geometric mean number per tow. Survey indices for all ages declined below the time series average (0.29) from 1994 to 1999, rising substantially above the average from 2001 to 2003 (0.43) (Figure 20 D). The 2004 index was just below the time series average. Survey indices are strongly influenced by age-0 and 1 fish over the time series (78 % average) and have become more so over time, ranging from 54 % juveniles at the beginning of the time series to 96% at the end of the time series.

Sampling for local age and growth parameters has not taken place since 2001; therefore there is no local age length key. Survey catch was aged based on length-at-age from historical age keys. Since the survey is heavily influenced by age-0 and 1 fish little bias is expected from aging using this method.

9.4.4 Stock status

A local exploitation history was not determined since the fisheries independent survey targets primarily juvenile tautog and is not geographically comprehensive. The survey catch has become increasingly comprised of age-0 and 1 fish over time, implying that adult biomass may be declining at the eastern end of Long Island. In contrast, recruitment in that area, like in adjoining Long Island Sound, appears to be improving.

Based on local recreational harvest and commercial landings trends F is probably down considerably from the peaks of the pre-management years, but like adjoining states, stocks have not increased to the levels seen in those years.

9.5 New Jersey

9.5.1 Management History

Prior to 1994, there were no commercial or recreational management restrictions on the harvest of tautog. Beginning in 1994, New Jersey implemented a series of progressively stricter management measures, including a minimum size limit increasing from 11" in 1994 to 14" in 1997 (commercial) and 1998 (recreational) plus a recreational possession limit and commercial quota. These measures remained essentially unchanged for several years until 2003, when new recreational possession limits were required to reduce harvest. In the same year, commercial seasons were changed at the request of participating fishermen. The measures implemented in 2003 are still in effect.

9.5.2 Fisheries Dependent Data

Between 1950 and 1966 commercial tautog landings in New Jersey were relatively stable, averaging approximately 16.3 mt per year (Table 3, Figure 17 E). Between 1963 and 1966, landings decreased to below 9 mt per year and stayed at this level for several years. In 1972, landings began a gradual increase back to previous levels, exceeding 22.6 mt in 1980 and 1981. In 1982 annual landings increased dramatically to over 63 mt and generally remained above 40.8 mt per year until 1996. Implementation of commercial regulations in 1994 resulted in a rapid decline in landings from 73.7 mt in 1994 (time series high) to 12.4 mt in 1999. Since 1999, landings have rebounded somewhat to between 15.9 mt and 29.5 mt, well below the quota of 46.7 mt (103,000 pounds).

From 1982 and 2004, the recreational catch (number of A+B1+B2 fish) has varied widely between years, ranging from approximately 237,000 fish caught in 1998 to almost 2.5 million fish caught in 1986. In general, catch appears to have varied without trend over the entire time series, with an average catch of approximately 1 million fish per year.

Recreational harvest ranges from 11,600 fish in 1998 to over 2.3 million fish in 1986 (Table 5, Figure 18 E). Based on the MRFSS data, the number of tautog harvested in New Jersey increased from approximately 500,000 fish in the early 1980s, to around 1 million fish by the early 1990s. From 1992 to 2004, there has been a decreasing trend in harvest. Average harvest from 2002 to 2004 was around 189,000 fish, approximately one-fifth of the harvest in the three years before regulations.

Between 1982 and 1994, catch per unit effort (CPUE) appears relatively stable, generally ranging between 4 and 6 fish per trip (Figure 19 E). From 1995 to 2001, CPUE increases substantially to between 6 and 10 fish per trip before returning to previous levels in 2002. Overall, the recreational fishery CPUE shows a positive slope from 1982 to 2004.

9.5.3 Fisheries Independent Data

New Jersey has conducted a stratified random trawl survey in nearshore ocean waters since 1988. The survey is conducted five times per year (January, April, June, August, October) between Cape May and Sandy Hook, NJ. The sampling area is stratified into 5 areas north to south and 3 depth zones (<5, 5-10, 10-20 fathoms) for a total of 15 strata. During each survey, a total of 39

tows are conducted, with the sample size in each stratum determined by stratum area. The sampling gear is a two-seam trawl with a 25 m head rope and 30.5 m footrope. The cod-end has a 6.4 mm liner. An annual index of tautog abundance is determined as the stratified mean number per tow, weighted by stratum area. The index values were aged using the Southern Region age-length keys used in the coastwide VPA.

In two of the first three years of the survey, the age-aggregated index was greater than one fish per tow (Figure 20 E). Beginning in 1990, the index began a steady decline from the second highest point in the time series (1.1 fish per tow) to the time series low in 1997 (0.04 fish per tow). Since 1997, the index appears to have increased slightly to 0.23 fish per tow in 2003 and 0.14 in 2004. However, it appears that relative abundance may be highly influenced by availability of the fish to the gear rather than actual abundance. This is assumed because the recent increases in abundance are not restricted to a single cohort. Rather, when the total index is high, the index for each age is high. Similarly, the decreases in the indices in the early part of the time series occur on all ages concurrently, instead of on oldest ages first as might be expected if the stock was overexploited. For this reason, there is some concern about the utility of the trawl survey index in assessing local tautog population status.

9.5.4 Stock status

A plot of relative exploitation shows little trend over the time series but does indicate higher levels of exploitation in the mid 1990s, dropping to low levels immediately post management, returning to moderate levels for 2000 - 2001 and declining back to low levels from 2002 through 2004 (Figure 21 D).

Cross sectional (i.e., within year) catch curves were created using recreational harvest data. The age at full recruitment ranged from age-3 to age-7. For all years except 1999, full recruitment occurred at or before age-6. Instantaneous total mortality (Z) was computed on ages 7 to 12, except in 1999 when ages 8 to 12 were used. Instantaneous fishing mortality (F) was computed as Z minus a constant natural mortality rate of 0.15.

From 1995 to 2003, F generally ranged from 0.1 to 0.2, dropping below 0.1 in 1997 and 2000. During this time period, there has been no observable trend in F. Unfortunately, the first year that annual keys are available is the second year of management and it is therefore not possible to compare fishing mortality rates before and after implementation of management measures. However, the data suggest that fishing mortality on ages 7 to 12 has been well below the management target of $F_{40\%} = 0.29$ since at least 1995.

Longitudinal (i.e. cohort specific) catch curves were also created using recreational harvest per unit effort (HPUE) data from the MRFSS. HPUE by length was determined using the recreational length frequency distributions described in Appendix F, New Jersey Status Report. Mortality was only computed for cohorts with information on four or more ages, 1986 (ages 9 to 12) to 1993 (ages 7 to 10). Cohort fishing mortality decreased from 0.68 in 1986 to 0.2 in 1989. It remained at low levels (less than 0.11) for several years before increasing dramatically to 0.35 in 1992 and 0.49 in 1993. The two highest points of the time series (1986 and 1993) may be affected by estimating mortality on only four data points. For the cohorts with five or more years worth of data, F has been below the $F_{40\%SSB}$ (0.29) target, except for the 1987 and 1992 year classes.

Available data suggest that fishing mortality on tautog in New Jersey has decreased since the implementation of regulations. Commercial harvest in the last three years is less than 50% of the harvest in the three years prior to management. Similarly, recreational harvest has decreased nearly 80% over the same time period, while recreational CPUE has remained stable. Relative F

estimates using recreational CPUE show a decrease in F in the last decade, and relative F based on total harvest shows low levels of exploitation for the past three years. Recreational catch curves indicate that fishing mortality on ages 7 to 12 has been below the management target since 1995. These data suggest that the management measures adopted for the tautog fisheries in New Jersey have been successful in attaining the management objectives.

On a cautionary note, there is some concern that there is no strong evidence of stock rebuilding with decreased fishing pressure. Trawl survey indices have increased in recent years, but it was shown that the increase was concurrent on all ages, rather than consecutively as one or more strong year classes recruited to the gear. Recreational CPUE increased in the late 1990s, but has since decreased again. In addition, some trends suggest a recent increase in fishing mortality, including the commercial harvest, recreational CPUE, recreational catch curves, and relative F using trawl survey indices-at-age. These indicators should be watched over the next few years to determine whether these indices are showing true increases in F or are simply a function of inter-annual variability.

9.6 Delaware

9.6.1 Management History

In 1992 Delaware implemented a minimum size of 15" and a possession limit of 3 fish per day, April - June, and 20 fish per day the remainder of the year. In 1995 the commercial hook and line fishery became limited entry. In 1998 the July - March possession limit was reduced to 10 fish per day and a seasonal closure of September 1st - 17th was implemented. Additionally, the minimum size limits were adjusted to allow a 14" minimum size during July - March. In 2003 Delaware increased the length of the closed season to September 28th in response to Amendment 3.

9.6.2 Fisheries Dependent Data

Commercial fishery landings are minimal in Delaware, accounting for 0.3% of the states recreational fishery landings. Annual commercial landings in Delaware have averaged 454 kg and account for only 0.16% of the coastwide commercial total from 1982 to 2004. An increase in landings has occurred in the most recent two years (2003-2004 average = 1,241 kg), equal to 1% of the coastwide total during this period (Table 3, Figure 17 F).

Annual recreational landings (Type A+B1) have been erratic since 1982, with sporadic, single-year peaks occurring in 1989 and 1995 (Table 5, Figure 18 F). The 1982 to 2004 average was 102,536 individuals (Type A+B1), accounting for 5% of the coastwide average. Recent landings in 2002 and 2004 were slightly larger than normal. Numbers of angler-released fish (Type B2) have increased substantially since recreational harvest restrictions began in 1992.

Recreational fishing effort has increased over the time series. Directed fishing effort (defined as trips with tautog as the primary or secondary preferred species sought) has climbed since 1982. Total catch (Type A+B1+B2) per directed trip has regularly fluctuated without directional trend, whereas recent landings (Type A+B1) per directed trip are generally lower than that seen in the 1980s. The onset of size and harvest restrictions in the early 1990s coincides with the depressed, yet relatively, stable harvest CPUE (Figure 19 F).

9.6.3 Fisheries Independent Data

Delaware does not have a fisheries independent survey suitable for accessing tautog abundance. Age data has been collected for the past eleven years and represents catch lengths and ages from the recreational and commercial fisheries.

9.6.4 Stock status

Instantaneous total mortality rates (Z) were calculated from catch curve analyses of the recreational fishery catch-at-age distributions from 1996 to 2004. Two catch curve approaches for calculating Z were employed based on the declining log-transformed catch-at-age (descending limbs) across 1) multiple cohorts within a single year (hereby referred to as cross-sectional catch curves), and 2) across adjacent years following a single cohort through time (hereby referred to as longitudinal catch curves). The descending limb of the catch curve was composed of ensuing ages to the right of the age of maximum catch, and further restricted to sample sizes of at least 5 aged specimens. Annual recreational catch per unit effort (Type A+B1 landings per directed trip) was used in order to standardize effort across years in the longitudinal catch curve analysis. Catch ages were based on state age data.

Annual instantaneous total mortality rates (Z), averaged 0.49 from 1996 to 2004. Given the management target of Z=0.44 (F_{target} + M = 0.29 + 0.15), the Delaware portion of the coastwide population appears to be close to the target mortality rate. Instantaneous fishing mortality rates (F), assuming a constant natural mortality rate, have averaged 0.34. Unfortunately, no information about annual recruitment or fishing vulnerability across fully recruited ages is available. Also, the age distribution in some years may have been spuriously affected by low collection numbers of age samples. These caveats should be considered when interpreting these results.

Limiting the results of the longitudinal catch curve analysis to cohorts with at least four data points in its descending limb produced Z values that appear to decline across the 1990 to 1995 cohorts. The average Z calculation for these six cohorts was 0.55, albeit with considerably high uncertainty associated with individual slopes and low coefficient of determination (R^2) values. The ostensible non-linearity of these catch curves suggests that either mortality is not constant across age classes, vulnerability to the fishery changes across age classes, or perhaps data are too sparse or unreliable for this analysis.

The status of the resident tautog stock of Delaware is uncertain given only fishery-dependent information, yet positive signs of unexpanded long-term fishery landings, regularly fluctuating (yet non-declining) recreational total catch CPUE, and consistent (if not declining) short-term mortality rates near the management target lessen imminent concern for the local stock. However, the decline of older age classes (>6 years old) in recent years and rising fishing effort might be indicators of potential overfishing on the stock. Larger sample sizes taken from the recreational fishery landings in upcoming years should illuminate whether this observed age truncation was a sampling artifact or perhaps a true sign of overfishing and/or an overfished state.

9.7 Maryland

9.7.1 Management History

In 1998, Maryland imposed a daily harvest limit of five fish per day and a minimum size limit of 14 inches total length (TL) for both the commercial and recreational fisheries in 1998. In 2003, a regulation change by the Maryland Department of Natural Resources (MD DNR) was enacted to

comply with Amendment III. This action closed the recreational fishery during the month of December.

9.7.2 Fisheries Dependent Data

Maryland's commercial harvest is highly variable over the time series ranging from a low of no fish in 1983 to a high of 2.74 mt in 2004 (Table 3, Figure 17 G), but the trend depicts steadily increasing landings.

Maryland's recreational landings also are highly variable over the time series ranging from a low of 486 fish per year in 1985 to a high of 157,000 fish in 1994, but depict three distinct trend phases (Table 5, Figure 18 G). Annual harvest in the early and mid 1980s averaged approximately 17,000 fish. In the late 1980s to the late 1990s annual harvest rose to approximately 70,000 fish. From 1998 on, when management would be expected to effect recreational catches, the annual harvest averages approximately 20,900 fish, similar to the early part of the time series.

Recreational CPUE is variable over the time series with higher CPUE early in the time series and lower CPUE since implementation of the FMP (Figure 19 G).

9.7.3 Fisheries Independent Data

Maryland does not have a local survey that regularly captures sufficient numbers of tautog to provide a comprehensive index of abundance, but the existing trawl survey depicts steady abundance during the time series. Based on the local age collection and age and length distributions age truncation over time is not indicated.

9.7.4 Stock status

The status of tautog in Maryland waters is uncertain given that there is little fisheries independent data. However, Maryland shares Chesapeake Bay and nearby Atlantic Ocean waters with Virginia, so exploitation trends may be similar. Virginia may have a relatively static population. Catch age sample distributions reveal no truncation in age classes over time indicating that historical overfishing may not have taken place as in more northern states. Increased commercial catches, while relatively minor compared to northern states, bear watching since existing commercial regulations may not adequately control commercial harvest.

9.8 Virginia

9.8.1 Management History

In May 1997 Virginia established a 13" minimum size for both fisheries and the commercial fishery was closed annually from May 1 through August 31 at that time. In accordance with FMP requirements Virginia increased the minimum size to 14", effective April 1, 1998. The recreational season was also closed from May 1 through June 30 with a 10 fish possession limit. Effective January 1, 1999 the recreational fishery went to a 7 fish possession limit and no closed season. The 7 fish possession limit with no closed season has remained in effect since that time. The commercial closed season and gear restriction have stayed the same since 1997.

9.8.2 Fisheries Dependent Data

The commercial fishery averaged 1.4 mt between 1980 and 1993 (Table 3, Figure 17 H). The fishery saw an increase in the mid 1990s that has remained consistent to the present (1994- 2004),

with a mean harvest of 8.2 mt. 1995 had the highest commercial landings for the 25-year period (12.6 mt).

The increased commercial landings that began in 1994 are directly associated with an increase in hook and line landings, and do not reveal any effect from the regulations that went into place with the FMP. Using VMRC mandatory reporting data for the period 1994-2004, landings from hook and line account for an average of 80% of total commercial landings. Due to the opportunistic nature of the fishery, seasonal closures and possession limits may not be a constraint for commercial landings.

Prior to regulations imposed in 1997 in response to the FMP, recreational harvests (A+B1 catch) averaged just over 228,000 fish per year for the period 1982-1995 (1982 has the lowest landings at 71,599 fish and 1983 the highest at 579,795 fish) (Table 5, Figure 18 H). The average harvest for the years 1984-1996 is 212,424 fish. The harvest average for 1997-2004 is 65,505 fish. 2003 and 2004 have shown large increases in estimated recreational harvest. Recreational CPUE is without trend over the time series except for a noted spike in 1983 (Figure 18 H).

9.8.3 Fisheries Independent Data

In accordance with FMP sampling protocol, Virginia's Stock Assessment Program (SAP) has been collecting biological data on finfish since 1988. In 1998, the SAP, in cooperation with Old Dominion University's Center for Quantitative Fisheries Ecology Laboratory, initiated removal of otoliths from 13 important finfish species, including tautog, in order to obtain age data. During 1998-1999, otoliths from over 400 tautog caught by commercial gear were collected to be analyzed for age information. More than 500 samples were obtained in 2003 and 2004. The aging samples also represent the fishery by gear and spatially. Assuming the vast majority of Virginia's recreational landings for tautog are hook and line, as are the majority of commercial landings, the samples collected should reflect the entire fishery.

VIMS has been conducting a fishery independent juvenile trawl survey since 1955 but does not collect enough tautog to derive an index of abundance. Currently, the survey samples approximately 35 Bay stations and 60 river stations. Between 1955 and 2003 there were a total of only 311 tautog captured in the survey (average length of fish captured in this period is 289mm/11.4in). From 2000 through 2002 there were only 12 tautog captured. In 2003, only seven individuals were captured. Data for 2004 is not yet available. Catch rates per year have been stable, averaging 6 fish per yr.

9.8.4 Stock status

Virginia has no reliable stock size indicator but the VIMS survey shows stable catch rates over time implying little change in stock levels over the time series.

Catch curve analyses show mortality rates in Virginia have remained below the target F=0.29, over the past seven years. Equilibrium cross-sectional catch curve analysis suggests a slight reduction in total mortality in recent years relative to the 1980s and early 1990s. Non-equilibrium catch curves were also constructed for the years (1997, 1999-2004) assuming that mortality may have changed over time. Without local independent data to confirm steady recruitment for Virginia's tautog stock, cross sectional catch curves cannot definitively demonstrate total mortality rates (Hoenig et al, 2005). However, recruitment estimates from the VPA do not show any decreasing trend over time throughout the northern management area and actually show an increase in biomass and recruitment in recent years (ASMFC 2002).

The MRFSS effort data corresponds to lower fishing mortality in recent years (with a notable increase in only the last two years). This supports the conclusion that fishing mortality has not exceeded the target level. Fishing effort has risen in the last two years and, coincidentally, the extreme left-most two points of the (descending limb of the) catch curve are steep. This suggests that effort and mortality may be rising and should be monitored to look for a sustained change.

10.0 Recommendations and Findings

10.1 Current stock status

An evaluation of the current coastwide stock status for tautog, based on the coastwide VPA and the updated biological reference point, suggests that overfishing is occurring on a coastwide basis. State by state stock status review does not contradict this finding and indicates that local stocks are historically overfished in the Northern Region based on catch-at-age distributions and current stock levels. F levels in that region have dropped considerably since FMP implementation but may be rising again. Conversely limited data suggests that tautog may not be historically overfished in the southern end of the Southern Region and that fishing mortality rates there may not have yet reached the overfishing definition, but may be approaching that level. Stock levels and mortality rates in the northern Mid-Atlantic Bight appear transitional between the two regional findings.

Increasingly restrictive regulations over the years since FMP implementation appear to have reduced or capped fishing mortality rates from the coastwide high levels noted just prior to the FMP. However, increases in recreational harvest and total losses in the states of Rhode Island, Connecticut, New York and Virginia over last few years imply that regulations in those states may not be totally effective at capping recreational landings over the long term, since most still have liberal bag limits during seasons when high catches could be expected. These trends require close scrutiny over the next several years to hold total losses to acceptable levels, with respect to desired mortality rates, and states whose landings have risen over past few years may want to take proactive management measures to cap harvest.

In addition, while current fishing levels are reasonably low and not significantly elevated above the target they may be too high under current stock conditions to expect successful stock rebuilding in the near future, unless favorable environmental conditions return and are sustained. Stock levels and spawning stock biomass appear to be at levels about one-third of those noted in the early part of the time series. SSB/R analysis suggests that to attain median recruitment on average that spawning stock biomass should be increased to 2.5 times the current level. It is highly recommended that updated VPA model runs be performed as soon as 2005 state indices are available to determine the 2004 terminal F value and corroborate recent exploitation trends.

10.2 Research Recommendations

1. Commercial harvest and discard length frequency data is desirable for future stock assessments.

2. Increased sampling of recreational catch length frequency data, including discards is needed.

3. Southern states fisheries independent stock indices would be valuable to support a refined VPA or two regional VPA's.

4. An ageing workshop should be held to resolve conflicting age information from the southern end of the range and determine if true growth rate differences exist.

5. Environmental variables and their role in tautog recruitment should be explored in concert with other southern demersal species that have exhibited similar trends in the past 20 years .

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12.0 Tables

Table 1. State regulations.

Commercial regulations

STATE	SIZE LIMIT	POSSESSION LIMITS	SEASONS	QUOTA	GEAR RESTRICTIONS
Massachusetts	16"	40	April 15-May 15 July 11-October 31		Yes
Rhode Island	16"	10	April 15-May 31	17,116 lbs	Yes
	16"	10	August 1-September 15	17,116 lbs	
	16"	10	October 15-December 31	17,116 lbs	
Connecticut	14"	a	January 1 - April 30 June 15-Dec 31 September 22 - Dec 13		Yes
New York	14"	b	April 8 - last day of February		Yes
New Jersey	14"		April 15-June 30 November 1-January 15	103,000 lbs	Yes
Delaware	14"/15"	See recreational	See Recreational		
Maryland	14"	5			Yes
Virginia	14"		Jan 1- April 30 Sept 1- Dec 31		Yes

Recreational Regulations

STATE	SIZE LIMIT	POSSESSION LIMITS	SEASONS
Massachusetts	16"	3	-
Rhode Island	16"	3	May 1-October 14
	16"	10	October 15-December 31
Connecticut	14"	4 (daily)	Jan 1-Apr 30, June 15 - Sept 7, Sept 22 – Dec 13
New York	14"	10	October 1-May 31
New Jersey	14"	4	January 1-May 31
	14"	1	June 1-November 14
	14"	8	November 15-December 31
Delaware	14"	10[c]	Jul 1 - Mar 31
	15"	3	Apr 1 - Jun 30
Maryland	14"	5	D
Virginia	14"	7	Open all year

a. The trawl fishery has a possession limit of 75 fish, the commercial hook, fish pot, fyke net, and gill net fisheries the possession limit is 25 fish, and in the lobster pot fishery the possession limit is 10 fish. Holders of Connecticut Marine Pound Net Registration may possess up to twelve fish year round except that during the May 1 through June 14 closed season all female tautog must be released without avoidable injury. All possession limits are daily limits.

b. New York has a 25 fish vessel trip limit for commercially caught tautog, except only 10 per vessel are allowed when lobster pot gear and more than six lobsters are in possession.

c. Delaware has a 28 day closure from September 1 through September 28.

d. Maryland has a closed recreational fishing season from December 1 through December 31.

Table 2. Age keys and sample sizes.

Northern Region Age Keys		
years	sources	n's
1982-1986	CT	1236
1987-1989	RI + CT	1208
1990-1992	RI + CT	826
1993-1995	MA, CT, + NY	768
1996-1998	MA, CT, + NY	1709
1999-2001	MA, RI, CT + NY	1542
2002	MA, RI, + CT	998
2003	MA, RI, + CT	825

Southern Region Age Keys		
years		n's
1982-1989	HM	696
1990-1995	GW	940
1996	GW,NJ,DE	738
1997	GW,NJ,DE	1309
1998	VA,NJ,DE	655
1999	VA,MD,NJ,DE	1075
2000	VA,MD,NJ, DE	1055
2001	MD,NJ,DE	466
2002	MD,NJ,DE	640
2003	MD,NJ	440

Table 3. Commercial Landings by state (mt).

Year	MA	RI	CT	NY	NJ	DE	MD	VA	totals
1982	31.4	39.1	9.6	41.0	67.2	0.4	0.0	1.2	190.0
1983	26.1	64.7	15.2	40.1	45.6	0.4	0.0	0.8	192.9
1984	30.9	151.8	14.8	46.5	58.8	0.6	1.2	0.5	305.2
1985	28.7	182.9	22.7	38.3	56.9	1.5	1.1	0.7	332.9
1986	75.2	164.7	47.3	91.3	45.7	0.1	1.2	0.8	426.3
1987	113.4	190.7	72.2	102.2	43.2	0.2	1.7	1.2	524.9
1988	125.7	149.2	50.8	115.7	39.9	0.3	2.8	1.3	485.6
1989	159.7	97.4	45.2	129.5	23.5	0.2	1.8	3.4	460.8
1990	131.1	95.7	37.2	82.3	45.0	0.2	1.8	2.3	395.7
1991	160.7	159.5	24.5	102.7	42.3	0.6	1.4	2.3	494.0
1992	132.6	163.2	29.8	76.7	52.8	0.1	1.8	2.0	458.9
1993	72.7	91.4	39.0	40.6	69.6	0.1	0.6	2.5	316.7
1994	16.8	59.3	19.5	32.4	73.8	0.2	0.8	5.2	207.9
1995	16.0	43.1	9.3	33.1	52.6	0.3	2.0	13.6	169.9
1996	14.8	29.4	15.1	47.8	40.6	0.0	1.6	11.9	161.2
1997	29.1	18.0	6.6	35.5	22.6	0.4	3.5	11.6	127.1
1998	41.4	9.2	3.1	31.2	19.2	0.8	2.6	6.7	114.3
1999	34.3	11.8	5.9	17.2	12.4	0.4	2.9	9.5	94.4
2000	43.5	19.8	3.9	18.1	18.0	0.1	1.8	6.7	111.9
2001	38.3	25.4	10.1	28.5	27.3	0.1	2.1	6.6	138.4
2002	67.2	22.7	12.1	27.6	16.6	0.3	2.3	10.4	159.1
2003	39.1	24.7	18.5	34.2	29.6	1.7	2.4	4.9	155.0
2004	40.0	16.7	7.4	34.7	23.0	1.2	2.7	3.5	129.3
means	64.9	82.4	23.3	55.1	41.1	0.4	1.7	4.8	

Table 4. Catch length sampling

Year	Northern Region mt/100 lengths	Southern Region mt/100 lengths
1982	420	382
1983	246	566
1984	302	475
1985	518	434
1986	440	370
1987	556	592
1988	405	559
1989	105	182
1990	108	98
1991	182	183
1992	202	152
1993	114	179
1994	137	196
1995	130	183
1996	72	98
1997	82	55
1998	166	53
1999	199	183
2000	287	520
2001	426	213
2002	793	138
2003	202	88

Table 5. Recreational Harvest by state and released alive totals, in numbers.

year	MA	RI	CT	NY	NJ	DE	MD	VA	total harvest	released alive
1982	1,051,022	214,938	231,187	646,693	583,550	137,328	35,105	71,599	2,971,422	292,888
1983	670,508	245,796	200,676	612,163	344,580	4,350	2,126	579,795	2,659,994	676,332
1984	258,256	490,128	287,470	286,077	516,086	28,388	42,835	207,192	2,116,432	647,963
1985	100,941	115,404	182,318	1,105,234	840,627	62,001	486	91,957	2,498,968	716,738
1986	1,980,719	671,592	333,396	1,183,144	2,369,852	141,290	5,476	322,905	7,008,374	1,102,622
1987	617,068	130,729	312,430	929,887	1,015,123	99,706	90,523	126,783	3,322,249	1,405,775
1988	621,679	207,799	234,198	828,183	564,286	94,491	107,570	368,320	3,026,526	1,240,696
1989	250,077	116,506	303,782	562,549	710,958	249,928	34,709	284,477	2,512,986	1,064,713
1990	233,444	153,433	75,871	953,622	841,770	61,526	45,467	111,998	2,477,131	1,237,551
1991	176,905	291,946	191,137	871,221	1,067,283	128,985	26,770	168,068	2,922,315	2,256,630
1992	357,949	193,786	319,221	413,236	1,018,205	68,769	106,255	100,952	2,578,373	1,607,427
1993	216,553	118,775	180,055	505,632	773,213	82,475	60,231	300,484	2,237,418	1,971,107
1994	78,483	82,304	150,109	196,937	208,003	65,837	157,260	231,740	1,170,673	1,479,578
1995	72,461	54,570	120,259	118,006	707,963	300,303	43,542	222,186	1,639,290	2,102,583
1996	79,798	55,528	72,558	82,826	470,431	57,751	9,695	224,447	1,053,034	1,157,693
1997	39,075	70,628	32,200	92,907	196,724	65,133	85,682	106,678	689,027	1,079,576
1998	25,034	56,084	66,797	68,887	11,667	62,584	6,512	50,923	348,488	1,398,486
1999	91,476	52,136	15,701	196,564	165,505	95,309	20,180	42,880	679,751	2,282,525
2000	87,552	38,687	10,648	79,245	462,371	113,686	20,129	34,725	847,043	1,725,896
2001	115,658	39,993	16,579	45,913	467,728	50,541	23,715	28,985	789,112	2,032,270
2002	102,662	62,423	100,240	629,772	347,831	185,684	42,038	25,987	1,496,637	3,172,031
2003	46,808	120,061	167,875	128,729	102,593	63,181	13,555	76,236	719,038	1,678,945
2004	20,873	165,201	114,918	364,460	111,769	139,079	19,977	157,623	719,038	2,178,405
means	317,174	162,976	161,723	473,995	604,266	102,536	43,471	171,171	2,021,014	1,500,367

Table 6. Catch-at-age input data from the coast wide VPA analysis.

AGE	1982	1983	1984	1985	1986
1	52.7	85.6	58.3	92.3	179.5
2	142.0	240.7	172.3	280.0	449.2
3	190.0	371.9	310.5	258.1	785.7
4	340.7	467.0	365.5	376.3	951.1
5	430.2	404.2	349.4	388.8	945.1
6	393.6	311.0	300.4	360.1	852.6
7	382.7	279.8	245.7	337.7	847.5
8	296.7	189.8	172.5	237.8	594.2
9	264.9	168.6	137.3	213.1	512.1
10	179.0	117.3	80.5	140.6	344.7
11	113.1	73.0	54.2	83.6	227.8
12	304.0	160.9	139.6	164.1	734.2

AGE	1987	1988	1989	1990	1991
1	81.6	89.0	61.2	5.4	3.2
2	200.5	177.6	163.7	59.1	35.6
3	313.4	224.1	325.4	376.2	272.1
4	467.6	344.1	439.6	603.6	505.6
5	486.4	421.2	381.2	691.5	673.1
6	552.5	453.8	356.0	427.2	541.7
7	521.9	429.5	326.9	254.1	403.5
8	405.8	365.2	273.3	189.5	296.6
9	312.1	279.9	236.0	112.6	180.1
10	137.1	156.5	111.2	63.3	110.5
11	82.6	108.3	81.1	45.9	81.7
12	233.0	354.7	203.3	119.1	255.9

AGE	1992	1993	1994	1995	1996
1	1.5	10.2	0.7	0.2	0.1
2	23.6	73.8	23.9	8.0	15.3
3	240.1	236.5	120.2	70.0	75.9
4	428.0	415.7	256.8	211.8	178.0
5	637.2	508.4	271.6	452.5	238.6
6	485.4	402.8	201.4	377.5	221.8
7	337.3	327.5	174.7	284.9	186.9
8	251.5	213.7	119.6	172.5	120.4
9	161.0	108.4	69.9	95.1	61.4
10	100.8	76.7	46.4	56.8	41.2
11	81.5	41.5	22.3	28.2	20.2
12	223.1	129.0	48.6	64.1	37.7

Catch At Age - Input Data

AGE	1997	1998	1999	2000	2001
1	0.1	0.1	0.5	0.0	0.1
2	6.6	3.5	9.3	3.0	2.4
3	32.2	13.5	26.2	109.8	98.1
4	100.3	38.4	47.6	160.9	157.6
5	150.9	63.4	104.9	133.0	132.6
6	157.0	78.3	149.5	129.7	131.3
7	132.2	76.3	145.0	130.0	124.5
8	91.5	64.9	120.2	105.6	111.1
9	48.2	36.0	73.0	60.0	60.2
10	31.9	21.8	49.5	42.5	38.5
11	14.9	13.4	28.9	20.2	19.3
12	29.4	22.3	36.8	57.3	50.0

AGE	2002	2003
1	0.1	0.0
2	5.8	2.7
3	45.1	19.6
4	212.8	98.0
5	389.3	193.3
6	378.7	193.1
7	261.9	124.0
8	189.8	76.3
9	99.0	60.9
10	60.3	39.4
11	22.9	21.5
12	44.8	29.1

Table 7. Mean weights-at-age and spawning stock biomass weight-at-age input data from the coast wide VPA analysis.

Weight At Age - Input Data

AGE	1982	1983	1984	1985	1986
1	0.1470	0.1430	0.1430	0.1410	0.1410
2	0.2490	0.2910	0.3690	0.3770	0.3420
3	0.5180	0.5440	0.6660	0.7220	0.6820
4	1.2190	1.1680	0.9640	0.9920	0.9740
5	1.6380	1.5180	1.3640	1.3530	1.4440
6	1.9830	1.9180	1.8970	1.8290	1.9560
7	2.3000	2.3110	2.2870	2.1260	2.3340
8	2.5940	2.5610	2.6120	2.4100	2.6210
9	2.9160	2.7850	3.0070	2.6890	2.8350
10	3.2670	2.9840	3.3070	3.0280	3.1650
11	3.4760	3.2290	3.9500	3.3290	3.3670
12	4.5580	4.1190	4.4480	3.9560	4.5320

AGE	1987	1988	1989	1990	1991
1	0.3020	0.2590	0.3120	0.3090	0.3090
2	0.4940	0.4320	0.5020	0.3080	0.3030
3	0.7540	0.7180	0.7220	0.8640	0.8970
4	1.0290	1.0400	0.9920	1.1560	1.1610
5	1.4630	1.4640	1.3130	1.4610	1.5530
6	1.7700	1.7630	1.5770	1.7780	1.9680
7	1.9390	1.9380	1.7120	2.1710	2.3260
8	2.0790	2.1410	1.9180	2.3340	2.4490
9	2.4210	2.5460	2.1900	2.4010	2.6030
10	2.9740	3.1740	3.0440	3.2380	3.2460
11	3.2730	3.6080	3.3120	3.4090	3.4280
12	3.8950	4.5020	4.1330	4.3030	4.3130

AGE	1992	1993	1994	1995	1996
1	0.3090	0.3090	0.3090	0.3090	0.2760
2	0.2900	0.2120	0.2630	0.2630	0.6460
3	0.9790	0.9050	0.8770	1.1552	1.3370
4	1.1990	1.1300	1.1990	1.3500	1.5260
5	1.4780	1.3180	1.3650	1.4870	1.8130
6	1.8320	1.8360	1.7470	1.8970	2.0770
7	2.2160	2.1210	2.0540	2.1220	2.2070
8	2.4310	2.3910	2.3960	2.4100	2.5960
9	2.5480	2.7910	2.6200	2.7920	2.8260

10	3.3450	3.0490	2.9930	3.0680	3.5010
11	3.5370	3.9060	3.4520	3.5080	3.5440
12	4.3950	4.5180	4.2100	4.1920	4.3570

AGE	1997	1998	1999	2000	2001
1	0.2740	0.2830	0.2040	0.1240	0.1150
2	0.8980	0.5440	0.5900	0.8770	0.3730
3	1.3710	1.3980	0.8810	1.0140	0.7710
4	1.5160	1.6120	0.9470	1.0010	1.0890
5	1.7250	1.8910	1.2140	1.2150	1.3310
6	1.9450	2.1190	1.3830	1.3390	1.4450
7	2.0180	2.0410	1.6670	1.7240	1.6290
8	2.4250	2.3870	1.8890	1.9030	1.9320
9	2.6700	2.5800	2.0380	2.0090	2.1140
10	3.3230	3.2490	2.1820	2.3740	2.2620
11	3.3410	3.3020	2.2520	2.2580	2.3160
12	4.3250	4.2850	2.5470	3.4660	2.9430

AGE	2002	2003
1	0.1150	0.1150
2	0.3640	0.3500
3	0.6860	0.7810
4	1.0020	1.0050
5	1.2320	1.2260
6	1.3570	1.4350
7	1.5990	1.6980
8	1.8610	1.9040
9	2.1740	2.3690
10	2.4080	2.8200
11	2.4500	3.1000
12	3.4000	3.3160

Table 7 (Continued).

SSB Weight At Age - Input Data

AGE	1982	1983	1984	1985	1986
1	0.1470	0.1430	0.1430	0.1410	0.1410
2	0.2490	0.2910	0.3690	0.3770	0.3420
3	0.5180	0.5440	0.6660	0.7220	0.6820
4	1.2190	1.1680	0.9640	0.9920	0.9740
5	1.6380	1.5180	1.3640	1.3530	1.4440
6	1.9830	1.9180	1.8970	1.8290	1.9560
7	2.3000	2.3110	2.2870	2.1260	2.3340
8	2.5940	2.5610	2.6120	2.4100	2.6210
9	2.9160	2.7850	3.0070	2.6890	2.8350
10	3.2670	2.9840	3.3070	3.0280	3.1650
11	3.4760	3.2290	3.9500	3.3290	3.3670
12	4.5580	4.1190	4.4480	3.9560	4.5320

AGE	1987	1988	1989	1990	1991
1	0.3020	0.2590	0.3120	0.3090	0.3090
2	0.4940	0.4320	0.5020	0.3080	0.3030
3	0.7540	0.7180	0.7220	0.8640	0.8970
4	1.0290	1.0400	0.9920	1.1560	1.1610
5	1.4630	1.4640	1.3130	1.4610	1.5530
6	1.7700	1.7630	1.5770	1.7780	1.9680
7	1.9390	1.9380	1.7120	2.1710	2.3260
8	2.0790	2.1410	1.9180	2.3340	2.4490
9	2.4210	2.5460	2.1900	2.4010	2.6030
10	2.9740	3.1740	3.0440	3.2380	3.2460
11	3.2730	3.6080	3.3120	3.4090	3.4280
12	3.8950	4.5020	4.1330	4.3030	4.3130

AGE	1992	1993	1994	1995	1996
1	0.3090	0.3090	0.3090	0.3090	0.2760
2	0.2900	0.2120	0.2630	0.2630	0.6460
3	0.9790	0.9050	0.8770	1.1552	1.3370
4	1.1990	1.1300	1.1990	1.3500	1.5260
5	1.4780	1.3180	1.3650	1.4870	1.8130
6	1.8320	1.8360	1.7470	1.8970	2.0770
7	2.2160	2.1210	2.0540	2.1220	2.2070
8	2.4310	2.3910	2.3960	2.4100	2.5960
9	2.5480	2.7910	2.6200	2.7920	2.8260
10	3.3450	3.0490	2.9930	3.0680	3.5010
11	3.5370	3.9060	3.4520	3.5080	3.5440
12	4.3950	4.5180	4.2100	4.1920	4.3570

SSB Weight At Age - Input Data

AGE	1997	1998	1999	2000	2001
1	0.2740	0.2830	0.2040	0.1240	0.1150
2	0.8980	0.5440	0.5900	0.8770	0.3730
3	1.3710	1.3980	0.8810	1.0140	0.7710
4	1.5160	1.6120	0.9470	1.0010	1.0890
5	1.7250	1.8910	1.2140	1.2150	1.3310
6	1.9450	2.1190	1.3830	1.3390	1.4450
7	2.0180	2.0410	1.6670	1.7240	1.6290
8	2.4250	2.3870	1.8890	1.9030	1.9320
9	2.6700	2.5800	2.0380	2.0090	2.1140
10	3.3230	3.2490	2.1820	2.3740	2.2620
11	3.3410	3.3020	2.2520	2.2580	2.3160
12	4.3250	4.2850	2.5470	3.4660	2.9430

AGE	2002	2003
1	0.1150	0.1150
2	0.3640	0.3500
3	0.6860	0.7810
4	1.0020	1.0050
5	1.2320	1.2260
6	1.3570	1.4350
7	1.5990	1.6980
8	1.8610	1.9040
9	2.1740	2.3690
10	2.4080	2.8200
11	2.4500	3.1000
12	3.4000	3.3160

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Table 8. Jan 1 calculated Rivard weights input data from the coast wide VPA analysis

JAN-1 Weights at Age - Input Data

AGE	1982	1983	1984	1985	1986
1	0.1040	0.0890	0.0880	0.0910	0.0750
2	0.1870	0.2070	0.2300	0.2320	0.2200
3	0.4000	0.3680	0.4400	0.5160	0.5070
4	0.7930	0.7780	0.7240	0.8130	0.8390
5	0.9800	1.3600	1.2620	1.1420	1.1970
6	1.1990	1.7720	1.6970	1.5790	1.6270
7	1.5850	2.1410	2.0940	2.0080	2.0660
8	1.8710	2.4270	2.4570	2.3480	2.3610
9	2.1300	2.6880	2.7750	2.6500	2.6140
10	2.3160	2.9500	3.0350	3.0170	2.9170
11	2.5030	3.2480	3.4330	3.3180	3.1930
12	4.5580	4.1190	4.4480	3.9560	4.5320

AGE	1987	1988	1989	1990	1991
1	0.2530	0.1860	0.3140	0.3120	0.3190
2	0.2640	0.3610	0.3610	0.3100	0.3060
3	0.5080	0.5960	0.5580	0.6590	0.5260
4	0.8380	0.8860	0.8440	0.9140	1.0020
5	1.1940	1.2270	1.1690	1.2040	1.3400
6	1.5990	1.6060	1.5190	1.5280	1.6960
7	1.9470	1.8520	1.7370	1.8500	2.0340
8	2.2030	2.0370	1.9280	1.9990	2.3060
9	2.5190	2.3010	2.1650	2.1460	2.4650
10	2.9040	2.7720	2.7840	2.6630	2.7920
11	3.2190	3.2760	3.2420	3.2210	3.3320
12	3.8950	4.5020	4.1330	4.3030	4.3130

AGE	1992	1993	1994	1995	1996
1	0.3730	0.3350	0.3350	0.2140	0.1530
2	0.2990	0.2560	0.2850	0.2850	0.4470
3	0.5450	0.5120	0.4310	0.5500	0.5930
4	1.0370	1.0520	1.0420	1.3350	1.5640
5	1.3100	1.2570	1.2420	1.3350	1.5640
6	1.6870	1.6470	1.5170	1.6090	1.7570
7	2.0880	1.9710	1.9420	1.9250	2.0460
8	2.3780	2.3020	2.2540	2.2250	2.3470
9	2.4980	2.6050	2.5030	2.5860	2.6100
10	2.9510	2.7870	2.8900	2.8350	3.1260
11	3.3880	3.6150	3.2440	3.2400	3.2970
12	4.3950	4.5180	4.2100	4.1920	4.3570

JAN-1 Weights at Age - Input Data

AGE	1997	1998	1999	2000	2001
1	0.1940	0.2070	0.0910	0.0910	0.0910
2	0.4980	0.3860	0.2040	0.1240	0.1150
3	0.9410	1.1200	0.5900	0.8770	0.3730
4	1.6220	1.6930	0.8810	1.0140	0.7710
5	1.6220	1.6930	0.9470	1.0010	1.0890
6	1.8780	1.9120	1.2140	1.2150	1.3310
7	2.0470	1.9920	1.3830	1.3390	1.4450
8	2.3130	2.1950	1.6670	1.7240	1.6290
9	2.6330	2.5010	1.8890	1.9030	1.9320
10	3.0640	2.9450	2.0380	2.0090	2.1140
11	3.4200	3.3120	2.1820	2.3740	2.2620
12	4.3250	4.2850	2.2520	2.2580	2.3160

AGE	2002	2003	2004
1	0.0910	0.0910	0.1150
2	0.1150	0.1150	0.1150
3	0.3640	0.3500	0.3500
4	0.6860	0.7810	0.7810
5	1.0020	1.0050	1.0050
6	1.2320	1.2260	1.2260
7	1.3570	1.4350	1.4350
8	1.5990	1.6980	1.6980
9	1.8610	1.9040	1.9040
10	2.1740	2.3690	2.3690
11	2.4080	2.8200	2.8200
12	2.4500	3.1000	3.1000

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13.0 Figures

Figure 1. Coastwide commercial landings trends.
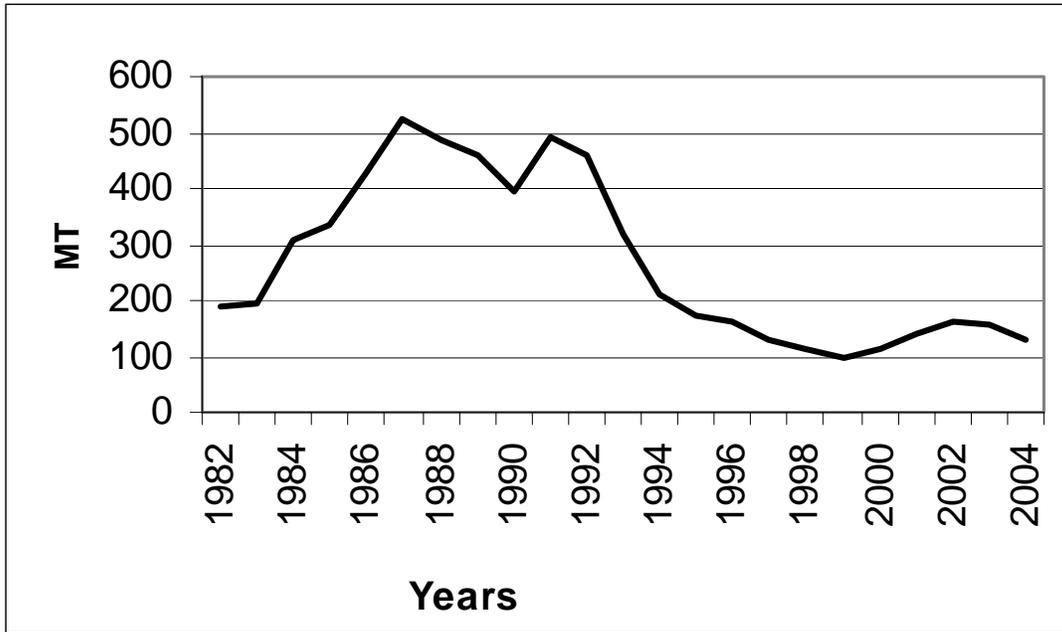
Figure 2. Coastwide recreational landings trends.
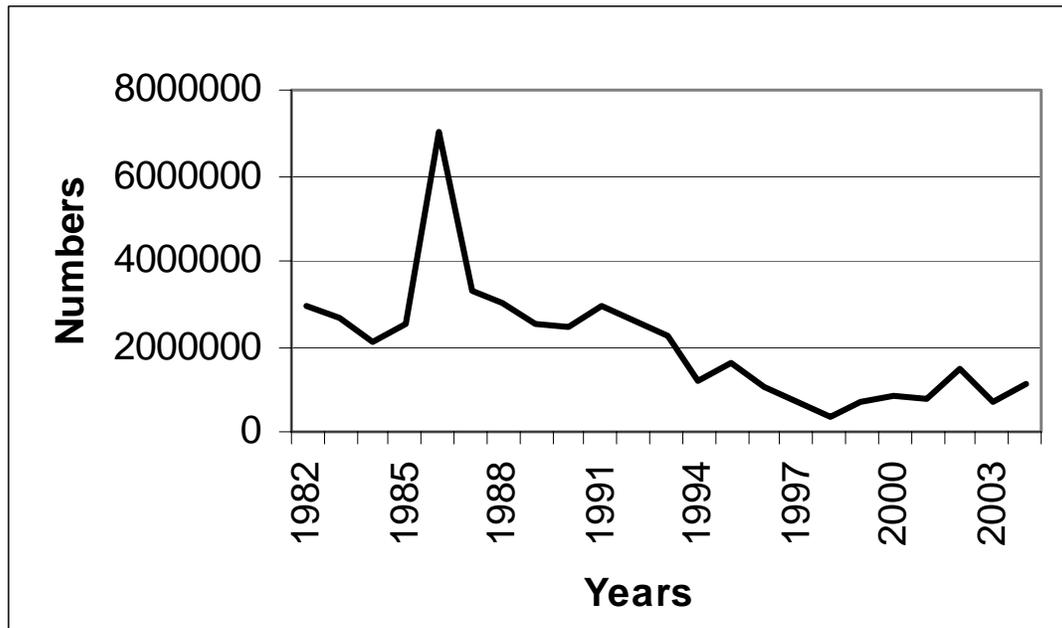
Figure 3. Coastwide recreational discard trends.
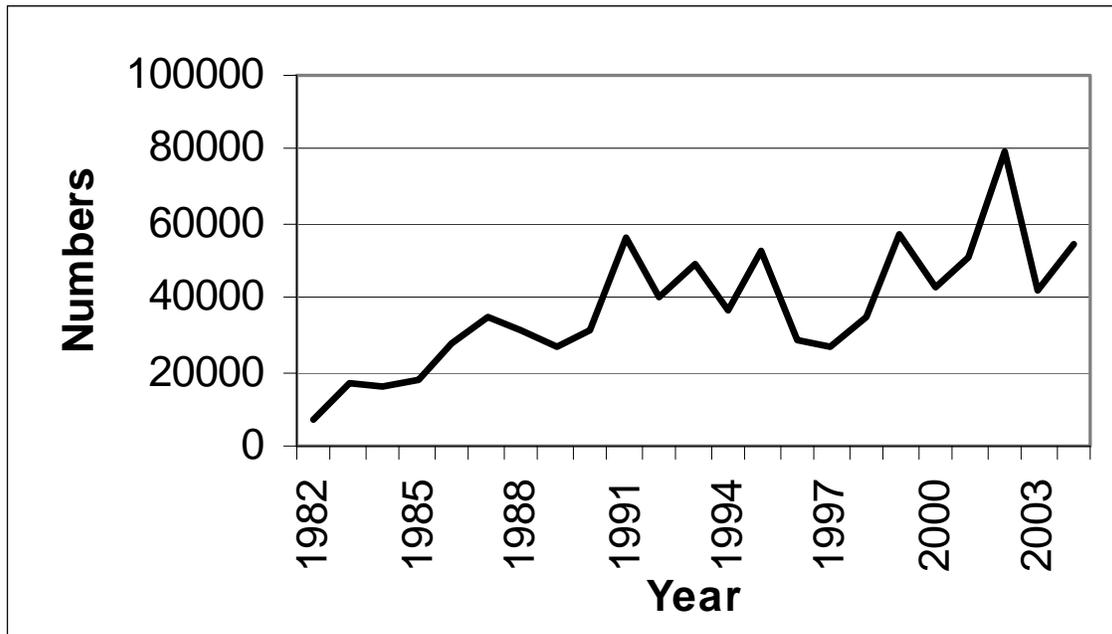
Figure 4. Recreational CPUE trends
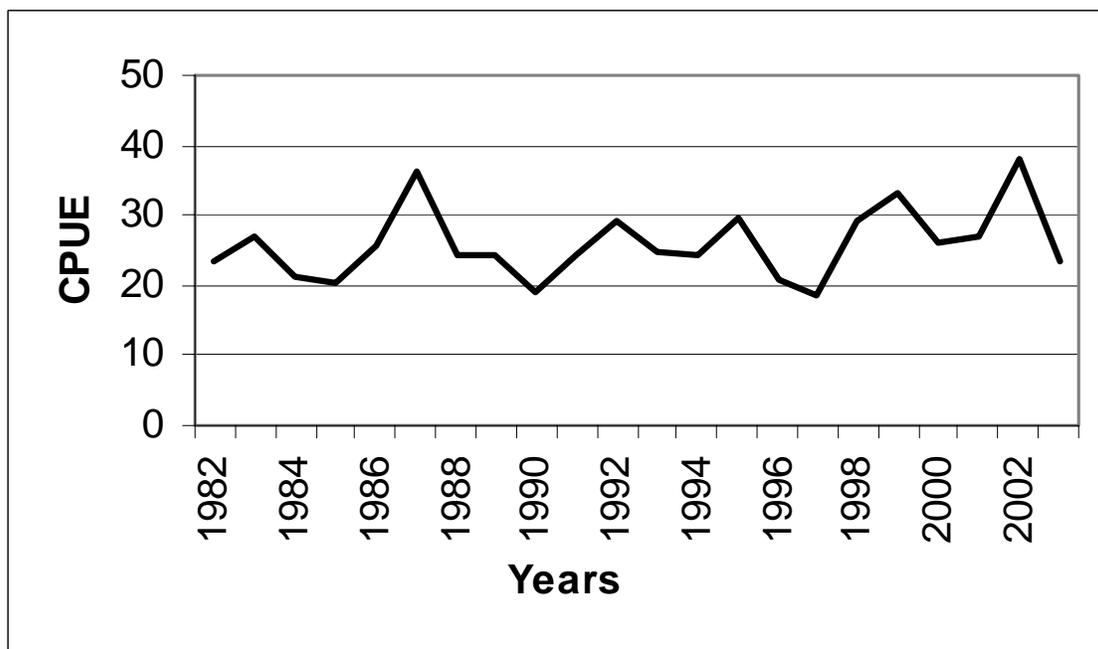
Figure 5. Northern Region recreational length frequency distributions.

1982 NR Recreational LFD

1986 NR Recreational LFD

1990 NR Recreational LFD
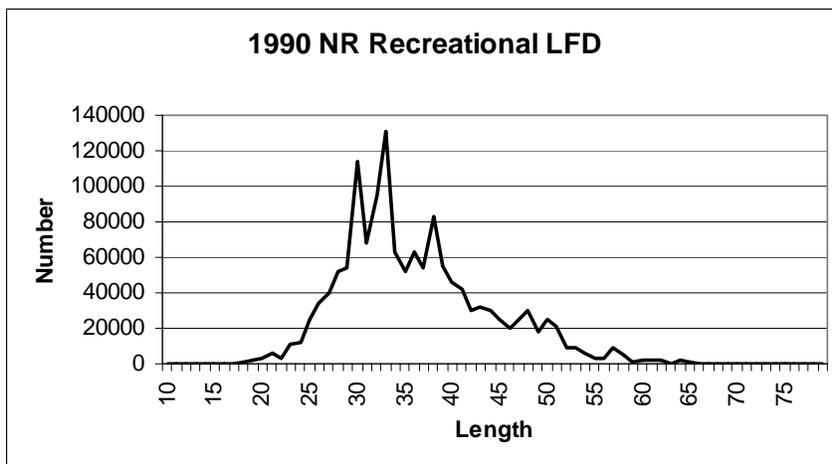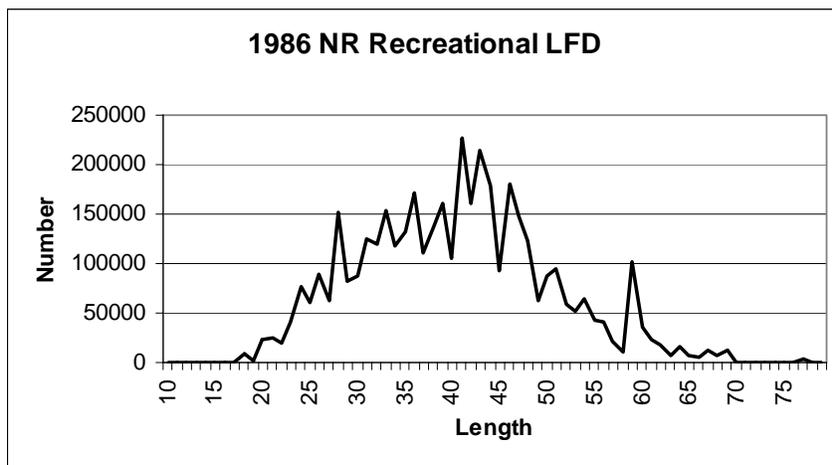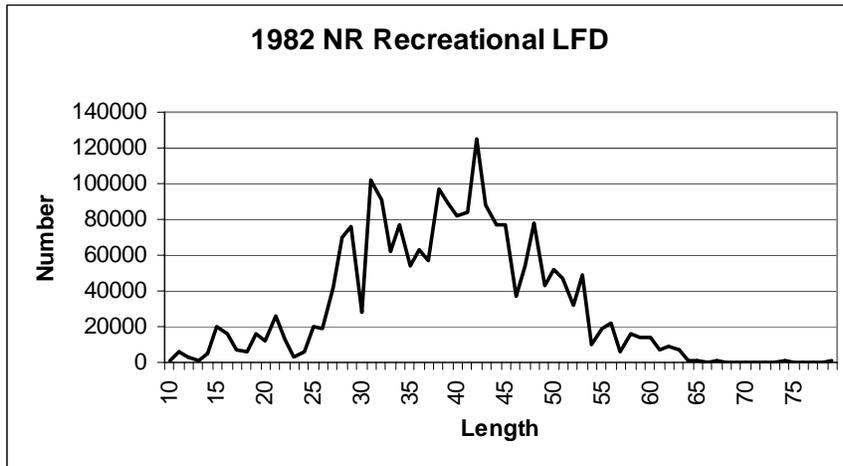
Figure 5 (continued). Northern Region recreational length frequency distributions.

1994 NR Recreational LFD

1998 NR Recreational LFD

2002 NR Recreational LFD
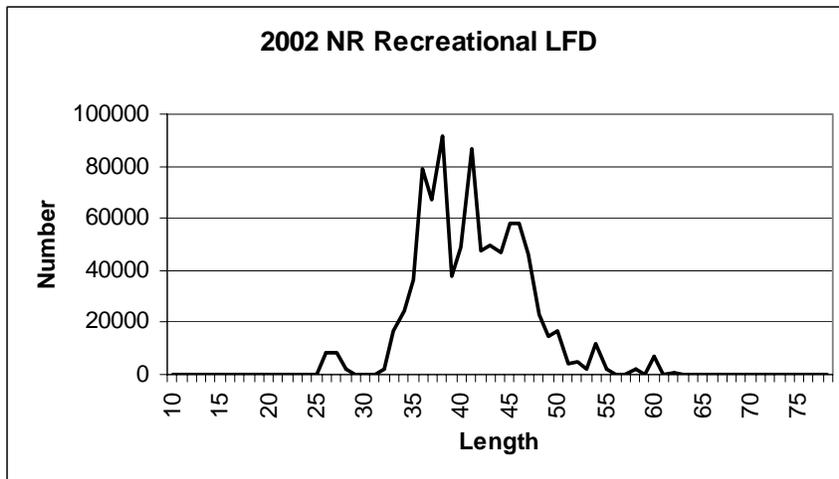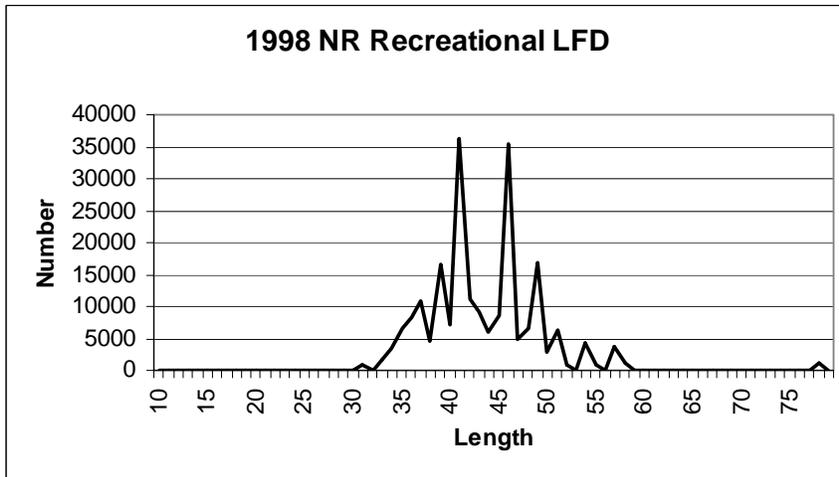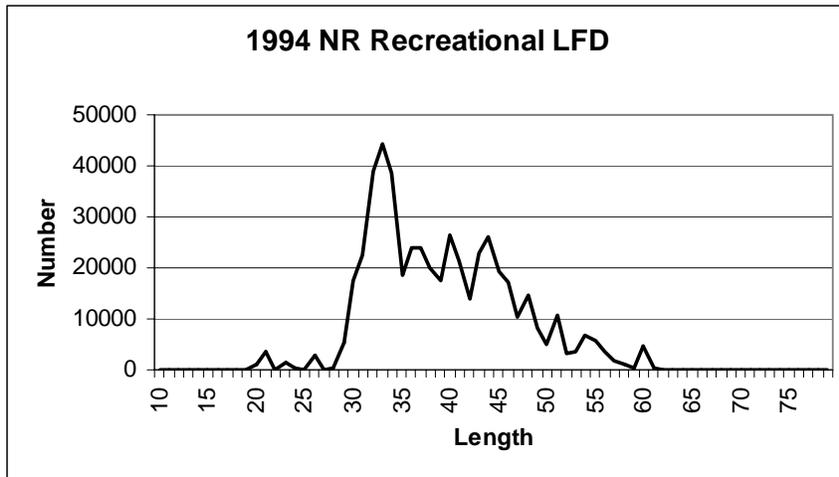
Figure 6. Southern Region recreational length frequency distributions.
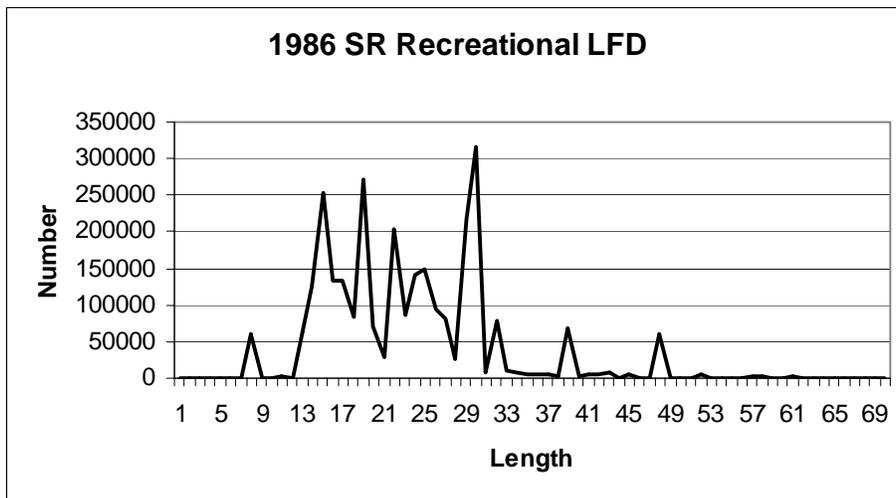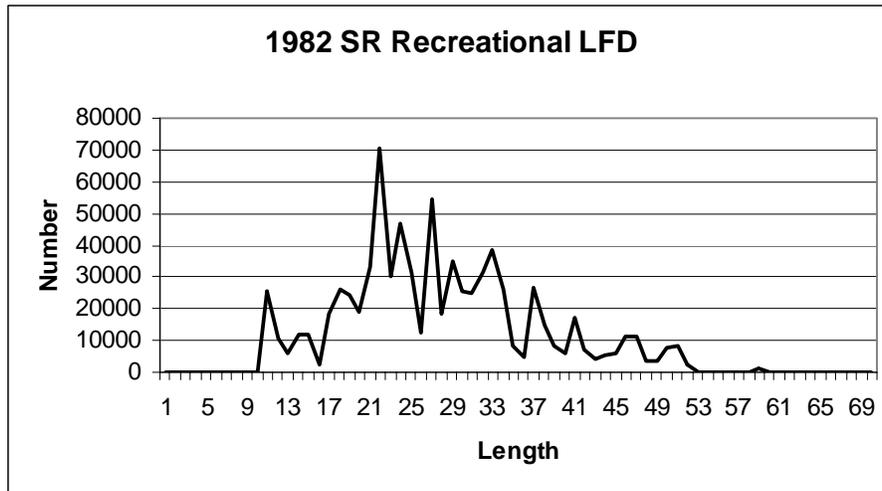
1982 SR Recreational LFD

1986 SR Recreational LFD

Figure 6 (continued). Southern Region recreational length frequency distributions.

1990 SR Recreational LFD

1994 SR Recreational LFD

Figure 6 (continued). Southern Region recreational length frequency distributions.

1998 SR Recreational LFD

2002 SR Recreational LFD
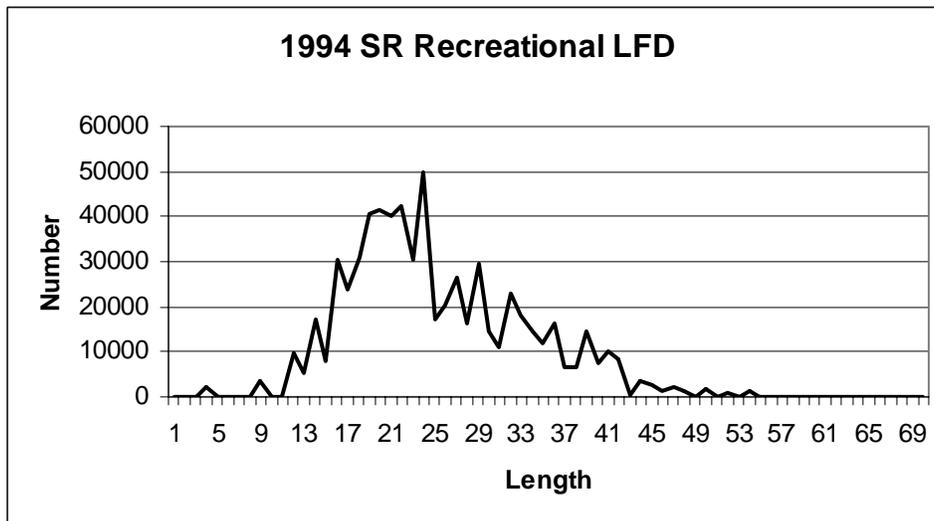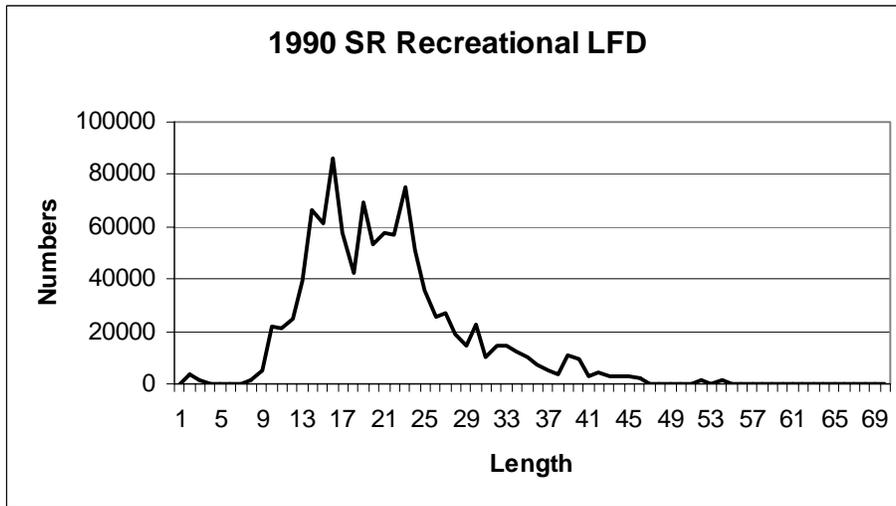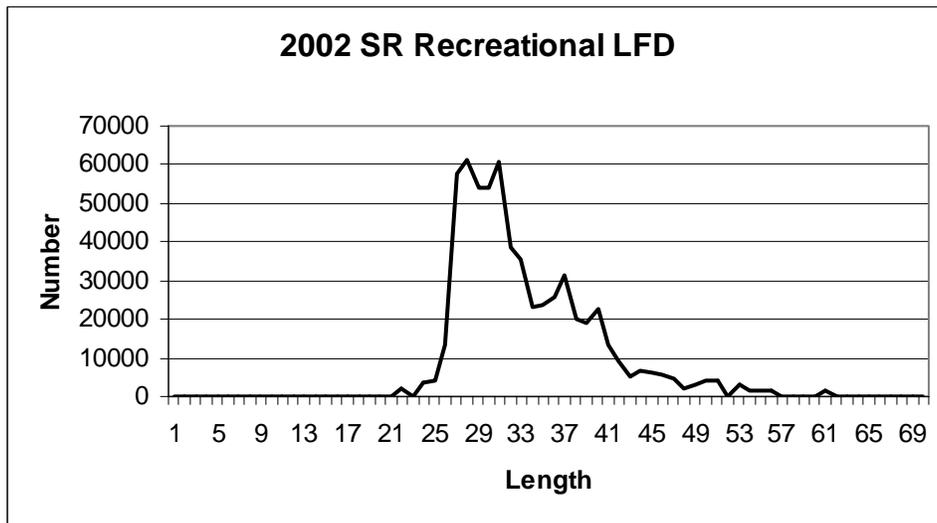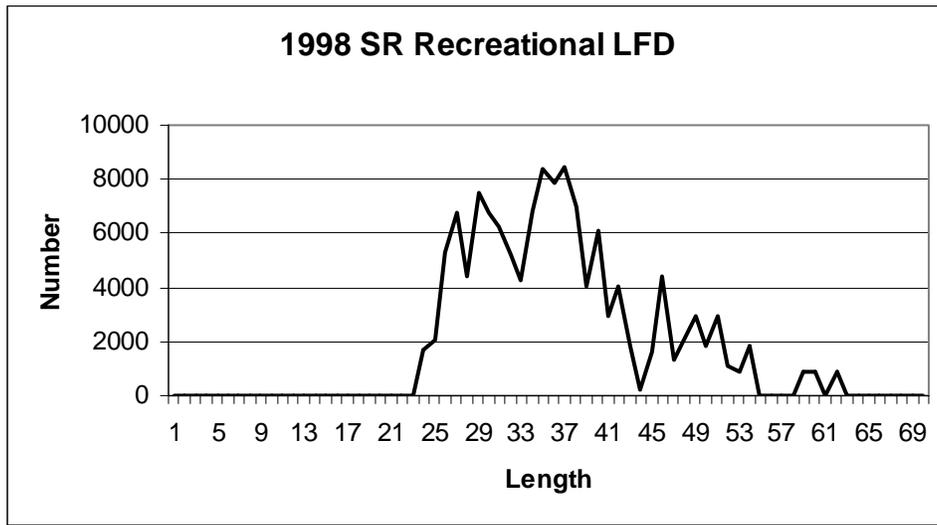
Figure 7. State survey index trends (standardized values).
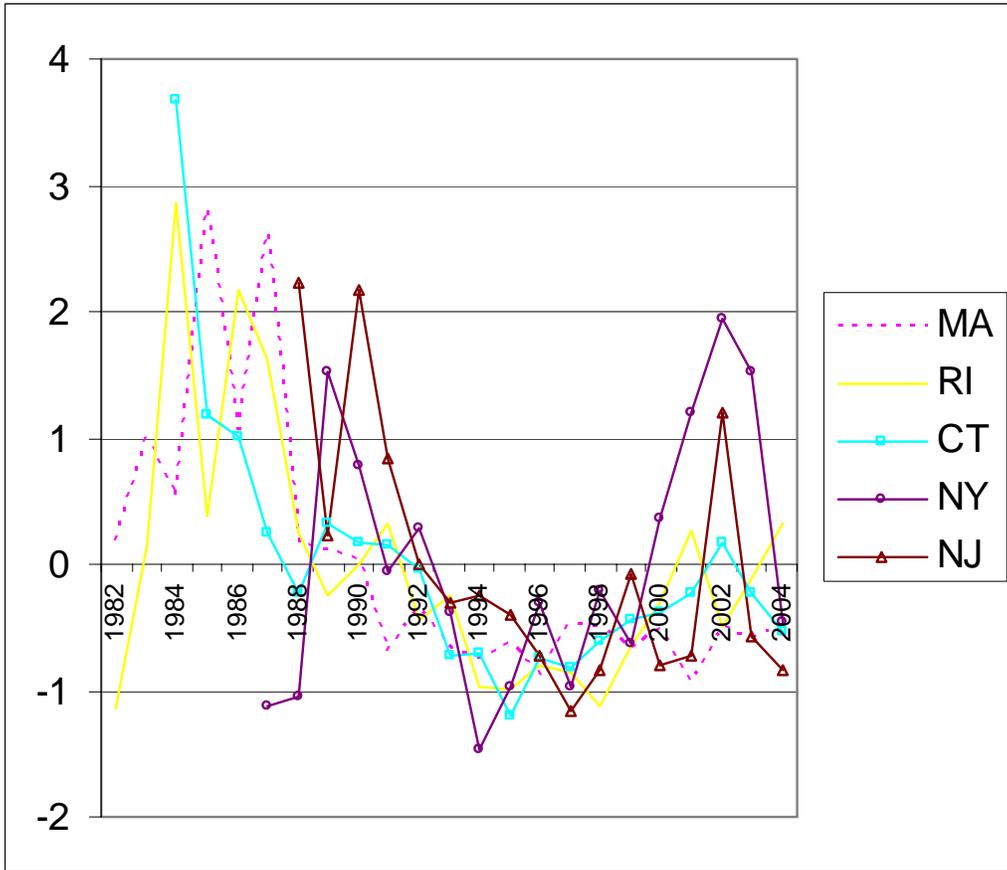
Figure 8. VPA terminal year F estimates
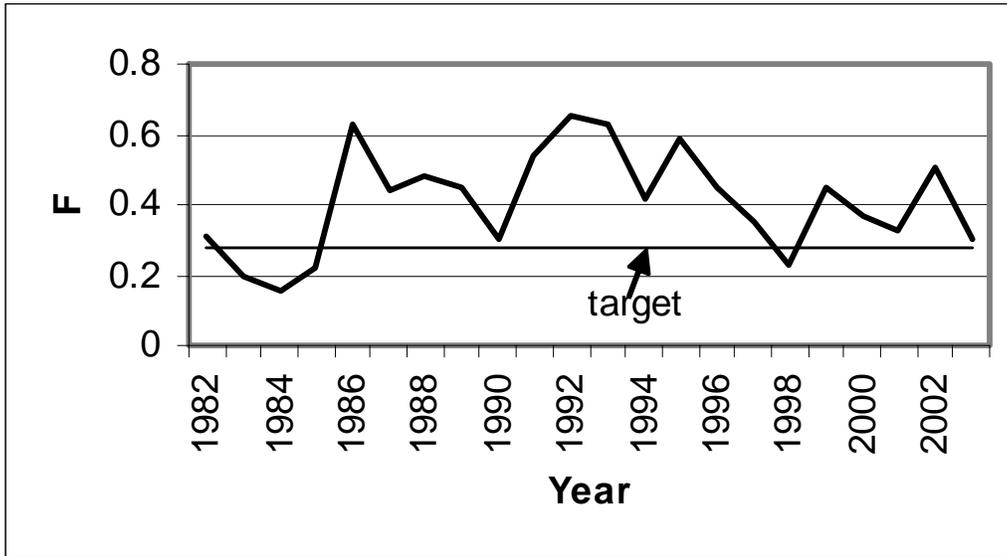
Figure 9. VPA estimated January 1 numbers
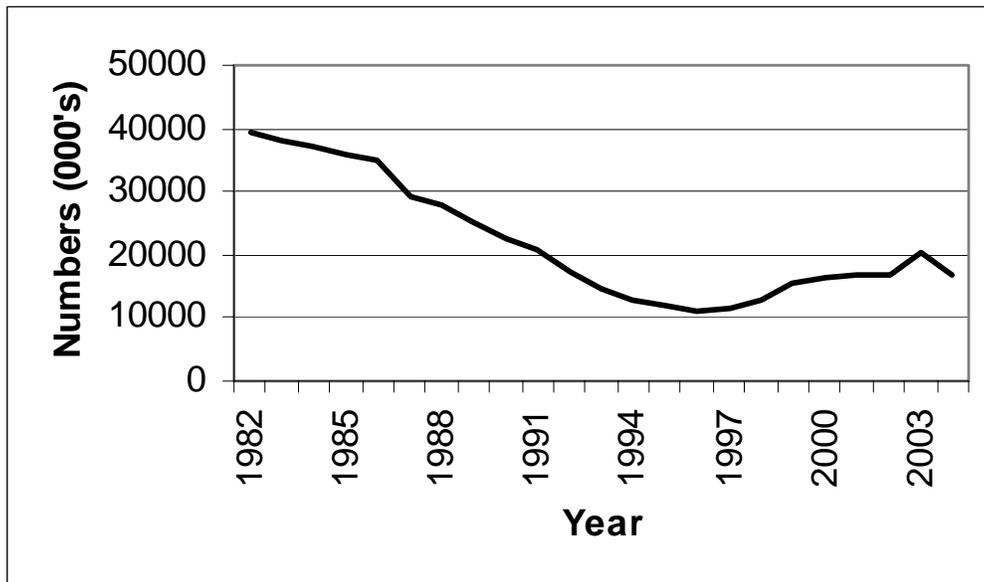
Figure 10. VPA estimated Jan 1 Biomass
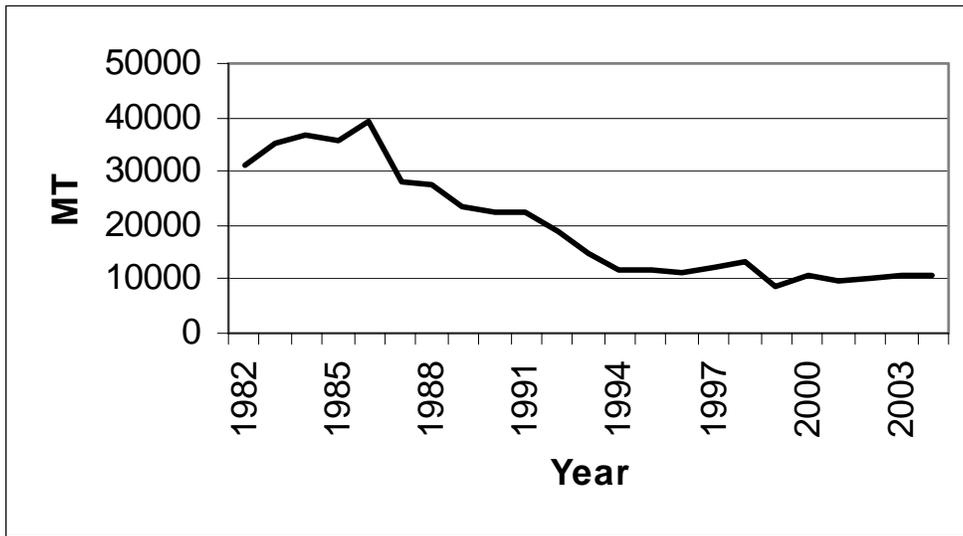
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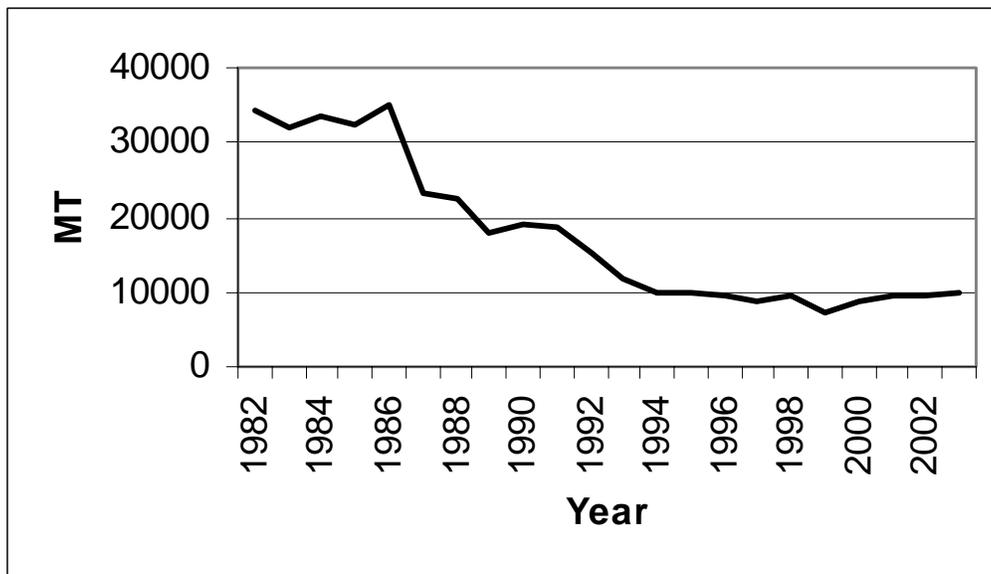
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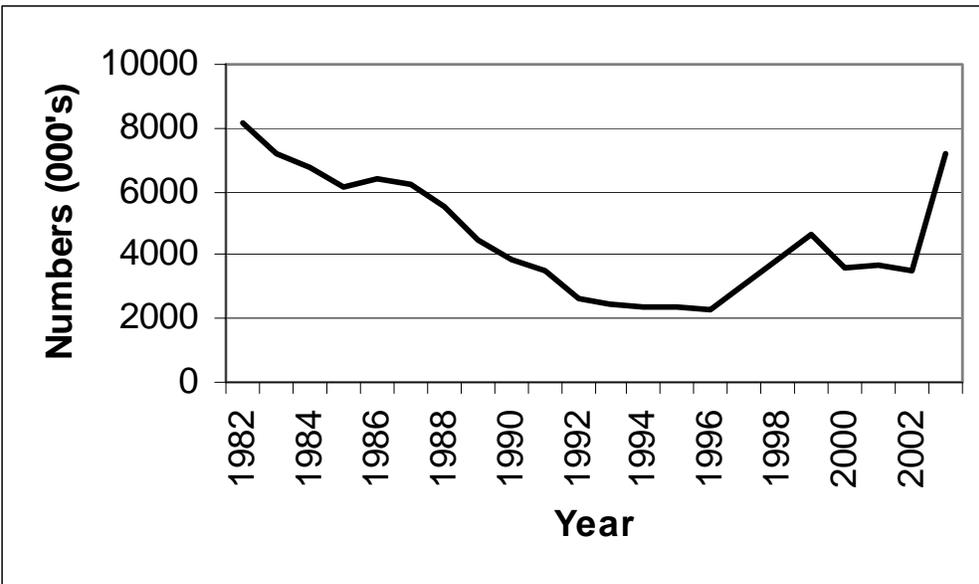
Figure 13. Bootstrap F
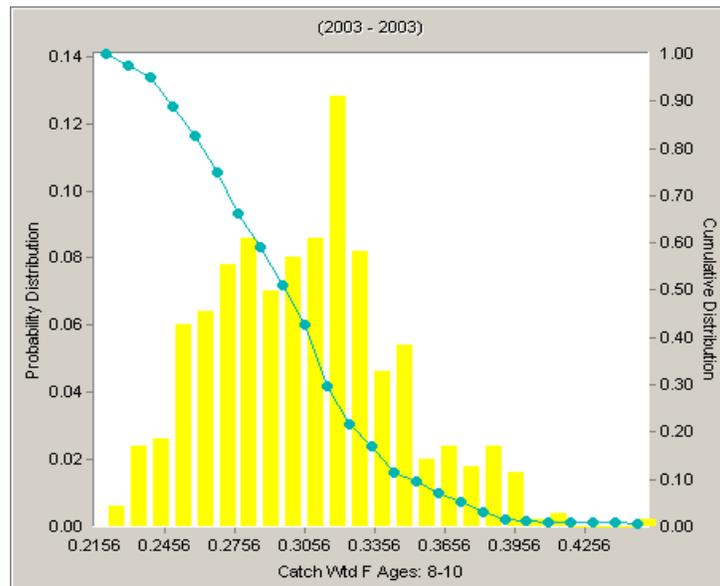
Figure 14. Historical Retrospective of terminal year VPA F estimate's

Figure 15. SSB/R

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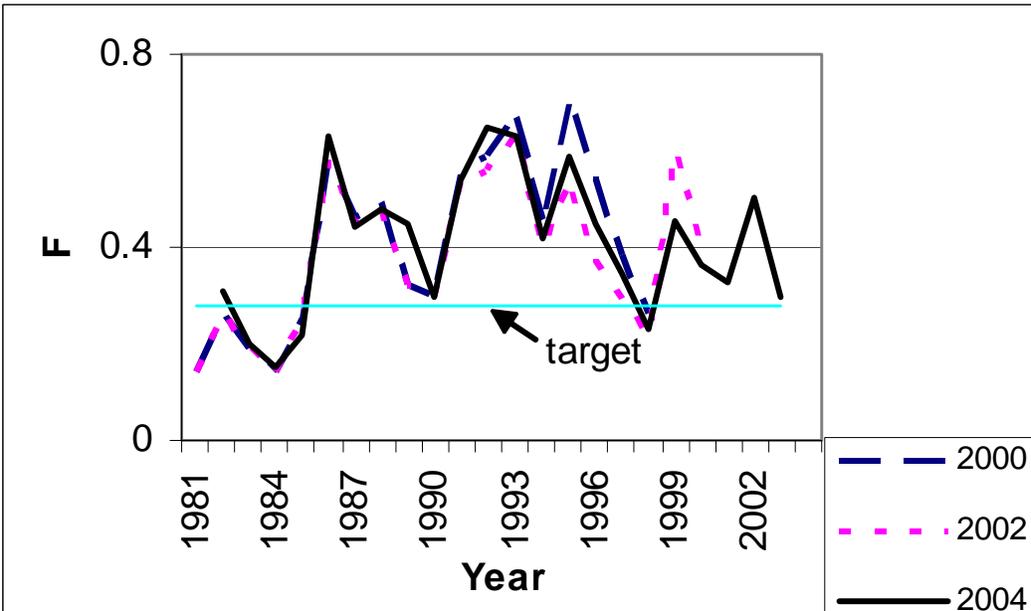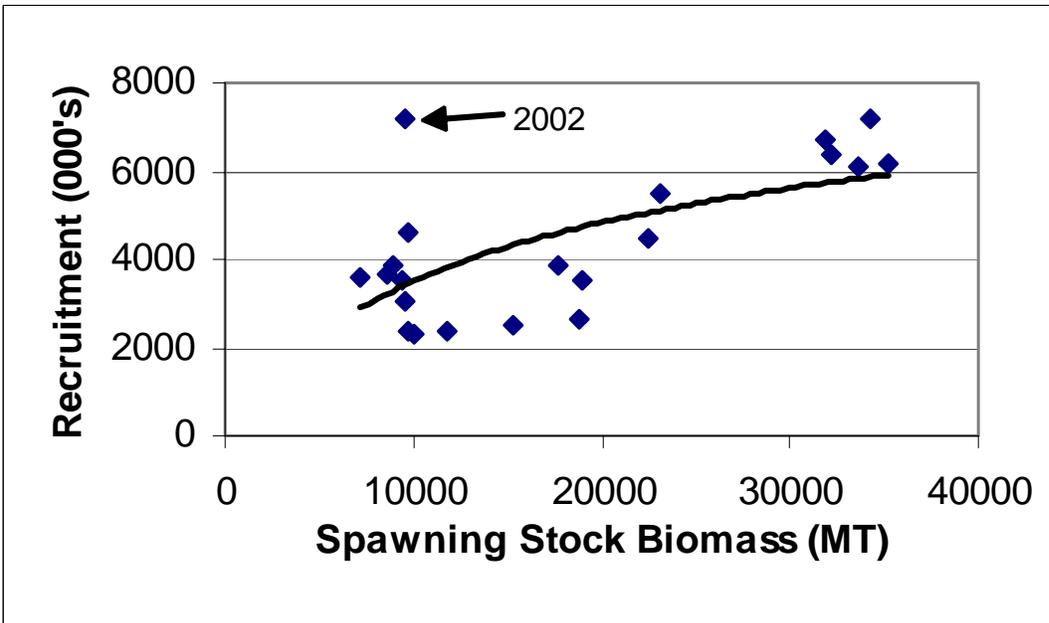
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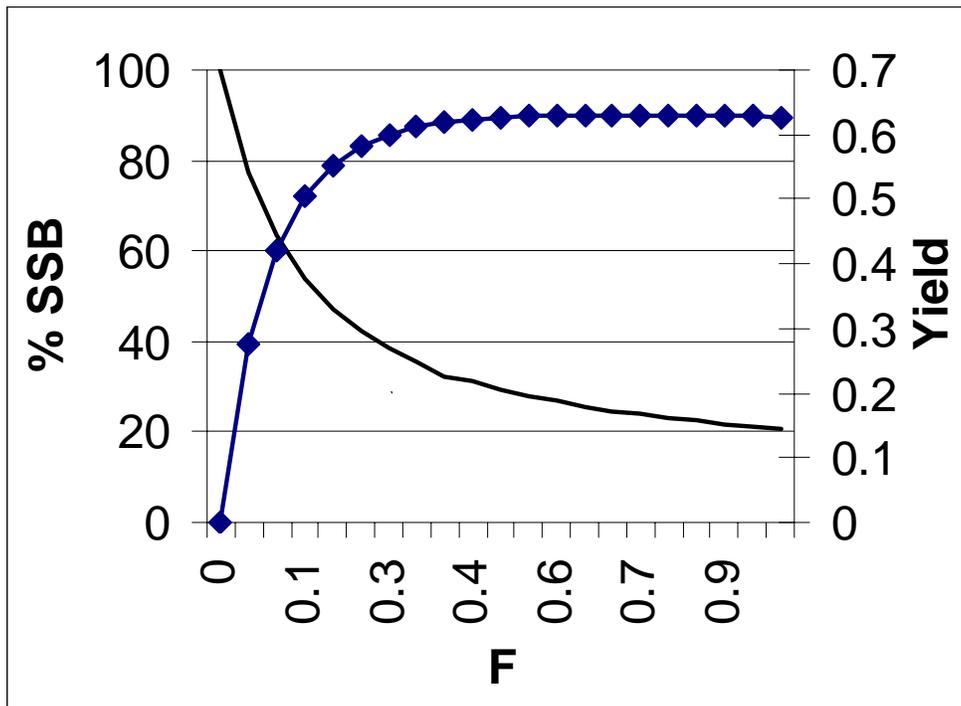
Figure 17. State commercial harvest trends, Northern & Southern Regions

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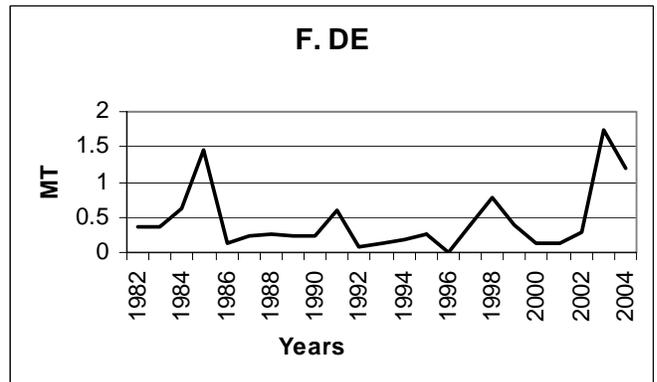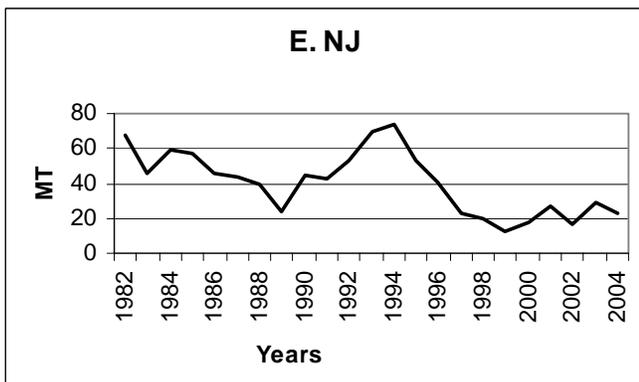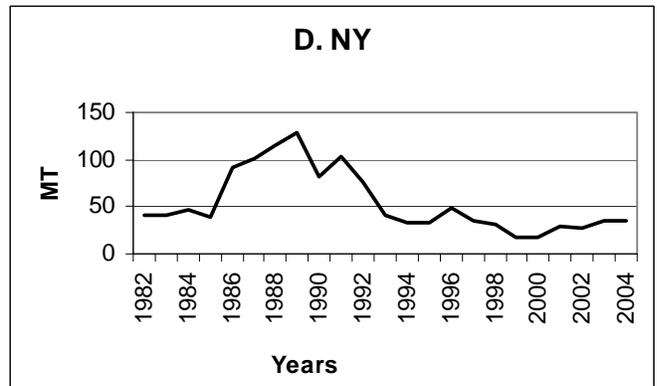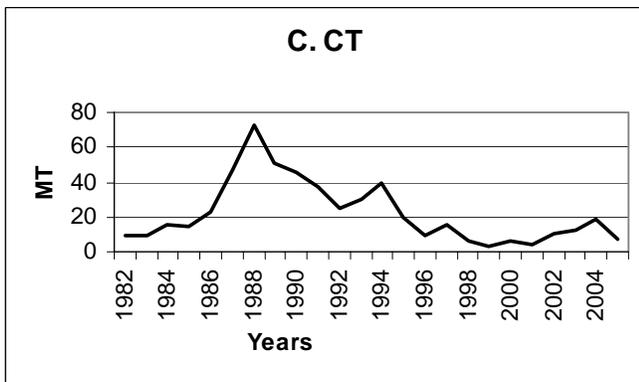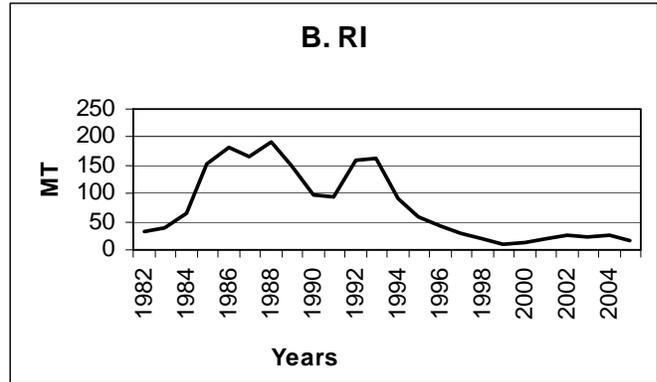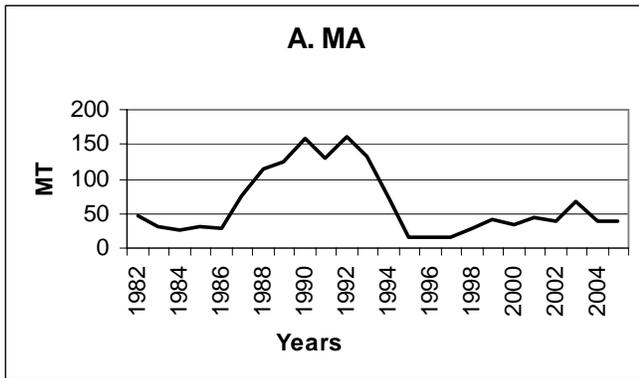
Figure 17 (continued). State commercial harvest trends, Northern & Southern Regions

G. MD

H. VA
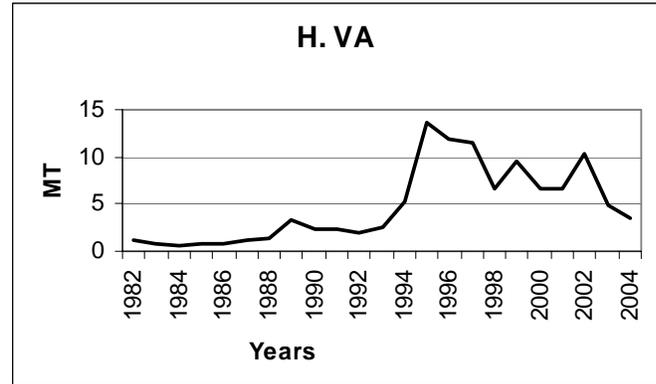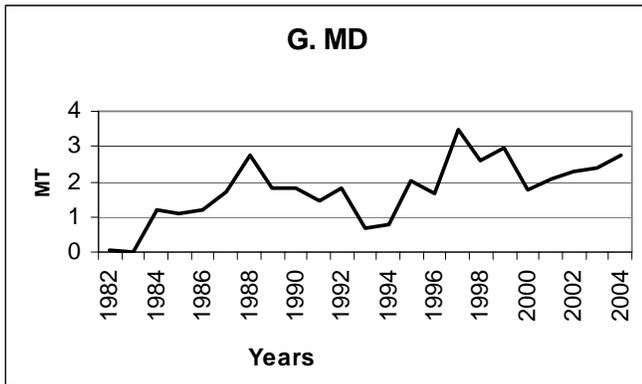
Figure 18. State recreational harvest trends, Northern & Southern Regions
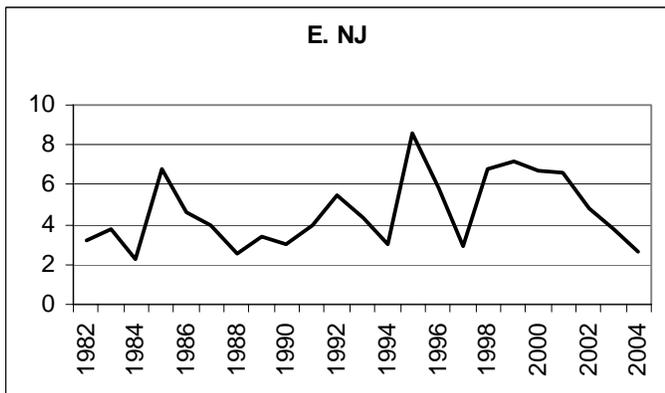

A. MA

B. RI

C. CT

D. NY
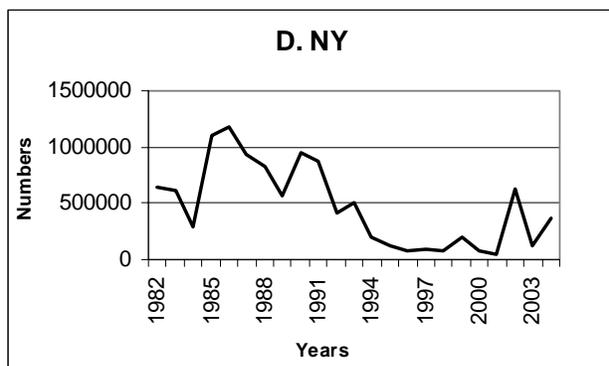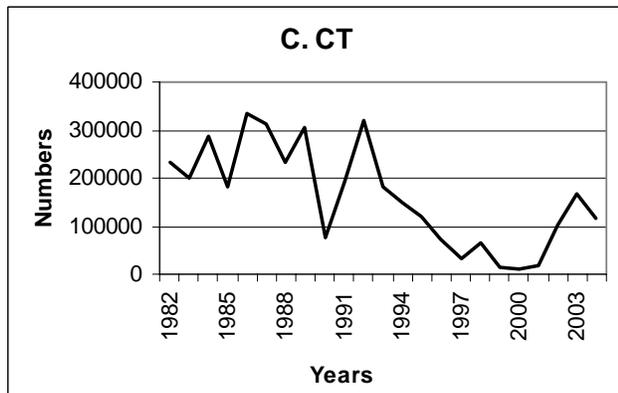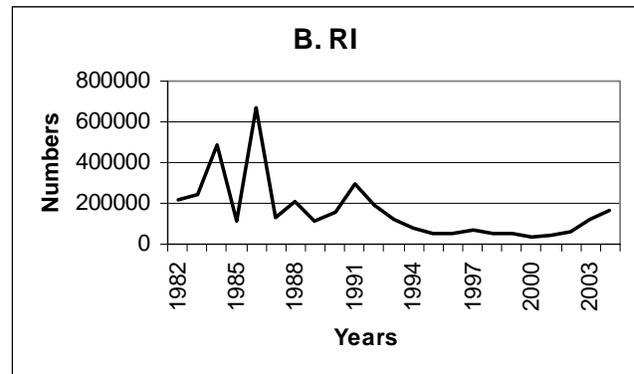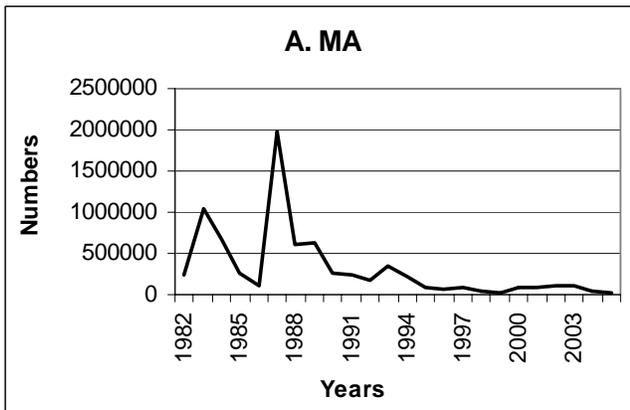
Figure 18 (continued). State recreational harvest trends, Northern & Southern Regions

E. NJ

F. DE

G. MD

H. VA
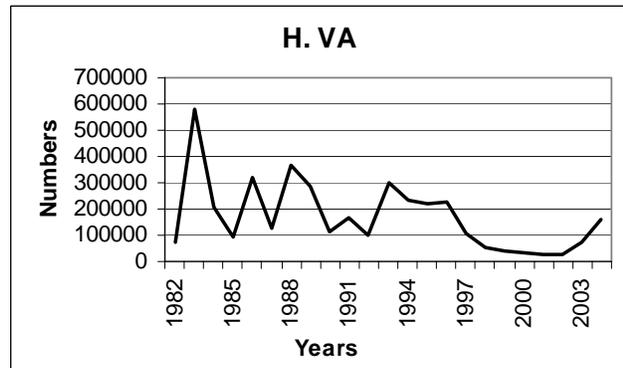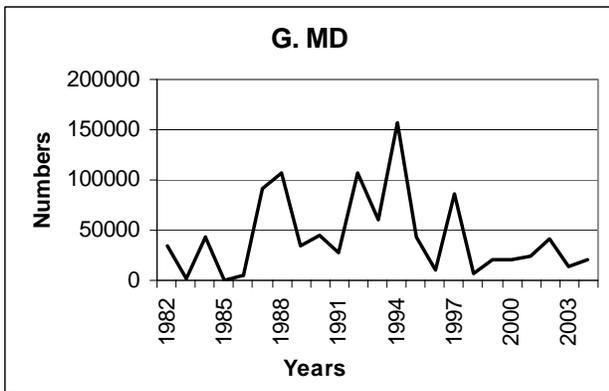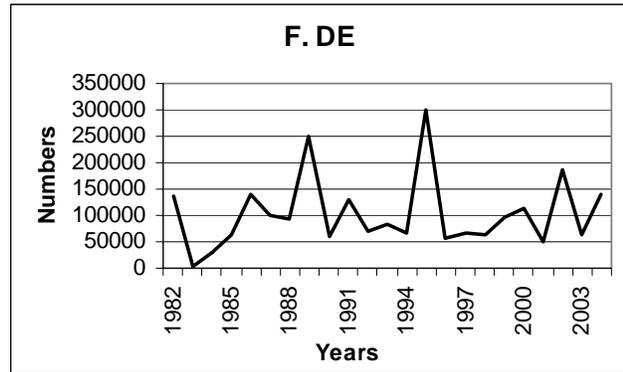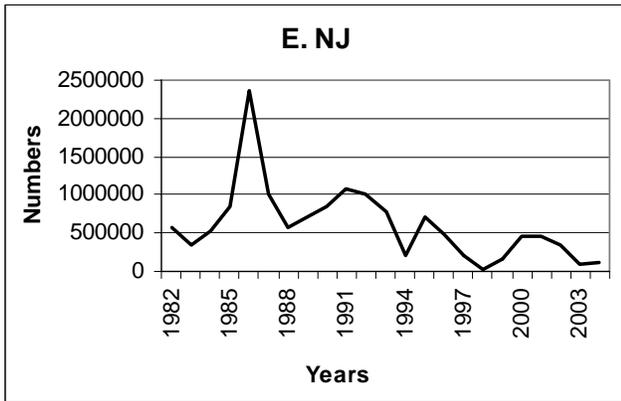
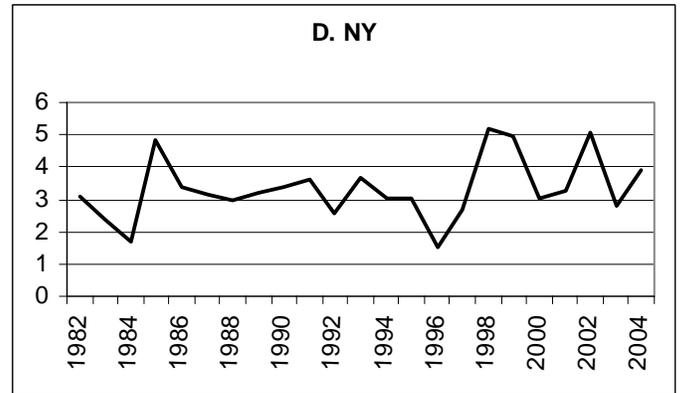Figure 19. State recreational CPUE trends, Northern & Southern Regions

A. MA

B. RI

C. CT
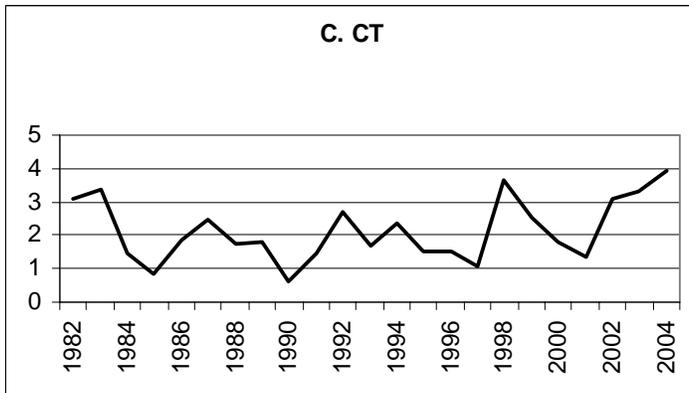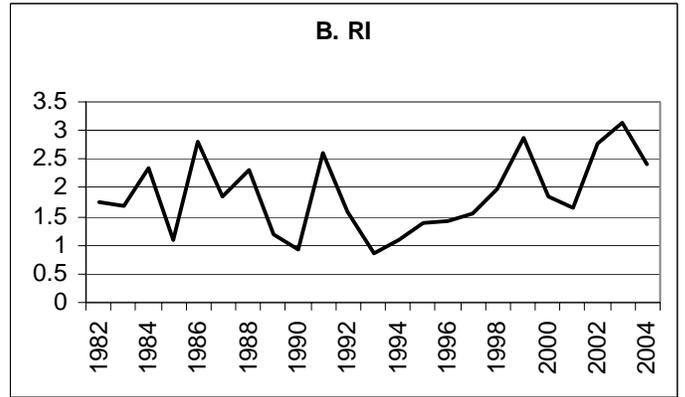
D. NY

E. NJ

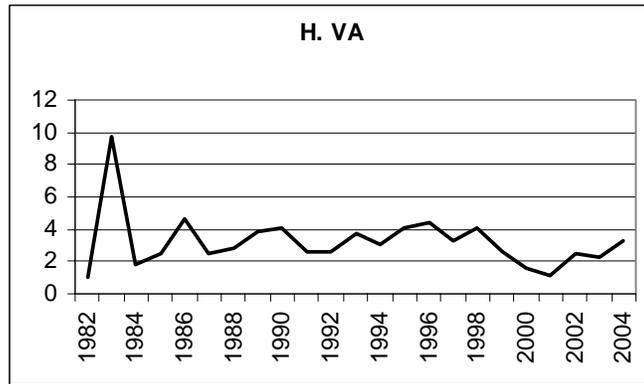**G. MD**
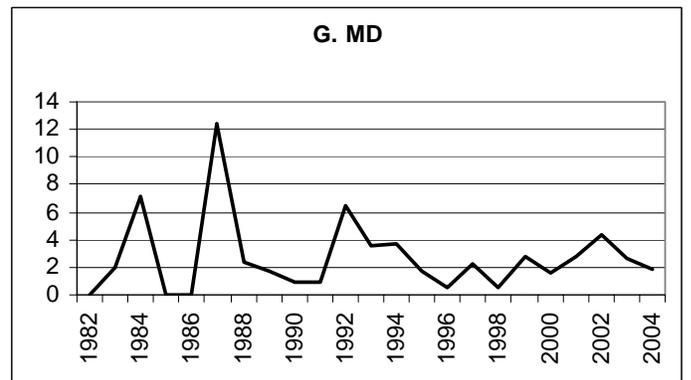
Figure 19 (continued). State recreational CPUE trends, Northern & Southern Regions

H. VA

Figure 20. State index trends
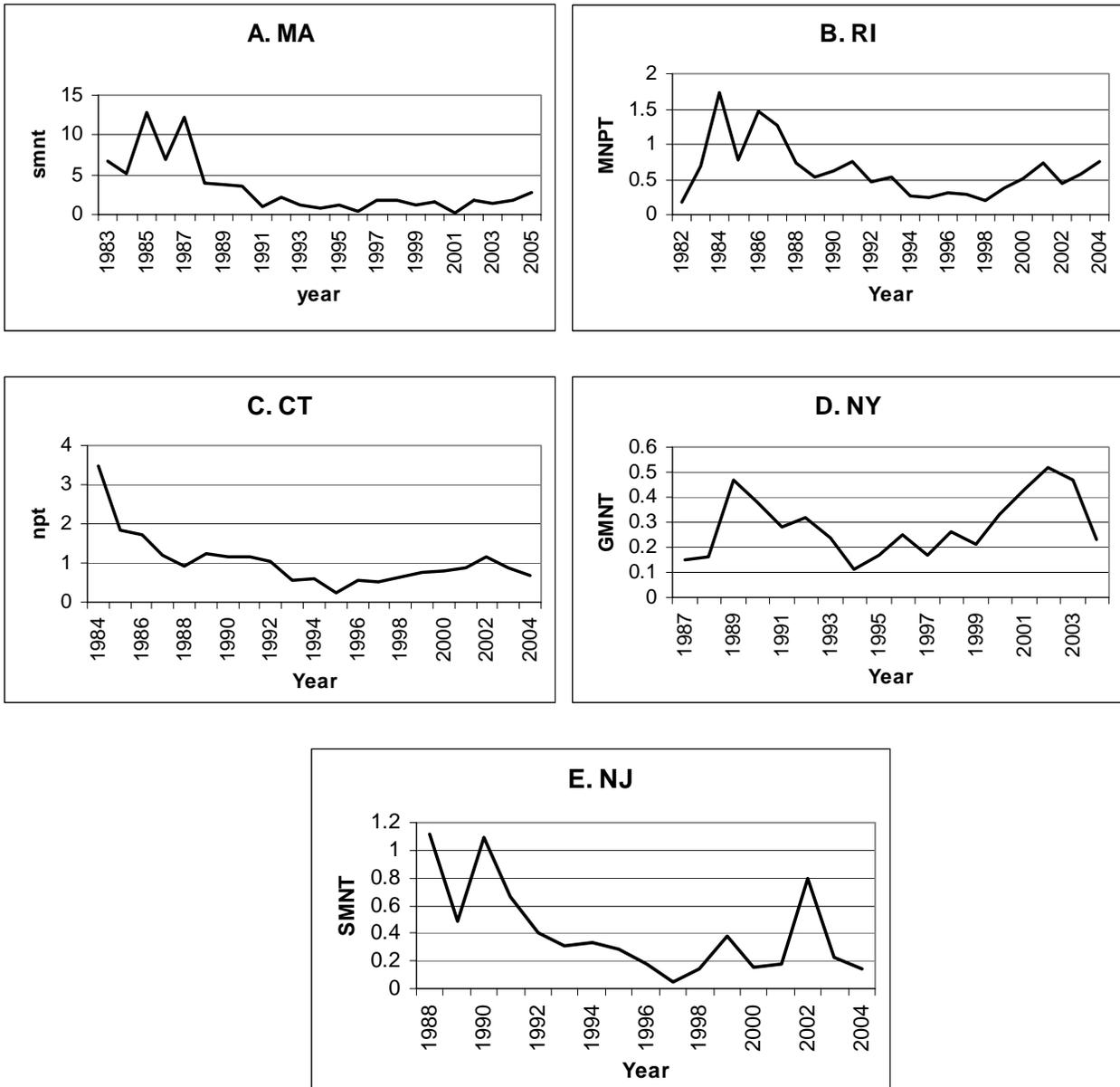
Figure 21. Relative exploitation
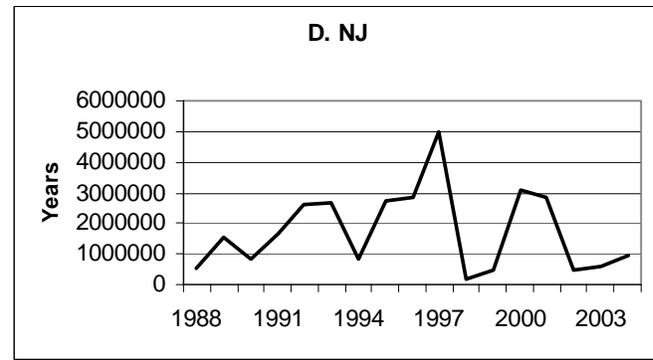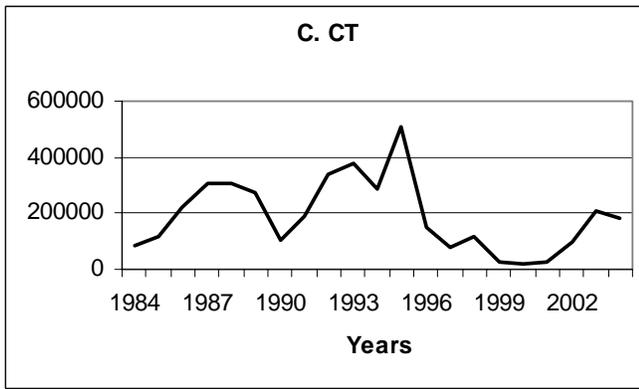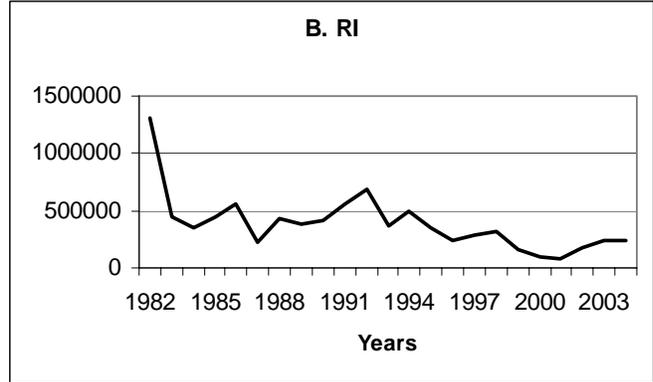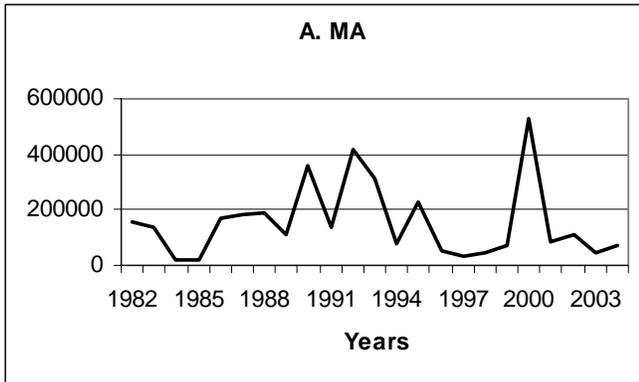
14.0 Appendices

Appendix A. VPA files – Available upon request from the ASMFC Science Program.

Appendix B. Massachusetts Status Report

Stock Status of Tautog in Massachusetts Waters

Prepared for the ASMFC Tautog Stock Assessment Sub-committee

By

Paul G. Caruso
Senior Marine Fisheries Biologist
Massachusetts Division of Marine Fisheries
South Shore Marine Field Station
50 A Portside Drive
Pocasset, MA 02559

Introduction

This document is an attempt by the Massachusetts Division of Marine Fisheries (MDMF) to determine local stock status as part of the ASMFC Stock Assessment process. Terms of Reference for the 2005 coastwide stock assessment call for measurement of stock parameters for the coastwide area and also to the smallest geographical area possible. While the assessment will update coastal stock parameters based on an analytical population model as in past assessments (ADAPT VPA), managers desire more localized information to assist with fisheries management decision making, since the current state of knowledge regarding tautog populations points to more discrete population units along the coast. Local tagging study results confirm this assumption in Massachusetts's waters, where three discrete stock units are assumed.

Management History

Prior to 1994 Massachusetts had a 12-inch minimum size for both the commercial and recreational fisheries. In 1994 the minimum size was increased to 16 inches in response to increased commercial fishing pressure and landings. At that time a 6 fish recreational bag limit and a 50 fish commercial possession limit were implemented. In response to the FMP a commercial closed season was implemented for the time periods November 1 to April 15 and May 16 to July 10, along with gear limitations and mandatory escape portals and escape vents for fish pots in 1996. In response to Addendum III of the FMP the recreational fishery bag/possession limit was reduced to 3 fish per angler per day beginning in 2003.

Fisheries Dependent Data

Recreational harvests (MRFSS A+B1 catch) from 1982 to the present range from a high of 2 million fish in 1986 to a low of 20,000 fish in 2004, averaging 317,000 fish over the time series (Figure 1 and Table 1). Catches have averaged only 68,000 fish annually since restrictive recreational fisheries management was implemented in 1994 (16 inch minimum size limit). Since six fish bag limits were imposed in 1996 only 65,000 fish have been harvested on average. Additional and more restrictive recreational fisheries regulations were adopted in 2003 (3 fish bag limit) and recreational catches have since dropped to 46,000 and 20,000 fish in 2003 and 2004 respectively. Since 1996 the released alive proportion of the catch (MRFSS B2 catch) has risen from 18.5% (1982 - 1993 mean) to 71% (1994 to 2004 mean). Estimated total recreational removals (harvest plus 2.5% of the B2 catch representing an estimate of release mortality) follow trends similar to the recreational harvest, since the contribution of release mortality to total mortality is still relatively small.

Recreational CPUE was determined as the harvest numbers from directed trips divided by the number of directed trips, where directed trips are identified when anglers stated tautog as the preferred primary or secondary species sought. Since 71% of the total recreational catch is from directed trips one might expect a poor correlation between CPUE and local abundance. Indeed, the directed CPUE is without trend over the time series (Figure 2), and the correlation to estimated abundance is weak and negative. The total recreational harvest more closely resembles local abundance as measured by local survey indices, with a correlation coefficient value of 0.67.

Commercial harvest trends are landings averaging 38 mt during the 1982 to 1985 time period, rising to a peak harvest in the late 1980s and early 1990s (average 121.5 mt), commensurate with development of a live fish wholesale market and high ex-vessel values. Harvest declined in the mid 1990s, to an average of 35 mt, commensurate with imposition of commercial regulations (Figure 3 and Table 1). A slight

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increase over the past few years can probably be attributed to increased effort, as tautog is one of the few remaining species not controlled by quota management or limited entry in Massachusetts.

Trends in overall fisheries removals closely track the recreational harvest and total recreational removal patterns since, as in the coastwide fisheries, the recreational catch predominates, making up an average 80% of local harvest over the time series.

Fisheries Independent Data

Survey indices are from the Massachusetts Biannual Coastal Trawl Survey and represent the stratified mean weight per tow and stratified mean number per tow from the spring survey leg in all regions south of Cape Cod (Figure 4). Survey indices averaged 5 fish per tow in the early 1980s, rising to a peak of 10.7 fish per tow in the mid 1980s. Survey indices declined in the late eighties and remained at low levels to 1.7 fish per tow (1987 to 2004 mean). The 2004 index (0.6) approached the time series low of 2000 (0.2). The 2005 index value has rebounded slightly to levels last seen in 1991.

Sampling for local age and growth parameters has remained at approximately the 200 fish level for the last ten years. That level is insufficient to create a viable local age length key. For that reason survey catch was aged using the Northern Region pooled years' and states' keys. The resulting catch-at-age matrix indicates a loss of older aged fish from the survey over time. In 1978 fish were routinely captured up to age-31. Beginning in 1993 few fish were caught older than age-21. In most recent years few fish were caught older than age-18 (Figure 5).

Stock Status

A local VPA or age based analytical model run could not be performed since recreational and commercial catch frequency data is insufficient in recent years to expand catch numbers to length and age. A Biomass Dynamic Model run cannot be performed because the available catch data has no contrast between the catch and indices (the "one way trip") within the recreational catch data time frame and recreational data are unavailable before 1981.

For an indication of fishing mortality trends localized Z estimates were made using within cohort catch curves (longitudinal) from the aged survey indices for all fully recruited ages. Estimates of F were derived as Z-M where M = 0.15. Age classes since 1993 contain too few fully recruited age groups to estimate Z or F by this method. In addition, the value of F calculated by this method is not comparable to mortality rates estimated from harvested catch since the data series contain fish that are recruited to the survey gear but not the fishery. Year classes recruiting to the fishery before local harvest restrictions fishing mortality rates averaged 0.25 (1988-1993), since restrictive local management was enacted the average F (recruitment 1994-2001) has dropped to 0.15 (Table 2).

Relative exploitation was also determined, as catch numbers over survey index numbers for the time series (Figure 6). Exploitation was moderate in the early 1980s rising and staying at high levels from the mid 1980s through 1995. In 1996 relative exploitation dropped to low levels and except for a noted spike in 2000 has remained at low levels.

Given the limited available data local stock status is uncertain. However, local survey indices suggest that stock levels are steady at about one third of observed levels before fisheries expansion and most recently rising to levels last seen in 1991. There is some indication that 2002 may have been a favorable year for recruitment based on age-1 survey index values and 2005 index values. Survey catch-at-age

patterns reveal age truncation over time indicative of past over fishing. But survey cohort catch curves reveal F levels dropping on cohorts that have recruited to the fishery post management. Exploitation patterns for recent years reveal similar trends and appear moderate compared to peak levels in the mid 1980s. Recreational fishery catches, and subsequent total removal patterns suggest that total removals may be more closely tied to local abundance than regulatory changes, with the exception of the past two years when the most recent regulatory cuts took effect. Steadily increasing commercial harvests, though moderate, are some concern given current resource levels and declining recreational harvest proportions.

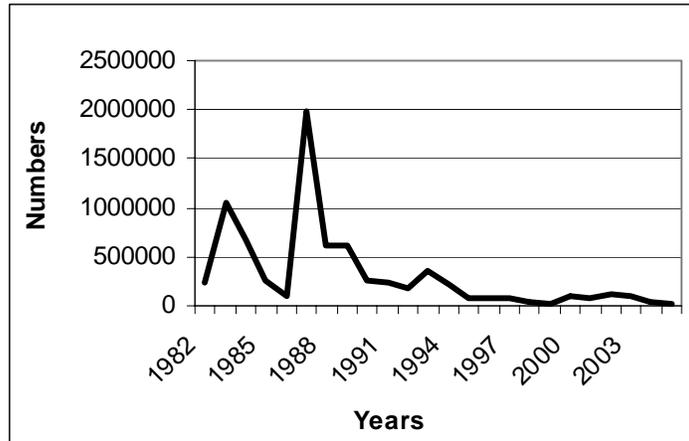Figure 1. Recreational harvest trends.
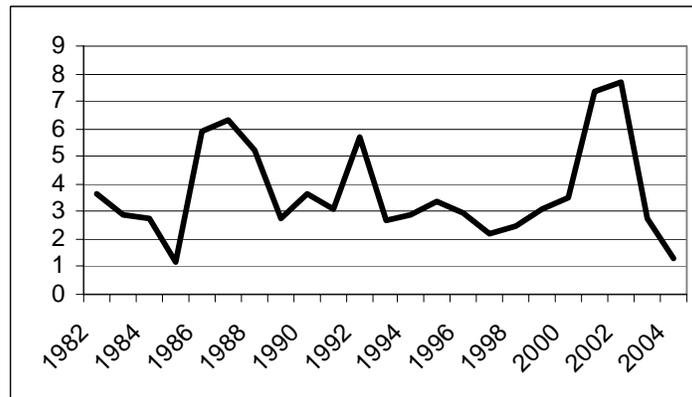

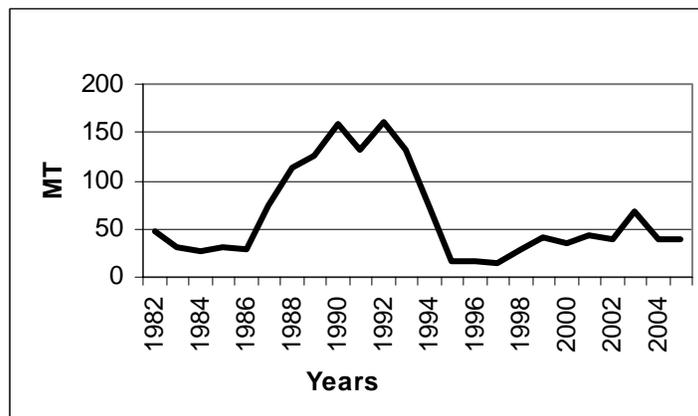Figure 2. Recreational CPUE trends.

Figure 3. Commercial harvest trends.

Figure 4. Survey Index trends
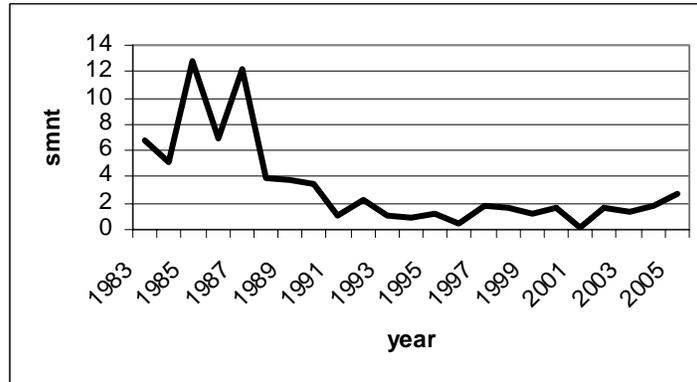
Figure 5. Survey age distribution trends.

MA Survey Age Distribution 1988

MA Survey Age Distribution 1998
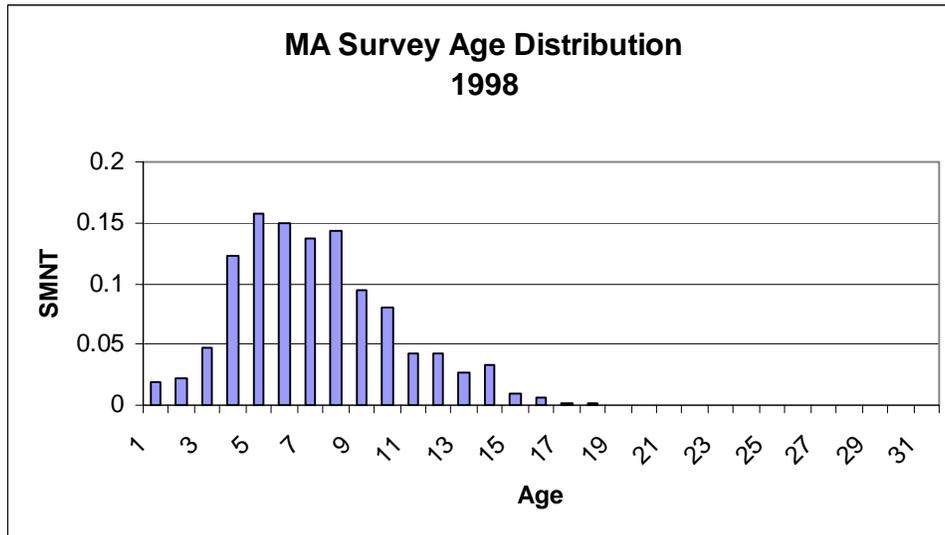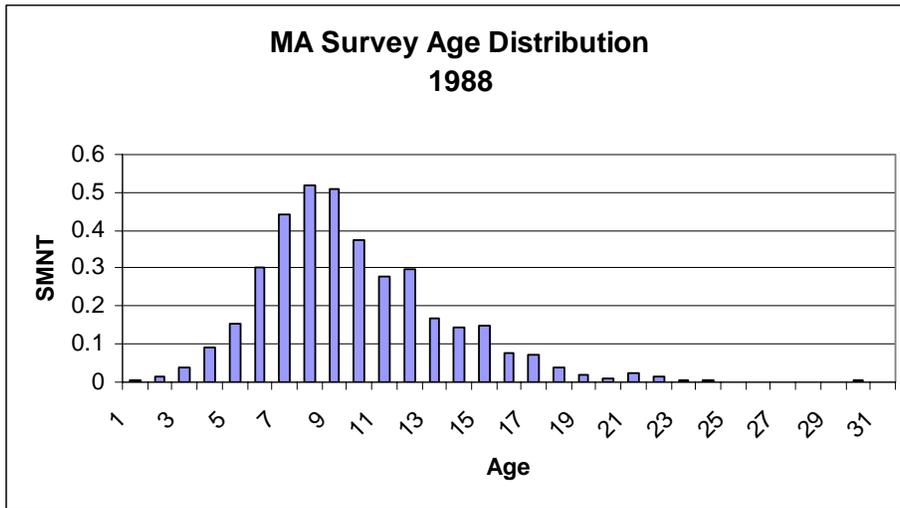
Figure 5 (continued). Survey age distribution trends.

**MA Survey Age Distribution
2003**
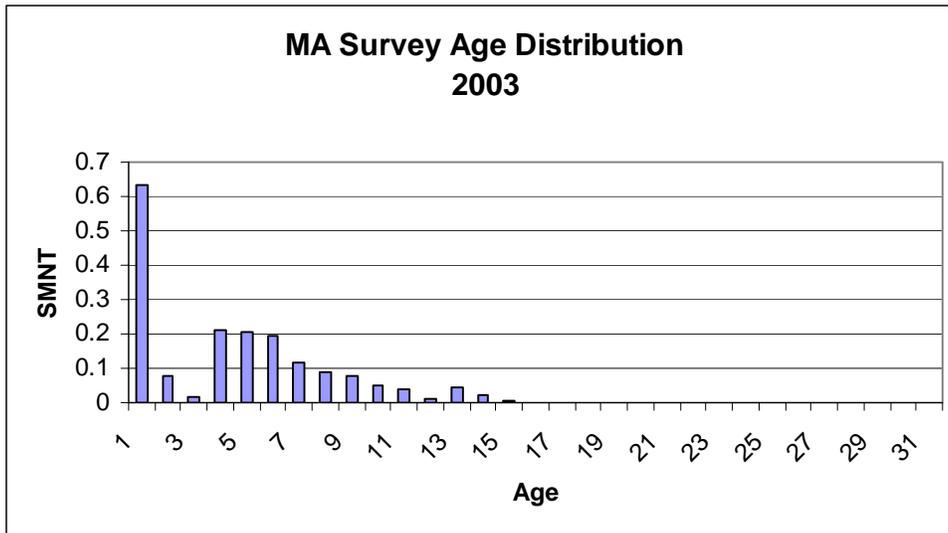
Figure 6. Relative exploitation trends.
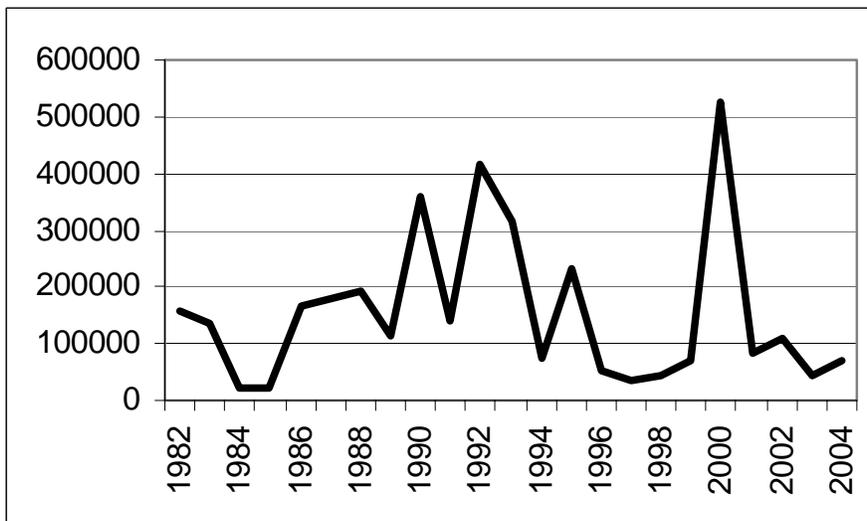
Table 1. Massachusetts Recreational and Commercial Harvests

Year	Recreational Harvest (#'s)	Commercial Harvest (mt)
1982	1051022	31.43
1983	670508	26.13
1984	258256	30.89
1985	100941	28.71
1986	1980719	75.21
1987	617068	113.40
1988	621679	125.69
1989	250077	159.71
1990	233444	131.12
1991	176905	160.73
1992	357949	132.58
1993	216553	72.73
1994	78483	16.81
1995	72461	16.01
1996	79798	14.78
1997	39075	29.14
1998	25034	41.42
1999	91476	34.30
2000	87552	43.55
2001	115658	38.25
2002	102662	67.17
2003	46808	39.10
2004	20873	40.00

Table 2. Survey Cohort Catch Curve Results

Year Class	Z	F	Recruitment Year
1980	0.49	0.34	1988
1981	0.41	0.26	1989
1982	0.46	0.31	1990
1983	0.36	0.21	1991
1984	0.35	0.2	1992
1985	0.3	0.15	1993
1986	0.32	0.17	1994
1987	0.15	0	1995
1988	0.33	0.18	1996
1989	0.36	0.21	1997
1990	0.31	0.16	1998
1991	0.43	0.28	1999
1992	0.28	0.13	2000
1993	0.21	0.06	2001

Appendix C. Rhode Island Status Report

**Assessment of Tautog in Rhode Island Waters Using a
Biomass Dynamic Model**.

By

Mark R. Gibson
Deputy Chief
Rhode Island Division of Fish and Wildlife
Jamestown Marine Fisheries Office
3 Fort Wetherill Rd, Jamestown RI 02852
October 15, 2004

Report to the Atlantic States Marine Fisheries Commission Tautog Technical
Committee and Management Board.

Introduction

The Atlantic States Marine Fisheries Commission (ASMFC) is the managing authority for tautog (*Tautoga onitis*) along the US Atlantic coast. The Commission's fishery management plan for tautog required a reduction in fishing mortality in steps. In response to an ASMFC coast wide stock assessment, Atlantic coastal states were required to implement regulations in 1998 to reduce fishing mortality rate (F) from the prevailing 0.58 to an interim 0.24 (ASMFC 1996). Additional reductions were required in out years to reduce F to the 0.15 long-term objective. This biological reference point was based on the conservative assumption that F should be limited to no more than the natural mortality rate (M). The Rhode Island Division of Fish and Wildlife (RIDFW) submitted an assessment update and management proposal for Rhode Island tautog to ASMFC. It showed that the state's preemptive efforts had reduced the F estimate to the interim F=0.24 level (RIDFW 1998). The assessment, using a non-equilibrium production model, indicated that fishing mortality had declined in 1996-1997 to the F=0.15-0.22 range. Abundance estimates had begun to increase in 1996-1997 over the historic lows reached in 1994-1995. These improvements followed implementation of a 16" minimum size in 1994, reduced commercial quotas beginning in 1996, and a 5 fish recreational bag limit in 1996. These regulations were more restrictive than required by ASMFC at the time. Current Rhode Island recreational regulations include the 16" minimum size and a three fish possession limit from May 1 to October 14. A 10 fish possession limit is in place from October 15 to December 31. The commercial fishery is managed with a quota divided amongst three seasons. The quota has been fixed at 57,000 pounds for several years.

The ASMFC tautog technical committee recently made revisions to the over fishing definition and adopted a reference point based on spawning stock biomass per recruit (SSB/R). The fishing mortality rate allowing for 40% of un-fished SSB/R to persist was chosen (F=0.29). The new over fishing definition was more liberal than the F=M convention and reflects the effectiveness of large minimum sizes in accumulating egg production. Rhode Island tautog were last assessed in 2002 and found to be at low abundance and moderately overfished (Lazar 2002). Fishing mortality rate in 2001 was estimated by VPA at 0.40, below the peak level of F=0.65 in 1992 but above the new ASMFC limit of F=0.29. Coincident to over fishing, stock biomass declined from over 7,000 tons in 1984 to only 1,047 tons by 1994 before rising to 1,312 tons in 2001. Recruitment, which had exceeded 500,000 fish during the period 1981-1987, was estimated at 388,000 in 2002. The catch-at-age data needed to support VPA is available only back to 1981 precluding analysis of long-term tautog stock dynamics. Also, VPA does not directly estimate biological reference points. While the SSB/R method is based in part on the VPA selectivity pattern, no stock regenerating function is considered that links generations. Finally, there is no complementary biomass based reference point. This could be a risk prone management strategy if stock biomass declines to critical levels for uncertain reasons while fishing mortality remained at F40%. In order to address these limitations, the 1998 RIDFW production model assessment was updated.

Stock Structure and the Fishery-
The tautog resource in the northern part of the species range is considered a group of localized stocks associated with structured, reef type habitats (ASMFC 1996). Tautog exhibit inshore-offshore movement patterns that are related to spring spawning and over wintering in deeper water. Tagging studies have shown that tautog display fidelity to spawning sites in Rhode Island (Cooper 1966, Lynch 1991). They also establish night, home sites that are vacated during daytime feeding excursions (Olla et al. 1974). Because of the fidelity to specific sites and largely restricted movements, Rhode Island tautog as characterized by local fishery catch and survey data were considered a stock for assessment purposes. The implications of a more complex, metapopulation stock structure to the assessment are discussed later.

Tautog are harvested both commercially and recreationally in Rhode Island. Because of restrictive commercial quotas, the recreational fishery greatly exceeds the commercial. The recreational fishery begins in wave 3 (May-June) on spawning tautog. This period has accounted for 18% of landings in the last five years. There is little summer activity in the fishery (July and August) with only 6% of the catch being realized. Waves 5 and 6 (September to December) account for 76% of the recreational catches. Fall and early winter are the traditional seasons for recreational tautog fishing in southern New England. A multitude of gears are employed by the commercial fishery. The rank order of commercial landings by gear type 1998-2002 was: otter trawl (27%), rod and reel (21%), gillnets (16%), fish/lobster pots (16%), spear/divers (11%), and floating traps (9%). The commercial fishery generally occurs earlier than the recreational fishery. Few landings are made during January to March but April has produced 11% of recent landings. May and June account for 44% of the landings, considerably more than for the recreational fishery. July and August account for 13% of the landings. A fall-early winter fishery occurs that accounts for 32% of the landings. The tautog commercial fishery is largely a by-catch one as a result of small quotas and low daily possession limits.

Methods and Data Sources

Abundance Indices- The University of Rhode Island Graduate School of Oceanography (URIGSO) trawl survey provides a long-term perspective for tautog abundance in Narragansett Bay. This weekly survey samples only two stations in the West Passage but has been conducted since 1959. Details of the survey design may be found in Jeffries et al. (1989). Data through August 2004 was provided by survey personnel at the graduate school (Rich Bell - pers. comm.). Because the URIGSO survey is the longest running trawl program, it was considered the primary index for assessment purposes.

The Rhode Island Division of Fish and Wildlife (RIDFW) conducts several surveys in and around Narragansett Bay that provide abundance estimates for tautog. A seasonal trawl survey is conducted in spring and fall at random stratified stations in the Bay as well as in the adjacent Sounds. Details of the survey may be found in Lynch (2002). A total of 42 stations are sampled per season (84 per year) and all tautog are enumerated, weighed, and measured for length. The survey has been conducted since 1979 and indices (mean weight per tow) through the spring 2004 cruise are available. A monthly component to the survey with 13 additional fixed stations in Narragansett Bay was added in 1990. Data from this survey are available through August 2004. The monthly survey tends to catch more tautog than the seasonal since the timing of sampling better coincides with the spawning migration of tautog in the bay. A summer index was computed from the May to August monthly samples. A juvenile finfish seine survey has also been conducted in Narragansett Bay since 1986. A total of 18 fixed stations are sampled once monthly from June to October with a 200' beach seine (Powell 1986, Dorf and Powell 1997). Age-0 tautog are enumerated and measured for length. A mean number per haul index is computed annually. Data through August 2004 were available from the seine survey. A similar seine survey was begun in the Rhode Island coastal salt ponds in 1994 to complete survey coverage of juvenile fish habitat. A separate index was computed for the coastal ponds. Indices of young of the year (YOY) tautog were assumed to be proportional to stock biomass in tuning the assessment model. This is a reasonable assumption since the time period covered by the seine surveys is one of low stock abundance when compensatory dynamics would be minimal.

Other Rhode Island tautog abundance indices include trawl surveys, seine surveys and impingement monitoring at Brayton Point power station on Mt. Hope Bay, an upper arm of Narragansett Bay. Mt. Hope Bay is a known spawning area for tautog as evidenced by collections of eggs and larvae by company consultants. Utility surveys began in 1972 and data are reported by the company annually to the RIDFW (USGen New England 2004). Since Mt. Hope Bay is only about 10% of Narragansett Bay, the utility

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indices were combined into one index so as not to have undue influence on a statewide assessment. The composite index was calculated as a simple average of the individual MRI surveys in Table 1. Stock indices in 2004 are based on incomplete surveys but are believed reliable since most tautog are sampled between May and August. In 2002 and 2003, only 3% of the tautog taken in the weekly URIGSO trawl survey were sampled after August.

Fishery Data- Recreational landings estimates (type A+B1) for tautog are made annually by the National Marine Fisheries Service (NMFS) and the Atlantic coastal states with the marine recreational fishing statistics survey (MRFSS). Revised estimates are available from 1981 to 2003 from the NMFS website. Estimates for 1978-1980 were taken from a state survey (McConnel et al. 1981) and from early MRFSS estimates (USDOC 1984). Rhode Island commercial landings for tautog were available from 1959 to 1996 from the NMFS website. Commercial landings for 1997-2003 were taken from the RIDFW computerized dealer reporting system. Estimates of recreational landings from 1959-1977 were made using several sources of information. Cooper (1964), made estimates of commercial and recreational tautog catch in 1961 which indicated that recreational catch accounted for 44% of the total RI harvest. Recreational catch estimates from 1978-1981 comprised greater than 90% of total harvest indicating a substantial growth in recreational fishing activity relative to commercial since Cooper's study. Independent data documenting the increase in marine recreational fishing nationwide is available in USDOI (1996). National hunting and fishing surveys showed that from 1955 to 1985, saltwater fishing days increased steadily from 58.6 million to 171.1 million or a rate of about 4% per year. Estimates of the recreational fraction of tautog catch in RI each year from 1959 to 1977 were made by iterating a starting proportion in 1959 and a rate of increase so that the estimates passed through the 0.44 observation of Cooper in 1961 and converged on the observed 1978-1981 proportions. Estimates of recreational catch in 1959-1977 were then hind cast off the commercial landings using the estimated recreational fractions:

$$R_t = [C_t/(1-p_t)]-C_t \qquad\qquad (1)$$

where: R = recreational landings
           C = commercial landings
           p = proportion of total landings from recreational
           t = year.

Recreational discards for years 1979-2003 were estimated as 5% of the MRFSS type B2 catch with mean weights estimated from the sub-legal tautog sampled in trawl surveys. There was no basis to estimate commercial discards. Conversion of length (mm) to weight (grams) was accomplished using a weight-length equation derived from 989 tautog individually weighed and measured during trawl cruises ($wgt=3.127x10^{-5} x len^{2.932}$).

A fishery dependent abundance index was examined in addition to those based on research surveys. A recreational fishery catch per unit effort index (CPUE) was calculated as the recreational catch estimate (A+B1+B2) divided by the number of state waters fishing trips in Rhode Island from the MRFSS data base. Further refinement of recreational effort, for example including only species preference trips, has not yet been evaluated

Auxiliary Estimates of F- Fishing mortality rate on tautog in Rhode Island was estimated from a RIDFW 1987-1992 tagging study by Gibson (1995). A multiple year tagging experiment was analyzed with the maximum likelihood methods of Brownie et al. (1985). That study compared the tag based estimates to historical estimates based on catch curves applied to age frequency data. Gibson fit catch curves to the linear portion of the descending limb of the log age frequencies. Data sets analyzed included Cooper's

(1964) samples taken in 1961 and the RIDFW age samples collected in 1987-1992. The regression slope of log frequency on age was taken as an estimate of total mortality rate (Z). M was assumed to be 0.15 and F=Z-M. For this assessment, the tag based estimates were updated based on additional returns from the 1987-1992 releases and the catch curve method was applied to new age structure data collected through the fall of 2003 from private recreational boats by RIDFW biologists. A total of 854 tautog were sampled for length and opercular bones in 2002 and 2003. The bones were cleaned of debris and boiled to improve readability. Age determinations were made by counting annuli using standard ASMFC conventions. The catch curve regression was applied to fish age-7 and older as in Gibson (1995). The suite of auxiliary F estimates was used to calibrate the stock production model. Auxiliary F estimates were assumed to be directly proportional to model F, that is q=1.0. This convention insures that F estimates from the production model are comparable to fully recruited F rates from age-structured assessments. It should be noted that if this constraint is relaxed, the production model produces biomass weighted F estimates that are lower than those derived independently from age and tagging data.

Analysis of Size Composition- Length frequency distributions in trawl survey catches and in MRFSS samples from the recreational fishery were analyzed to give an estimate of Z conditioned on von Bertalanffy growth parameters. Beverton and Holt's method, as modified by Ault et al. (1998) for reef fishes, was applied to length composition data. Their modification to the classic estimator allows for truncation in the length distribution arising from factors other than mortality such as gear selectivity or availability. This was considered likely in tautog when deployment of fishing effort is not uniform with respect to a contagious fish distribution. The method estimates Z rate by iteratively solving

$$[(L_\infty - L_\lambda)/(L_\infty - L_c)^{Z/k} = (Z(\overline{L}_c - L) + k(\overline{L}_\infty - L))/(\overline{Z}(L_\lambda - L) + \overline{k}(L_\infty - L)) \qquad (2)$$

where:
L= mean length in recruited size range
L_c= length at recruitment
L_λ= maximum length in sample
L_∞= von Bertalanffy asymptotic length
k= von Bertalanffy rate parameter
Z= total mortality rate.

L_∞ and k were estimated at 601 mm and 0.136 per year from age samples (n=1168) collected in 1997-2003 by the RIDFW. Sample statistics from the length distributions were computed and eq.2 was solved for Z using the EXCEL SOLVER. L_c was specified by examining the length distribution plots and choosing the peak of the distribution as the length at recruitment. Length samples were combined in 3-year blocks working backward from the 2001-2003 data. Trawl data and recreational fishery data were analyzed separately and the estimates compared.

Estimates of Stock Size and Fishing Mortality- Past assessments of Rhode Island tautog have used VPA (Gibson 1997, Lazar 2002) or the analysis of tagging data (Gibson 1995). With the requirements of the national Sustainable Fisheries Act (SFA) and new Rhode Island statute requiring rebuilding of depleted stocks (RIGL 20-2.1-9), production models such as ASPIC (Prager 1994) are increasingly used to assess stocks and to project rebuilding schedules (Gibson and Lazar 1998, NMFS 1998). Advantages to these models include simplified data requirements and explicit estimation of sustainable fishing rates and biomass rebuilding targets. For this study, a biomass dynamic model (BDM) similar to that in Prager (1994) was fit to landings and biomass indices and calibrated with auxiliary estimates of F. Biomass dynamic models are a mass balance approach in which stock biomass in a new year is the sum of last year's biomass plus new production minus the catch removed (Hilborn and Walters 1992). New

production is the net balance between additions from growth and recruitment and natural losses. If stock growth is assumed to follow the familiar logistic curve, a simple BDM in discrete form is:

$$B_t = B_{t-1} + r_m B_{t-1}(1-(B_{t-1}/k)) - C_{t-1} + e_p \qquad (3)$$

where:
$\quad$ B = population biomass
$\quad$ C = catch
$\quad$ r_m = intrinsic rate of increase
$\quad$ k = unfished population biomass.
$\quad$ t = year
$\quad$ e_p = process error term.

The r_m parameter is a measure of the population growth rate in the absence of density dependent factors for example at low abundance. The parenthetical term in eq. 3 is the density dependent feedback mechanism that reduces stock growth when abundance is high. Surplus production (P) during any time step is the change in biomass (B_t-B_{t-1}) plus the catch taken during the time step (C_t). Because the underlying logistic curve is symmetrical, P is related to B in a parabolic fashion. The discrete form of the production model is a simplification over the differential equation that forms the basis of Prager's (1994) ASPIC application. The discrete and differential forms of the model are essentially equivalent unless extreme values of r_m and fishing mortality (F) occur (Hilborn and Walters 1992). This is unlikely for tautog, a long-lived species that has been moderately fished in Rhode Island waters.

Since the actual biomass levels are not known, an observation model is needed in the form of survey catch per unit effort:

$$B_t = (U_t)/q + e_m \qquad (4)$$

where:
$\quad$ B = biomass
$\quad$ U = survey abundance
$\quad$ q = catchability coefficient
$\quad$ t = year
$\quad$ e_m = measurement error term.

The q parameter is the scalar that relates survey abundance to absolute stock abundance. Eqs. 3 and 4 condition the solution on catch since fishery removals are assumed to be known without error and constitute the only absolute quantity in the input data. Substitution of eq.4 into eq.3 and combining error terms gives the final biomass dynamic model form:

$$U_t = U_{t-1} + r_m U_{t-1}(1-U_{t-1}/kq) - qC_{t-1} + e \qquad (5)$$

Parameters in eq. 5 (r, k, and q) were estimated by minimizing the sum of squares deviations between observed and predicted log catch per unit effort under the assumption of lognormal errors:

$$\text{minimize} \sum_{t=1}^{n} (lnU_t - ln\hat{U}_t)^2 \qquad (6)$$

It should be appreciated that in a multiple index BDM configuration, eq. 6 has a component corresponding to each survey with a uniquely estimable catchability parameter. All abundance indices

were given equal weight in the BDM. A mixed error model was assumed so that the residual sum of squares (RSSQ) was composed of process error in the population dynamics model and measurement error in the CPUE indices (Polachek et al. 1993, Chen and Andrew 1998). This procedure involves estimation of additional parameters in the form of process errors and a starting biomass level (U_0). It is accomplished by comparing, in a least squares sense, the observed primary indices to the estimated values as well as the step a head population dynamic forecasts. External weighting in the minimization was adjusted until process error accounted for about 15% of process and measurement error (Conser and Idoine 1992). This allows for some deviation from the logistic population model, for example from recruitment variations or catch errors, but allocates most of the error to the input indices. Solutions were found with the EXCEL SOLVER employing a quasi-Newton search method with quadratic approximation near the solution. The original version of the EXCEL BDM was adapted from a catch survey application provided by J. Collie from the University of Rhode Island Graduate School of Oceanography. As suggested by Hilborn and Walters (1992) and Prager (1994), the objective function (eq. 6) was expanded to consider the auxiliary data.

$$\text{minimize } \sum_{t=1}^{n} (lnU_t - ln\hat{U}_t)^2 + \alpha \sum_{t=1}^{n} (lnF_t - ln\hat{F}_t)^2 \qquad (7)$$

Historical estimates of F from tagging and aging studies were used to aid in estimation of model parameters. Auxiliary estimates of F set the scope for the analysis, narrowing the allowable bounds for catchability estimates. Auxiliary data can be given various weights depending on the level of confidence in the data. Eq. 5 was fit to the landings-abundance index data for years 1959 to 2004. Auxiliary estimates of F from tagging and age structure were given equal weight relative to the CPUE indices ($\alpha =1.0$) in the RSSQ minimization. Model F was calculated by solving exploitation rate (catch/biomass) for F assuming M=0.15. An important model constraint on the SOLVER solution was biomass in 1959 equal to K. Because of high initial variability in the URIGSO index, unconstrained solutions estimated 1959 biomass in excess of K and 1959-1960 stock production was strongly negative. Both circumstances were considered unlikely. Cooper (1964) showed that there was some fishing pressure near the beginning of the assessment period so the stock would not be above K. Production by a stock near K should be small but positive according to logistic theory (Hilborn and Walters 1992).

Uncertainty in estimated quantities was evaluated with bootstrapping (Efron 1982). Residuals from the original model fit were randomly resampled and added to the input abundance indices and auxiliary F estimates. The model was then successively refit to the alternate input data series and output quantities accumulated over 500 replications. Means and variances for parameters and derived quantities were estimated directly from the bootstrap results. Uncertainty was expressed as a coefficient of variation (CV) or as an empirical 95% confidence range. Potential retrospective bias in the BDM by successively removing the terminal year of input data and examining the stability of prior year estimates of fishing mortality rate and stock biomass. For example, estimations of F and B in 1998 and 1999 were examined using terminal data years ranging from 2000 to 2004.

Mid term projections were made using the fitted population dynamics model (eq.3) and assumed rates of F. The ASMFC plan required that states implement measures in April 1999 to reduce F estimates to the final F=0.29 target. The projections assume that the estimated stock production parameters will hold constant in the near term future. Uncertainty in projected stock sizes was evaluated by bootstrapping the projection runs using the 500 replications of terminal stock size, fishing mortality rate, and the logistic parameters.

Results

Abundance indices for tautog are summarized in Table 1. The long term URIGSO abundance index shows variable but stable abundance from 1959 to 1976 (Figure 1). The index then declined and reached a historic low in 1994. Abundance has increased in recent years but not yet to former levels. Both RIDFW trawl indices show similar patterns with low points in the mid-1990s and increased abundance in recent years (Figure 2). The MRFSS catch per unit effort index remains low relative to past values. Recruitment indices are also summarized in Table 1. All three seine surveys show poor year classes in 1994 and 1995 when stock biomass indices were very low (Figure 3). Recent recruitment has rebounded to former levels with increasing stock biomass indicating a stock-recruit relationship.

Tautog landings data are summarized in Table 2. Both recreational and commercial landings were low from 1959 to 1972 (Figure 4). Recreational landings began to increase in the mid 1970's and reached peak levels in 1980. The increase in commercial landings was delayed until 1984 but the fishery reached levels ten times higher than in early years. The great surge in commercial landings was coincident to an exponential increase in ex-vessel price per pound for tautog (Figure 5). Price was less than $0.20 per pound prior to 1984. With the emergence and expansion of live market opportunities, price per pound increased steadily to over $1.00 by 1994. The commercial fishery reached it's zenith in 1987-1989 capturing about 40% of total fishery landings. Both fisheries experienced landings declines in the 1990s when stock abundance declined and restrictive regulations were imposed. Total landings reached levels of 970-1,090 tons in 1984-1986 but have declined to just over 100 tons in 2001. Recreational landings increased in 2002 and 2003 consistent with rising survey abundance.

Auxiliary estimates of F from tagging studies and catch curves applied to age data are summarized in Table 1. Cooper's historical aging data indicated a more extended age structure than currently existing with F only about 0.05 (Gibson 1995). Estimates of F increased over time to a maximum 0.71 during the early 1990s. Recent age composition data indicate a moderation in F rate. The 2002-2003 age samples produced a 7+ catch curve with Z=0.45 (SE=0.02) so that F=0.30 (Figure 6). Note that the years of inference for catch curve estimates in Table 1 are earlier than the year of data collection. Ricker (1975) states that mortality estimates from catch curves "pertain to past years, to the time when the year-classes involved were being recruited to the catchable size range". Length frequency data from the recreational fishery and trawl surveys are plotted in Figures 7 and 8. The recreational data clearly show the effects of increasing minimum size limits. Large numbers of small tautog were present in the catch in early years. These fish disappeared as size limits advanced. Size structure was extended in 1979-1982 with more fish over 58 cm than in recent years. Slopes of the curves over the 45-60 cm size range increase over time indicating a relative loss of larger fish from the population. The trawl length frequencies are not affected by size limit changes. They too indicate a steepening of slope in the larger size classes. Early survey data (1979-1982) show a robust size structure, with a typical pattern of incomplete recruitment at small sizes and a descending right hand limb. Later years show a more bimodal distribution of lengths. This may result from recruitment variations and/or higher mortality rate on intermediate size tautog (Botsford et al. 1992). Estimates of Z from the size composition data are plotted in Figure 9. Estimates are plotted on the center year of the three-year block. Z from both trawl survey and recreational fishery length samples showed positive but not significant slopes from 1981 to 2002. Mortality rates varied between 0.2 and 0.4. Mortality rate estimates were generally higher and more variable for the MRFSS length data. This would be expected since the size at recruitment to the trawl is lower and the mortality estimate corresponds with some partially recruited fish. Because of the sensitivity of the method to growth parameters and recruitment variations, these estimates should be viewed as relative rates only. They were not used in calibration of the assessment model.

Estimated stock sizes, fishing mortality rates, and miscellaneous parameters from the biomass dynamic model are summarized in Table 3. Precision on the logistic model parameters (r, k) and catchability coefficients (q) was generally good with bootstrap coefficients of variation ranging from 0.12 to 0.21. The relatively good fit of the BDM is a result of the high contrast in the data (Hilborn and Walters 1992). High initial abundance, low catches, and low F are informative about carrying capacity (k). The recent increase in abundance from a historic low is informative about population growth rate (r). The observed and model estimated URIGSO abundance index is plotted in Figure 10. The population dynamics process smoothed some of the large deviations during early years of the URIGSO survey. The strongly parabolic production relationship is further evidence of the applicability of the BDM to tautog data (Figure 11). Modeled abundance in absolute scale is given in Figure 12. The stock exhibited stability near K from 1959 to 1978 with stock biomass fluctuating around 3,000 metric tons. Stock biomass then declined steadily to 407 tons by 1995. Stock rebuilding has occurred with biomass exceeding 1,440 tons in 2003-2004. Bootstrap distributions for estimated stock sizes are given in Figures 13 and 14. Lower 95% confidence bounds on 2004 biomass and mean biomass were in excess of 900 tons clearly indicating that stock growth has occurred since the mid-1990. However, there was a 70% chance that 2004 biomass was less than B_{msy} and an 80% chance that mean biomass was less than B_{msy}.

Fishing mortality rate was generally low and below 0.10 from 1959 to 1977 (Figure 15). Fishing rate then increased steadily to over 0.80 in 1991-1992. The increase in F is consistent with increasing catch and declining abundance during the same time period. Reduced landings have allowed for a decline in F to under 0.31 since 1997. F in 2003 was estimated at 0.19. Precision on the F estimate was good with a bootstrap CV equal to 0.22. Mean 2001-2003 F was estimated at 0.13 with a bootstrap CV of 0.20. Bootstrap distributions on the terminal F estimates are plotted in Figures 16 and 17. There was a 97% chance that 2003 F rate was less than F_{msy} and a 100% chance that mean F rate was less than F_{msy}.

Management quantities of related to maximum sustainable yield (MSY) were also estimated and bootstrapped. Reference stock levels and mortality rates assuming logistic population dynamics are as follows:

$$F_{msy}= r/2$$
$$MSY= rk/4$$
$$B_{msy}= k/2$$

F_{msy} was estimated at 0.28 with a CV of 0.17 (Table 3). As noted earlier, current fishing mortality rates are likely below F_{msy}. The estimated value of F_{msy} is very close to the current F40%=0.29 reference point of ASMFC. MSY was estimated at 374 tons (CV=0.05). Stock biomass for MSY (B_{msy}) was estimated at 1628 tons (CV=0.14). Bootstrap distribution plots for the management quantities are given in Figures 18-20. Plots of the management quantities relative to the MSY level are shown in Figures 21. Fishing mortality rate was below the MSY level from 1959 to 1979. Over fishing began in 1980 and reached critical levels in 1991. Recent estimates have moderated and are below the over fishing level. Stock biomass was above that needed for MSY through 1986 but declined to less than 1/2 B_{msy} by 1995. The recent increase in biomass has raised the stock close to B_{msy}.

Model process and input data residuals are plotted in Figures 22-35. Process errors exhibited no long-term trend but tended to form blocks of 3-4 years with the same sign (Figure 22). Significant (P<0.05) negative autocorrelation occurred at a lag of 10-11 years. This may relate to the inability of the logistic model with constant r to account for mid frequency variations in stock productivity or availability. Measurement errors for the long-term URIGSO survey showed a similar blocking pattern (Figure 23). Model fit and

residuals for the RIDFW seasonal trawl index are found in Figures 24-25. The survey displays high variability in early years including a large negative residual in 1981 and a large positive in 1991. As noted earlier, the seasonal survey, which is conducted in April and May, may be mismatched in space and time with the migratory movements of tautog. Summer trawl trends and residuals are given in Figures 26-27. The pattern is smoother although the 2002 datum is suspiciously low. The MRFSS index is also noisy; particularly in early years before state add-on programs increased sampling intensity (Figure 28). Residuals shift from positive to negative as this CPUE index has not kept pace with increases in the fishery independent surveys (Figure 29). Refinement of the effort series to include only tautog trips may improve this index. The utilities index of tautog in Mt. Hope Bay clearly shows the great resource decline and subsequent recovery that has occurred (Figure 30). Residuals however trend from negative to positive indicating that the index overstates the bay wide increase in biomass (Figure 31). Recruitment indices of YOY tautog for Narragansett Bay and the coastal salt ponds both show improved recruitment after the failed 1994-1995 year classes (Figures 32 and 33). Residual patterns for both surveys indicate that YOY production in recent years has increased faster than can be explained by stock biomass alone (Figures 34 and 35). Considering the relationship between stock biomass and YOY production, 500 tons may be a critical stock level below which juvenile production is impaired (Figures 36 and 37). Larger stock sizes on the order of 1,000 tons may be needed for good YOY recruitment.

Prior year estimates of F and B were quite stable relative to changes in terminal year of data. F and B in years 1998 and 1999 differed by only a few percent when estimating them with terminal data ranging from 2000-2004. No retrospective patterns were evident. This stability is likely due to the inclusion of auxiliary F estimates in the objective function, which constrains the solution surface and the highly informative nature of the URIGSO index.

Projection results indicated that if fishing mortality rate remains at the mean 2001-2003 level (F=0.13), stock biomass would reach B_{msy} in 1-4 years (Figure 38). Continued stock growth beyond B_{msy} is possible with the stock reaching 1,800-3,000 tons by 2013. Table 4 summarizes projection results and future quotas for the commercial and recreational fishery assuming that the commercial fishery is allowed a long-term average catch share of 25%. With continued stock growth under status quo F, overall quotas would increase by 71% by 2013. It should be noted however that in 2003, F was above the 2001-2003 average F and that the recreational share of landings approached 90%. This occurred because recreational landings increased by 81% from 2002 to 2003 while commercial landings only grew by 9%. Regulatory adjustments may be needed to control growth of the recreational fishery.

Discussion

Long term abundance and landings data were used to assess the Rhode Island tautog stock. Abundance indices generally show a long-term decline to a historic low point in the mid-1990s. Most indices have shown significant increases since then. Estimates of mortality rates from tagging studies, age composition, and length frequency analyses generally show a rise in mortality over time followed by a moderation in recent years. A biomass dynamic model showed that tautog abundance was stable from 1959 to 1978. Increasing recreational fishing pressure followed by an order of magnitude increase in commercial landings preceded a stock collapse to historic low levels in 1994-1995. Recruitment of YOY tautog failed during the 1994-1995 period of low stock biomass. Fishing mortality rates regularly exceeded $F_{msy}=0.28$ from 1980 to 1997. Critical levels were reached in the early 1990s with F three times the MSY level and six times the natural mortality rate. With aggressive management, F has declined in recent years. Following implementation of increased minimum sizes, commercial quotas, and reduced recreational bag limits, F has declined to below the over fishing definition. The bootstrap results indicate that there is a 95% probability that F in 2003 was below the ASMFC 0.29 target mortality rate. A strong

increase in stock biomass to 1,448 tons has followed declining F. Recruitment of YOY tautog has improved with the increase in stock size. Biomass still remains below the 1,628 tons needed to produce MSY so further stock rebuilding is needed. Projection results indicate that B_{msy} can be reached in 1-4 years if fishing mortality rate is capped at current levels. The phase plot for F rate and stock biomass is found in Figure 39. A control rule policy that maintains F=0.2< F_{msy} when biomass exceeds 1,000 tons, should provide for continued stock growth to B_{msy}. If stock biomass falls below 1,000 tons and approaches the critical level, F should be reduced to near zero. Overall quotas can grow substantially if F is maintained at current levels and stock growth continues. Regulatory adjustments may be needed to control expansion of the recreational fishery to maintain F at current levels and provide an equitable share to the commercial sector.

Tautog assessment and management in Rhode Island present several difficult problems. The species may exist in a mosaic of patches in association with coarse substrates. Density on these patches may wax and wane as a result of search and shift behavior by harvesters or depletion of food reserves on the patches. Metapopulation dynamics are considerably more complex than conventional and could render traditional abundance indices unreliable when patch occupancy varies in space and time. It could also bias the age and length composition of the catch relative to the population if some fraction of the stock is unavailable to harvest. Consideration should be given to survey designs and assessment methods developed for reef type fishes in the Florida Keys (Ault et al. 1998). A tagging program was resumed in 2002 and will be useful in providing more auxiliary fishing mortality rates for calibration of assessment models and to estimate movement/dispersion rates between patches. Commercial length sampling is needed to characterize the size composition of the catch.

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Table 1- Abundance Indices and Auxiliary F Rate Estimates Used in RI Tautog BDM Assessment

	/1	/2	/3	/4	/5	/6	/7	/8	/9	/10
Year	URIGSO Annual Trawl	RIDFW Season Trawl	RIDFW Summer Trawl	RI MRFSS CPUE	RIDFW NB Seine	RIDFW CP Seine	Auxiliary F Rates	MRI MHBay Seine	MRI MHBay STD Trawl	MRI MHBay Impingement
1959	3.04						0.05			
1960	1.42						0.05			
1961	2.08									
1962	1.54									
1963	2.88									
1964	1.46									
1965	1.71									
1966	0.85									
1967	0.53									
1968	1.05									
1969	1.48									
1970	2.46									
1971	1.55									
1972	1.22							0.95	0.86	2.10
1973	1.85							0.15	0.78	0.36
1974	1.28							0.35	0.84	0.32
1975	1.88							1.05	1.04	0.46
1976	2.08							0.15	0.99	0.48
1977	0.93							1.50	1.04	3.32
1978	0.56							0.75	1.40	2.97
1979	0.44	2.35		0.38				2.20	0.96	0.50
1980	0.18	1.65		0.90				0.90	0.60	0.92
1981	0.46	0.32		0.38				0.05	0.93	1.15
1982	0.55	0.06		0.26				0.45	1.20	3.73
1983	0.56	0.60		0.41				0.90	0.72	0.31
1984	1.40	1.29		0.92			0.18	1.18	0.62	0.73
1985	0.35	0.56		0.16			0.18	0.63	0.89	0.51
1986	0.23	1.34		0.76	9.72		0.18	0.80	0.07	0.68
1987	0.18	0.91		0.25	9.70			1.40	0.06	1.70
1988	0.09	0.95		0.36	6.90			0.78	0.07	1.17
1989	0.25	0.39		0.24	6.30			0.15	0.06	0.51
1990	0.09	0.19	1.53	0.25	3.80		0.71	0.05	0.06	0.05
1991	0.11	1.33	1.92	0.42	8.90		0.71	0.10	0.03	0.09
1992	0.15	0.15	1.36	0.34	13.00			0.40	0.06	0.10
1993	0.08	0.53	0.59	0.17	6.00		0.62	0.65	0.19	0.34
1994	0.03	0.09	0.99	0.15	1.10	0.10	0.62	0.15	0.02	0.68
1995	0.06	0.14	1.11	0.14	0.80	0.10		0.10	0.02	0.11

Table 1 (continued)

Year	/1 URIGSO Annual Trawl	/2 RIDFW Season Trawl	/3 RIDFW Summer Trawl	/4 RI MRFSS CPUE	/5 RIDFW NB Seine	/6 RIDFW CP Seine	/7 Auxiliary F Rates	/8 MRI MHBay Seine	/9 MRI MHBay STD Trawl	/10 MRI MHBay Impingement
1996	0.11	0.29	0.60	0.12	6.14	0.05		0.15	0.13	0.08
1997	0.12	0.09	1.80	0.13	4.41	0.45	0.35	0.20	0.00	1.06
1998	0.04	0.09	0.50	0.14	2.90	1.20	0.35	1.30	0.11	0.44
1999	0.07	0.33	0.84	0.17	7.62	1.00	0.35	0.85	0.11	0.49
2000	0.18	0.36	1.11	0.08	16.18	1.65		2.96	0.06	0.43
2001	0.18	0.86	2.31	0.08	12.30	1.25		1.15	0.19	0.24
2002	0.16	0.27	0.55	0.14	7.55	0.95		0.85	0.08	1.70
2003	0.19	0.20	2.53	0.21	15.88	1.35		4.12	0.06	0.31
2004	0.16	0.87	3.23	0.13	8.52	0.71				

/1
URIGSO trawl samples 2 stations in west passage every
week of year (104 tows)

/2
RIDFW seasonal trawl samples 42 random stations in Narragansett Bay, RI Sound and
BI Sound each spring and fall (84 tows)

/3
RIDFW summer trawl samples 13 fixed stations in Narragansett
Bay during May-August (52 tows)

/4
MRFSS CPUE index is A+B1+B2 catch divided by RI
state waters fishing trips

/5
RIDFW Narragansett Bay seine survey samples 18 fixed stations in Bay each month
from June through October (90 hauls)

/6
RIDFW CP seine survey samples 18 fixed stations in coastal ponds each
month from May through October (125 hauls)

/7
Auxiliary F rate estimates from tagging studies or
analysis of age structure data

/8
MRI seine survey in Mt. Hope Bay a 300' seine deployed at four fixed stations monthly
from March to October (32 hauls)

/9
MRI Std Trawl Survey in Mt. Hope Bay samples 6 fixed stations
monthly, years 1986-2003 used in model calibration

/10
MRI Impingement index at Brayton Point Station calculated as number
tautog impinged divided by station flow

Note: all 2004 indices are
preliminary

Table 2- RI Tautog Landings Used in Biomass Dynamic Model. Recreational Landings for 1959-1978 are Hind cast Estimates Based on Commercial Landings, Tagging Studies, and Effort Data.

| | | Landings mt | | | | B2 | /2 Mean B2 Wgt | Discards | Adjusted |
| | Commercia | Rec | | | Rec B2 | Loss | | | |
Year	l	A+B1	Total	Frac Rec	No.	Rate	Kgs	MT	Total MT
1959	23.41	15.41	38.82	0.397		0.05	0.20	0.00	38.82
1960	30.86	22.06	52.92	0.417		0.05	0.20	0.00	52.92
1961	23.36	18.18	41.55	0.438		0.05	0.20	0.00	41.55
1962	25.82	21.95	47.77	0.460		0.05	0.20	0.00	47.77
1963	33.73	31.45	65.17	0.482		0.05	0.20	0.00	65.17
1964	28.09	28.84	56.94	0.507		0.05	0.20	0.00	56.94
1965	22.00	25.00	47.00	0.532		0.05	0.20	0.00	47.00
1966	30.09	38.07	68.16	0.559		0.05	0.20	0.00	68.16
1967	12.82	18.18	31.00	0.586		0.05	0.20	0.00	31.00
1968	19.23	30.82	50.05	0.616		0.05	0.20	0.00	50.05
1969	25.32	46.32	71.64	0.647		0.05	0.20	0.00	71.64
1970	23.73	50.17	73.90	0.679		0.05	0.20	0.00	73.90
1971	16.91	41.98	58.89	0.713		0.05	0.20	0.00	58.89
1972	17.05	50.73	67.78	0.749		0.05	0.18	0.00	67.78
1973	14.64	53.74	68.37	0.786		0.05	0.17	0.00	68.37
1974	15.91	75.12	91.03	0.825		0.05	0.21	0.00	91.03
1975	21.23	137.77	159.00	0.866		0.05	0.16	0.00	159.00
1976	34.32	346.21	380.53	0.910		0.05	0.21	0.00	380.53
1977	8.77	187.51	196.29	0.955		0.05	0.18	0.00	196.29
1978	12.32	591.65	603.97	0.980		0.05	0.15	0.00	603.97
1979	15.14	572.70	587.83	0.974		0.05	0.20	0.00	587.83
1980	24.59	1040.88	1065.47	0.977		0.05	0.29	0.00	1065.47
1981	31.73	302.08	333.80	0.905	26806	0.05	0.18	0.25	334.05
1982	39.23	353.61	392.83	0.900	19764	0.05	0.17	0.17	393.00
1983	64.82	279.82	344.63	0.812	46703	0.05	0.23	0.55	345.18
1984	152.14	822.65	974.78	0.844	165325	0.05	0.25	2.10	976.88
1985	183.27	126.08	309.36	0.408	19917	0.05	0.26	0.25	309.61
1986	165.05	928.45	1093.49	0.849	10853	0.05	0.33	0.18	1093.67
1987	191.14	230.65	421.78	0.547	37570	0.05	0.16	0.30	422.08
1988	149.50	278.24	427.74	0.650	82792	0.05	0.12	0.50	428.24
1989	97.64	134.95	232.59	0.580	31818	0.05	0.09	0.15	232.73
1990	95.95	177.08	273.03	0.649	62433	0.05	0.22	0.68	273.71
1991	168.91	457.98	626.88	0.731	105955	0.05	0.24	1.27	628.15
1992	163.53	298.51	462.04	0.646	72471	0.05	0.28	1.02	463.06
1993	91.63	177.15	268.79	0.659	51057	0.05	0.14	0.37	269.15

Table 2 (continued)

Year	Commercial	Landings MT Rec A+B1	Total	Frac Rec	B2 Rec B2 No.	Mean B2 Loss Rate	/2 Discards Wgt Kgs	Adjusted MT	Total MT
1994	59.42	149.39	208.81	0.715	62617	0.05	0.40	1.24	210.05
1995	43.18	107.77	150.95	0.714	61187	0.05	0.56	1.71	152.66
1996	29.46	113.11	142.57	0.793	58022	0.05	0.33	0.96	143.53
1997	18.00	136.87	154.87	0.884	74774	0.05	0.31	1.16	156.03
1998	9.23	143.79	153.02	0.940	91241	0.05	0.27	1.21	154.23
1999	11.86	101.71	113.57	0.896	153317	0.05	0.38	2.89	116.46
2000	19.87	92.55	112.42	0.823	64496	0.05	0.41	1.32	113.74
2001	25.48	75.17	100.66	0.747	74235	0.05	0.61	2.26	102.92
2002	22.73	120.51	143.24	0.841	135381	0.05	0.25	1.69	144.92
2003	24.81	217.88	242.70	0.898	196891	0.05	0.29	2.88	245.58

Table 3- Summary of Biomass Dynamic Model Parameter Estimates and Derived Quantities. Rhode Island Tautog Run.

Parameter or Derived Quantity	SOLVER Estimate	Bootstrap Mean	Bootstrap Std Dev	Coefficient Variation	Lower 95%	Upper 95%
Logistic intrinsic rate of increase (r)	0.460	0.459	0.062	0.135	0.335	0.583
Logistic carrying capacity parameter (K)	3255.0	3367.4	456.9	0.136	2453.6	4281.2
Primary URIGSO trawl survey catchability (q)	0.000370	0.000368	0.000054	0.146	0.000260	0.000475
Fishing mortality rate in 2003	0.187	0.185	0.041	0.224	0.103	0.268
Mean 2001-2003 F rate	0.127	0.126	0.025	0.200	0.076	0.177
Maximum sustainable yield (MSY)	374.3	380.2	19.7	0.052	340.9	419.6
Fishing mortality at MSY	0.281	0.281	0.049	0.173	0.184	0.379
Stock biomass for MSY	1627.5	1683.7	228.4	0.136	1226.8	2140.6
Auxiliary F rate scaling parameter			Fixed at 1.0			
RIDFW Narragansett Bay seine catchability	0.006639	0.006560	0.001080	0.165	0.004400	0.008720
MRFSS recreational cpue catchability	0.000202	0.000199	0.000025	0.123	0.000150	0.000249
RIDFW seasonal trawl catchability	0.000343	0.000340	0.000053	0.155	0.000234	0.000446
RIDFW summer trawl catchability	0.001436	0.001435	0.000278	0.194	0.000879	0.001992
RIDFW coast pond seine catchability	0.000642	0.000645	0.000133	0.206	0.000359	0.000862
MRI Mt Hope Bay index catchability	0.000412	0.000409	0.000063	0.153	0.000284	0.000534
Stock biomass 2004 MT	1448.4	1496.6	274.5	0.183	947.6	2045.5
Mean 2002-2004 stock biomass MT	1370.7	1421.6	226.9	0.160	967.9	1875.4
Projected stock biomass in 2004	1566.8	1618.6	233.6	0.144	1151.5	2085.7
Projected stock biomass in 2005	1747.5	1799.0	238.1	0.132	1322.7	2275.2
Projected stock biomass in 2006	1904.4	1954.8	241.7	0.124	1471.4	2438.1
Projected stock biomass in 2007	2033.1	2082.5	245.7	0.118	1591.1	2574.0
Projected stock biomass in 2008	2133.6	2182.9	251.3	0.115	1680.2	2685.5
Projected stock biomass in 2009	2208.8	2259.1	258.6	0.114	1741.9	2776.3
Projected stock biomass in 2010	2263.1	2315.5	266.9	0.115	1781.7	2849.3
Projected stock biomass in 2011	2301.4	2356.7	275.4	0.117	1805.9	2907.5
Projected stock biomass in 2012	2327.9	2386.4	283.4	0.119	1819.6	2953.2
Projected stock biomass in 2013	2346.0	2407.6	290.5	0.121	1826.6	2988.7

Table 4- Projections of RI Tautog Stock Size and Total Allowable Landings from BDM Model Output

Intrinsic rate (r)	0.46	
Carrying capacity (k)	3252.6	
Commercial share	0.25	
Discard allowance	0.10	

Year	Biomass	Exp Rate	F Rate	TAL MT	Quota MT	Rec Share	Comm Share
2003	1318.9	0.128	0.130	168.5	152	114	38
2004	1510.4	0.128	0.130	193.0	174	130	43
2005	1688.8	0.128	0.130	215.8	194	146	49
2006	1845.7	0.128	0.130	235.8	212	159	53
2007	1976.4	0.128	0.130	252.5	227	170	57
2008	2079.9	0.128	0.130	265.7	239	179	60
2009	2158.4	0.128	0.130	275.8	248	186	62
2010	2215.9	0.128	0.130	283.1	255	191	64
2011	2257.0	0.128	0.130	288.4	260	195	65
2012	2285.8	0.128	0.130	292.0	263	197	66
2013	2305.6	0.128	0.130	294.6	265	199	66
Total				2765.2	2488.7	1866.5	622.2

Fig.1- Abundance of Tautog in Rhode Island Waters from the URIGSO Trawl Survey
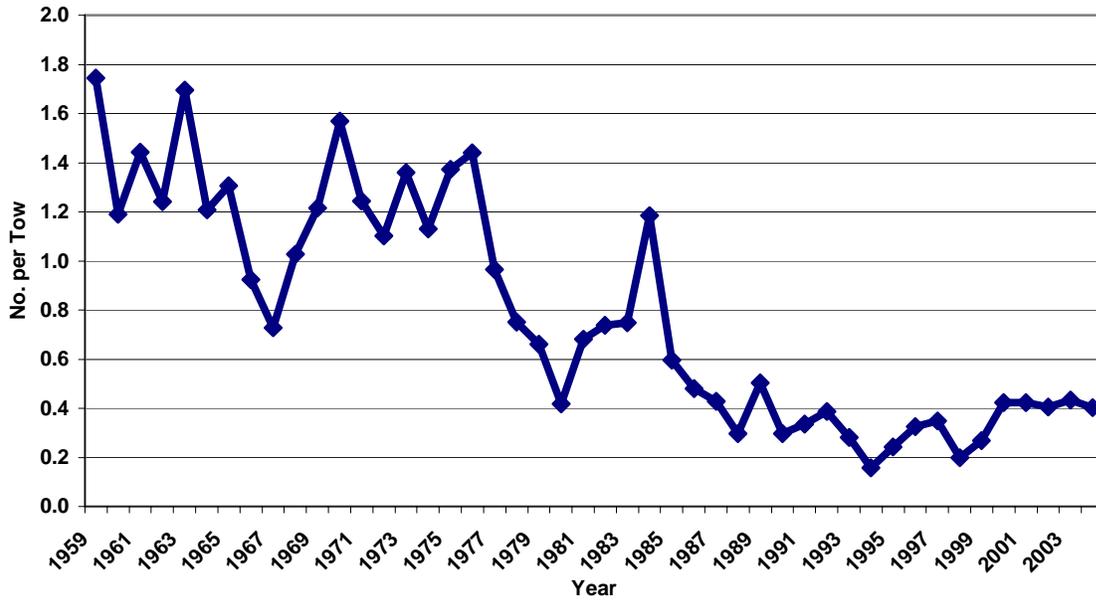
Fig. 2- Abundance of Tautog In Rhode Island Waters From RIDFW Trawl Surveys

Summer Trawl   Seasonal Trawl
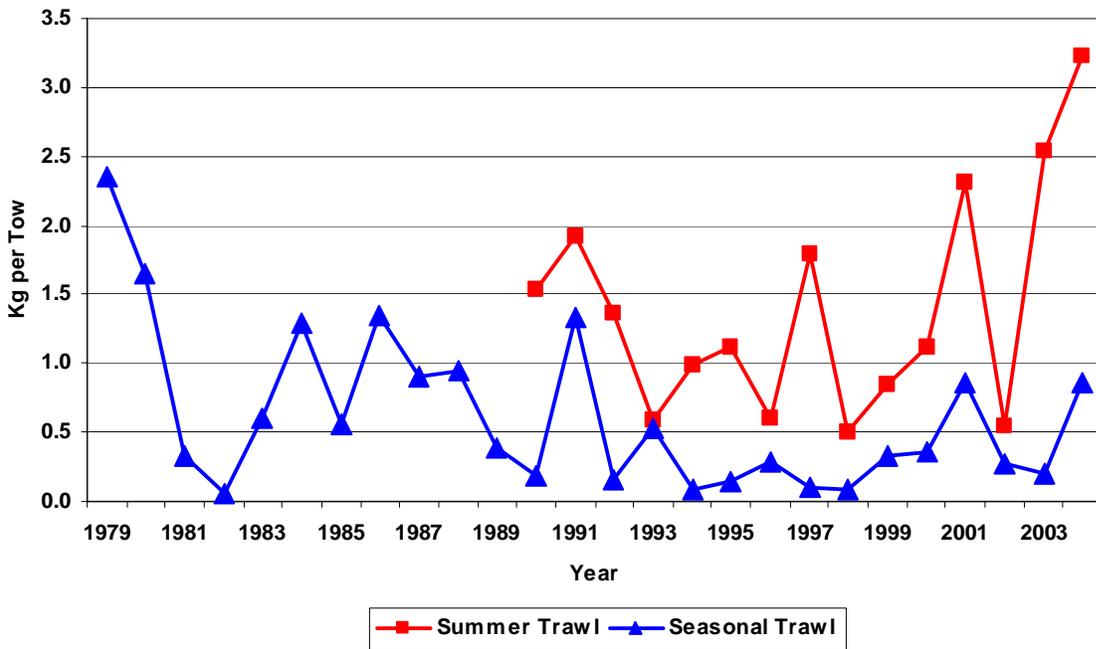
Fig.3- Abundance of Juvenile Tautog in Rhode Island Beach Seine Surveys
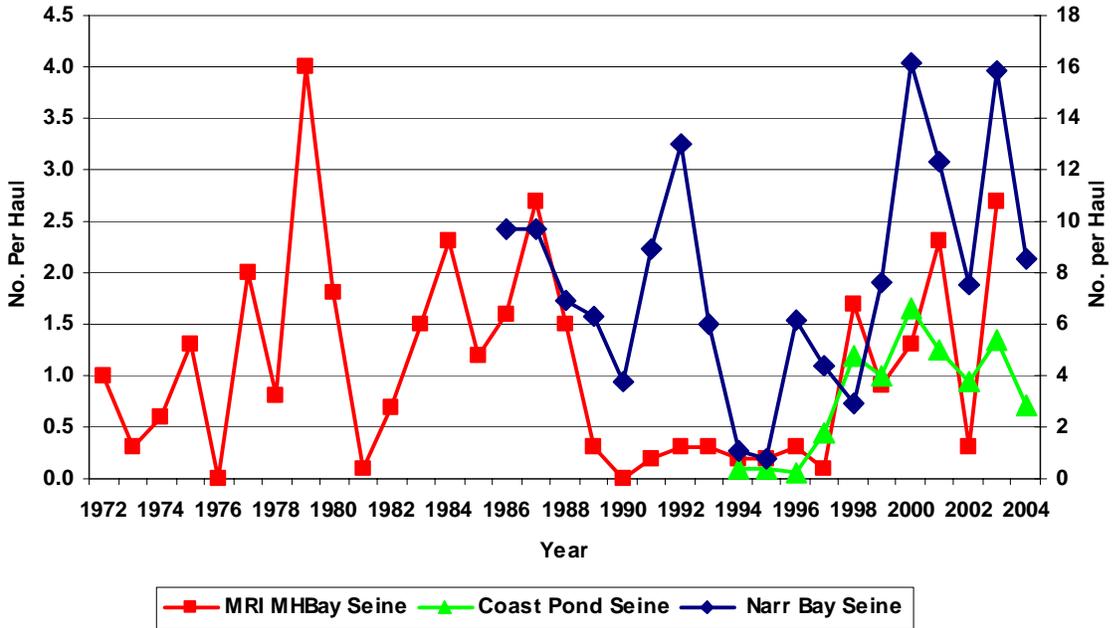
Fig.4- Rhode Island Commercial and Recreational Tautog Landings, 1959-2003
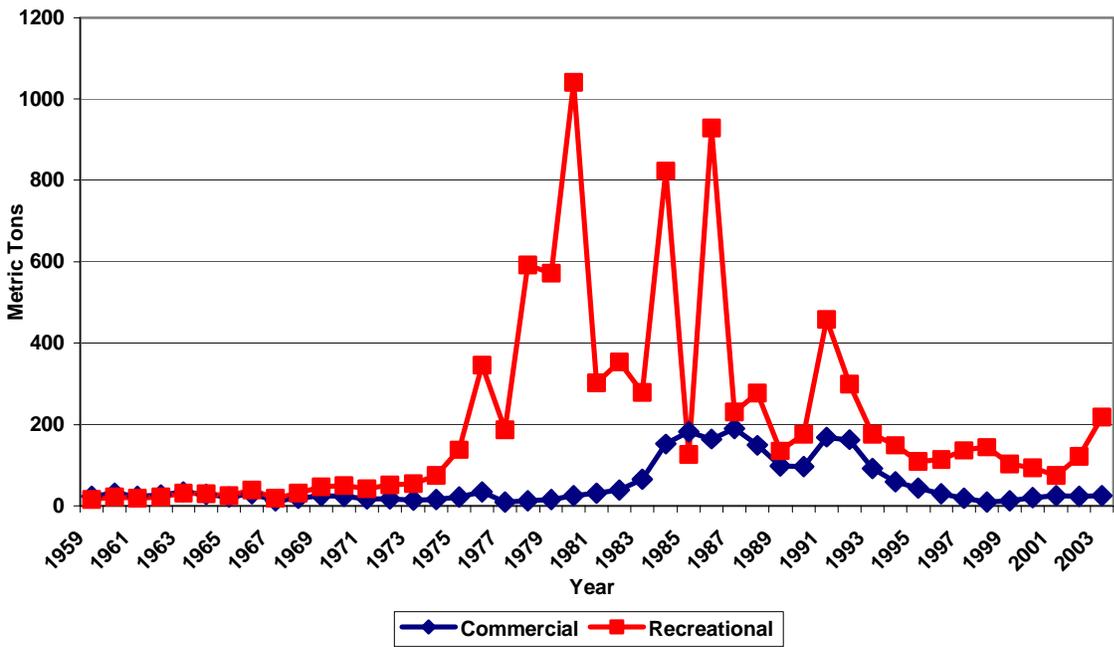
Fig.5- Price per Pound Data for Rhode Island Commercially Caught Tautog
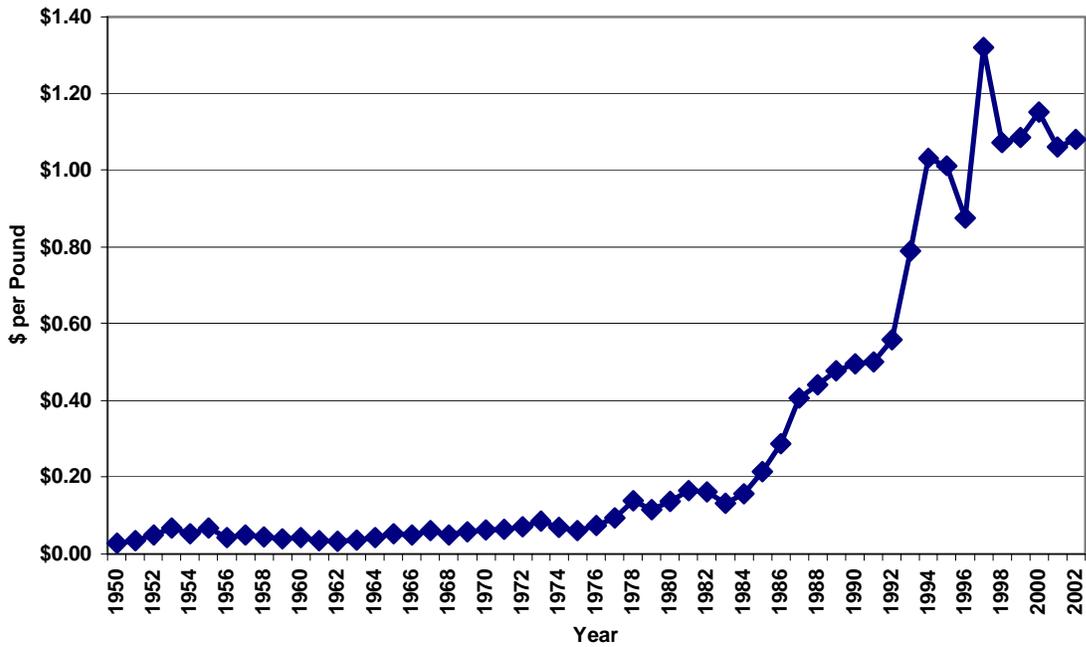
Fig.6- RI Tautog Catch Curve from 1997-2003 RIDFW Age Samples from Recreational Fishery

Z=0.45, r=0.98, P<0.001

◆ Observed ——— Fitted 7-18
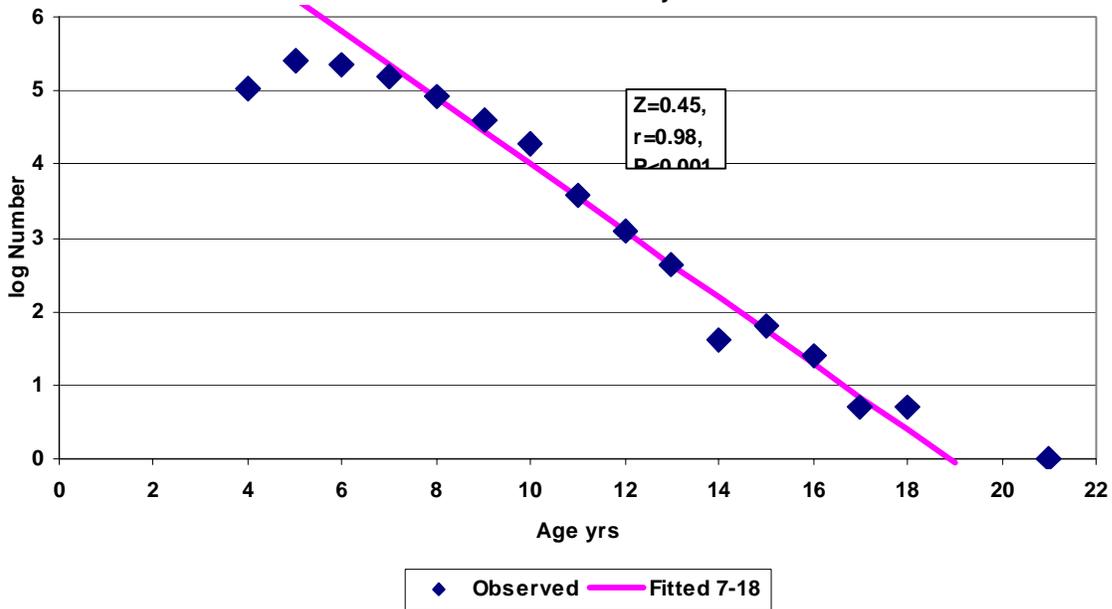
Fig.7- Tautog Length Frequencies in MRFSS Recreational Catch Samples
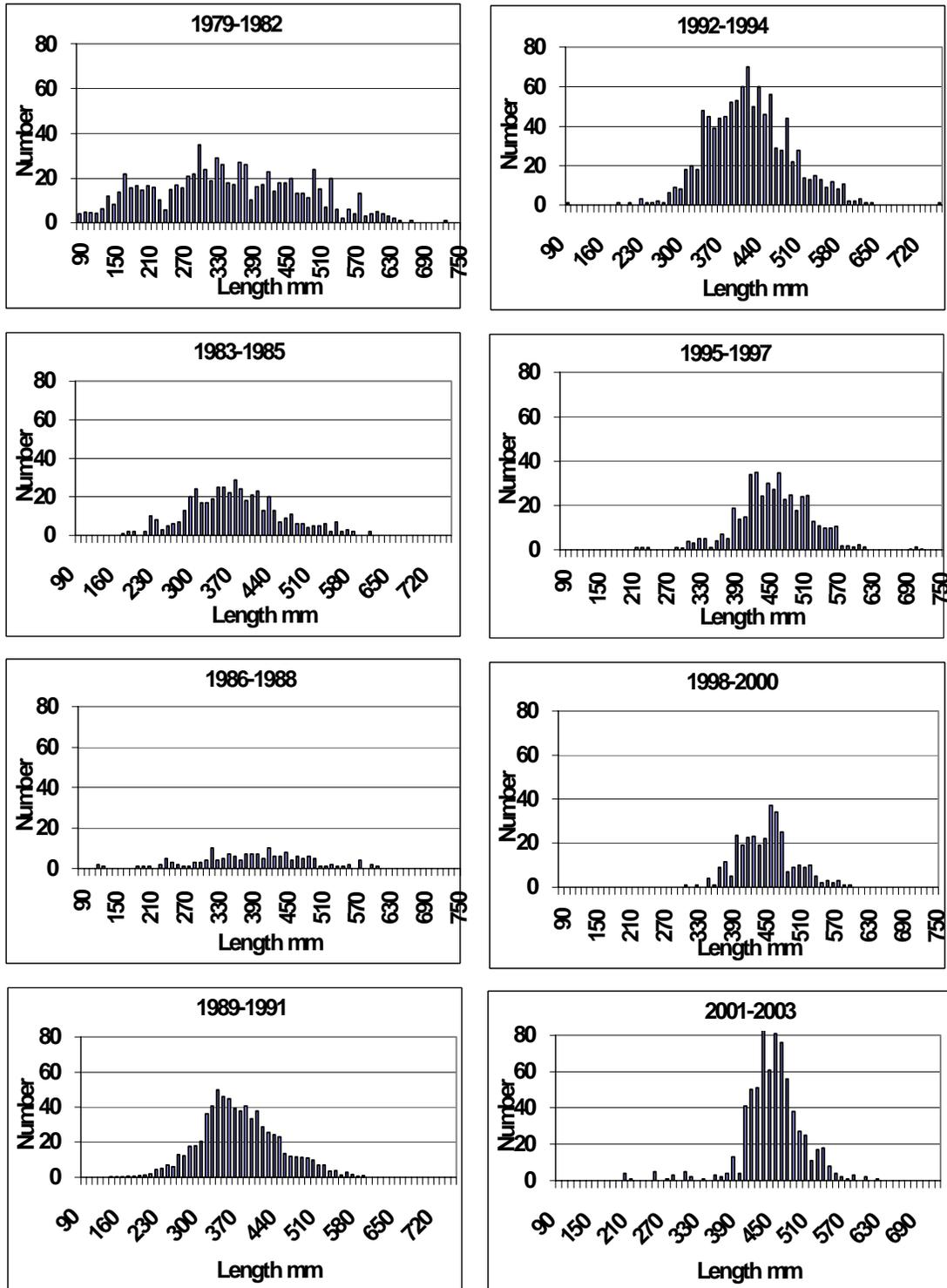
Fig.8- Tautog Length Frequencies in Rhode Island Trawl Surveys
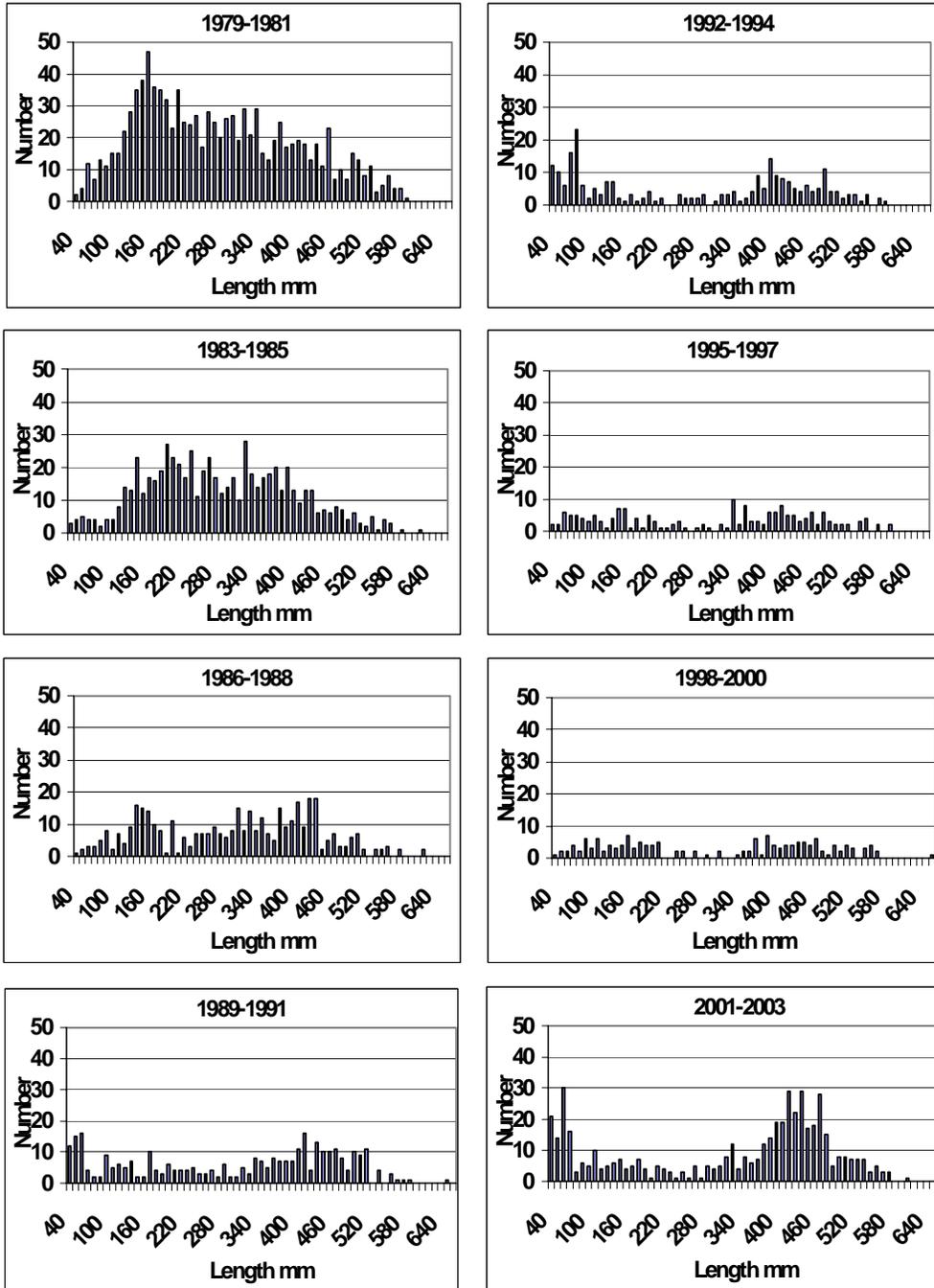
Fig.9- Length Based Estimates of Mortality Rate for RI Tautog from Recreational Fishery and Trawl Survey Samples
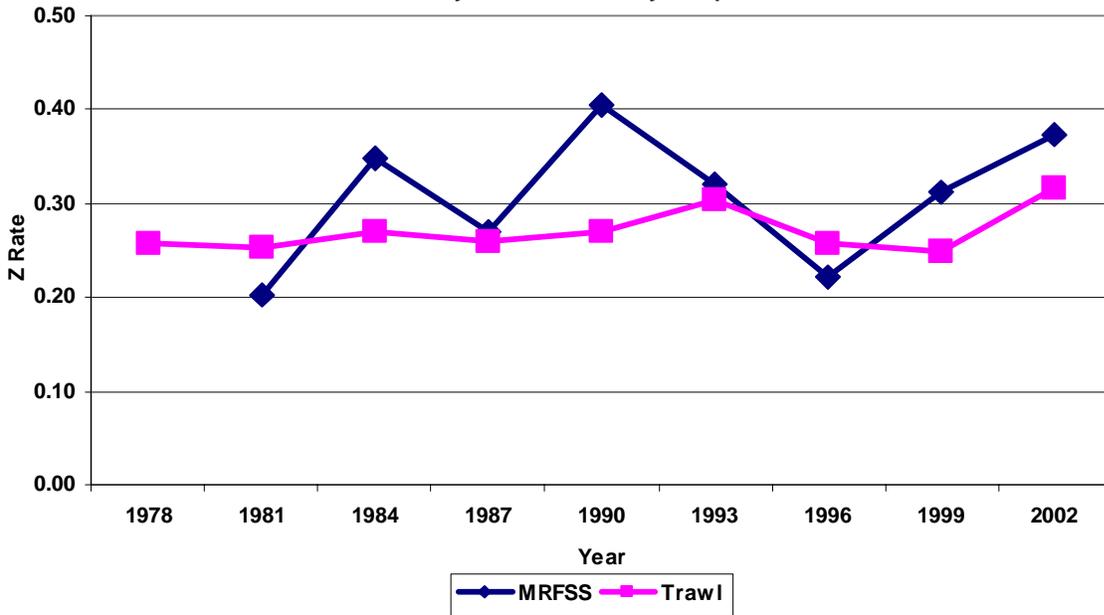
Fig.10- Observed and Model Estimated URIGSO Tautog Trawl Index

99
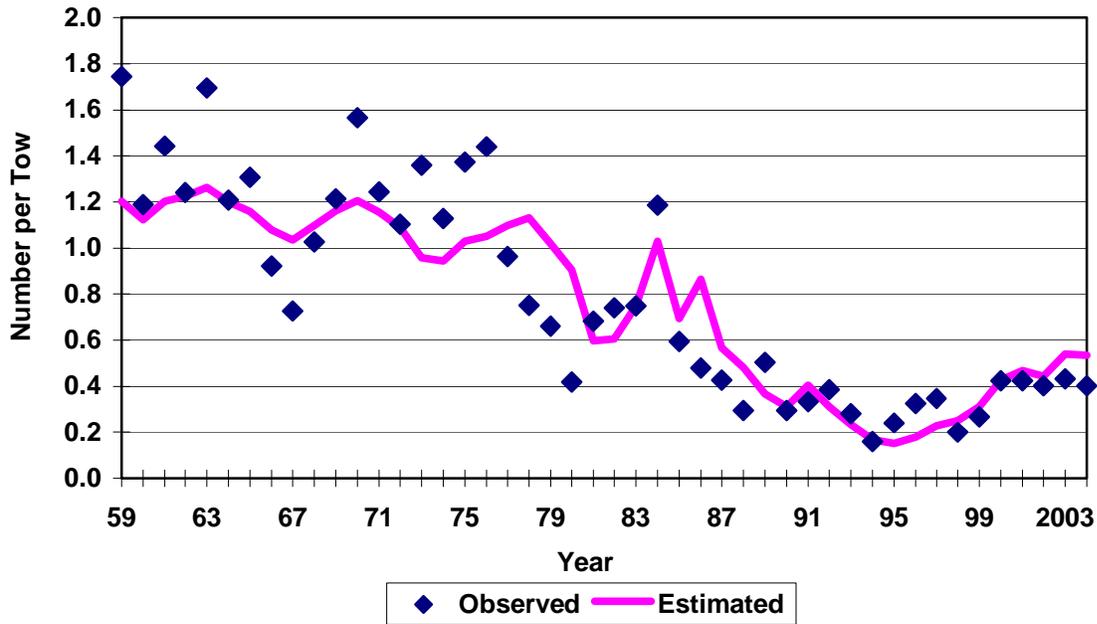
Fig.11- Rhode Island Tautog Stock Production vs. Stock Biomass

Fig.12- RI Tautog Landings and Estimated Stock Biomass Compared to B_{msy}
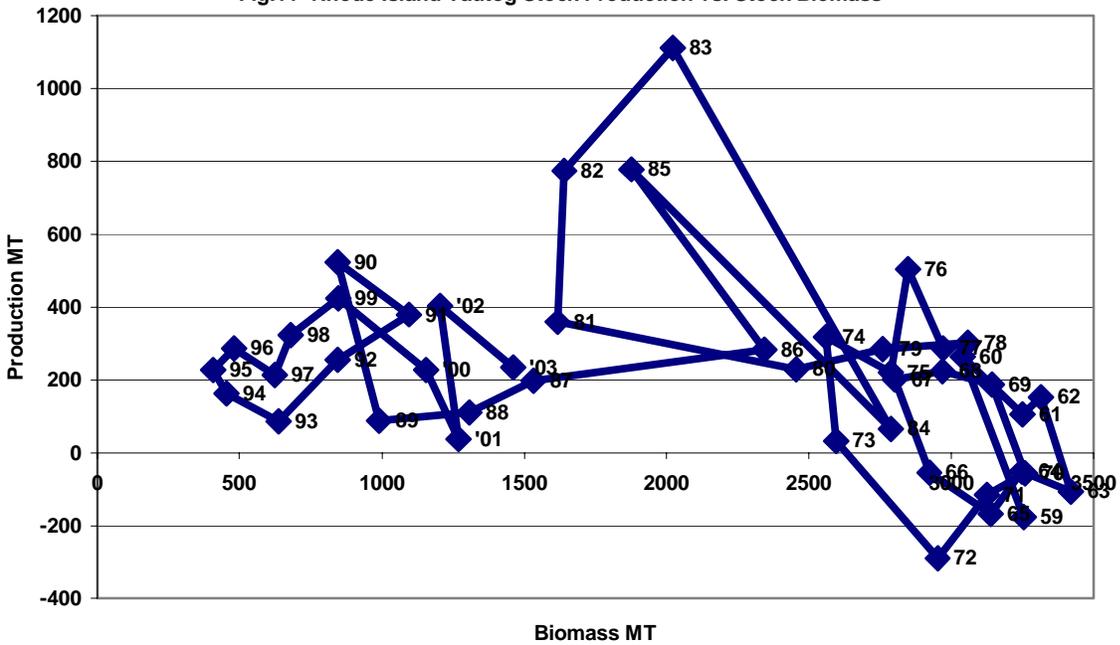
Fig.13 - Bootstrap Distribution for 2004 RI Tautog Stock Size
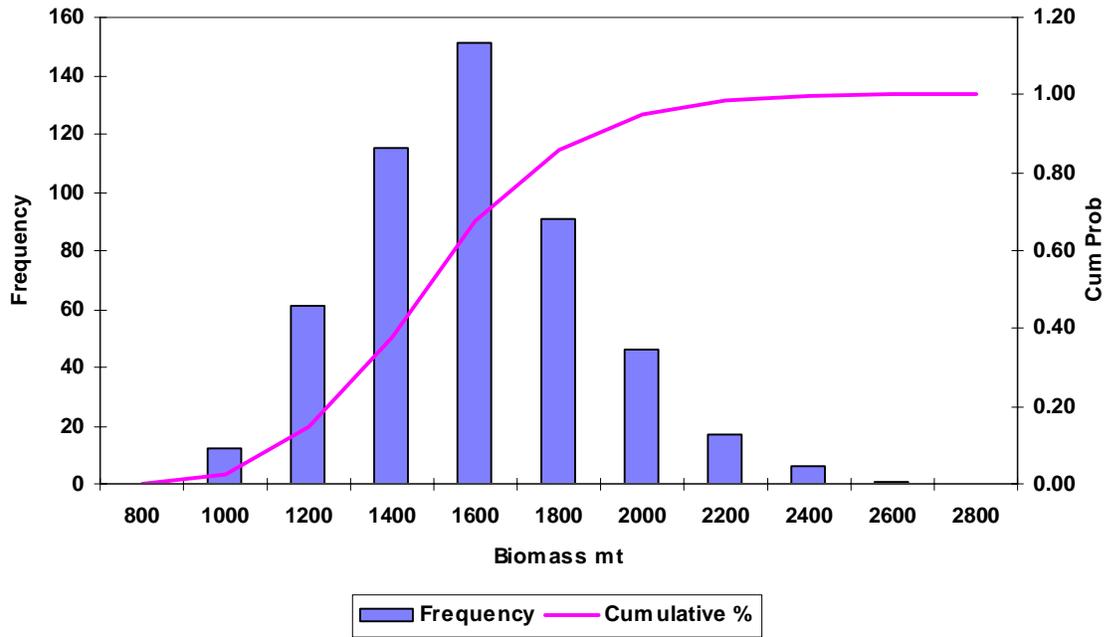
Fig.14 - Bootstrap Distribution for Mean 2002-2004 RI Tautog Stock Size

101
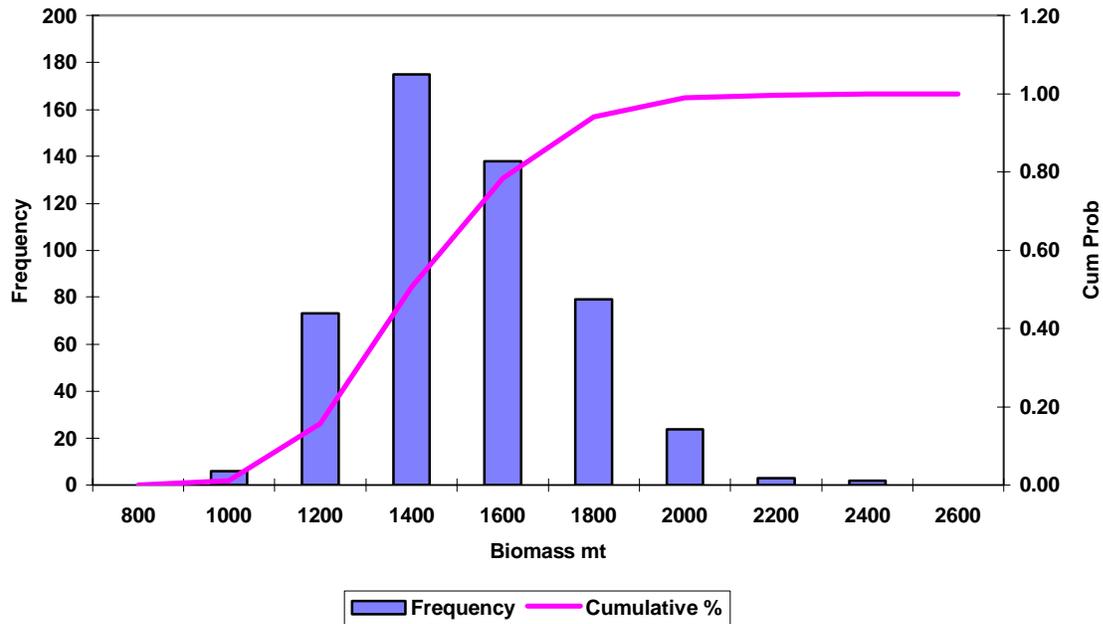
Fig.15- Rhode Island Tautog Estimated Fishing Mortality Rate Compared to F$_{msy}$

Legend: Annual F — Fmsy — Auxiliary F
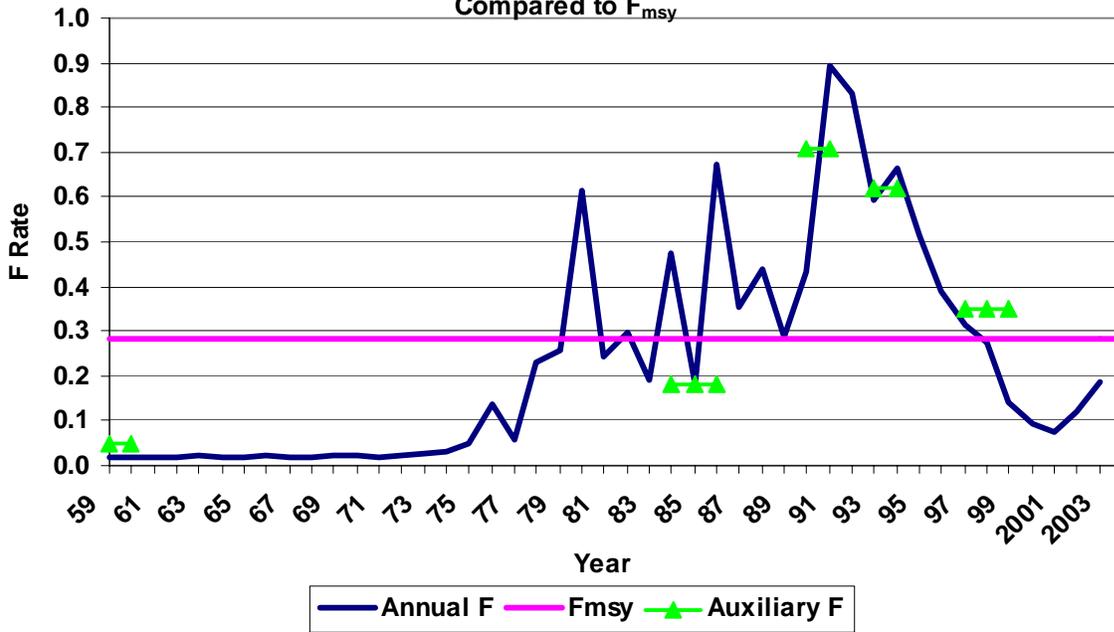
Fig.16- Bootstrap Distribution for RI Tautog 2003 F Rate

Legend: Frequency — Cumulative %
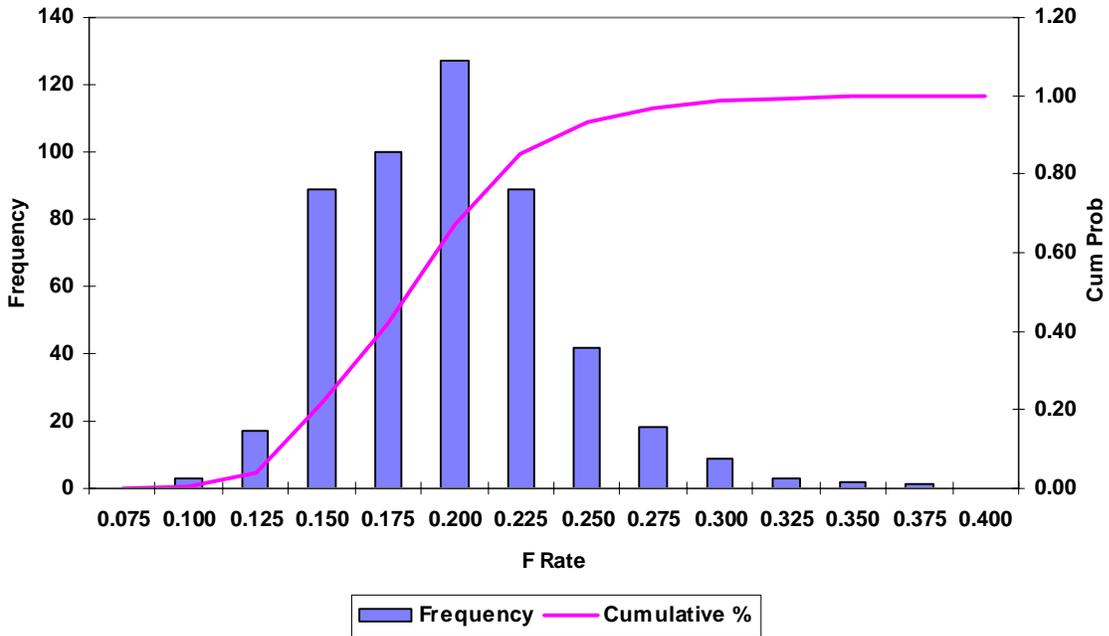
Fig.17- Bootstrap Distribution for RI Tautog Mean 2001-2003 F Rate
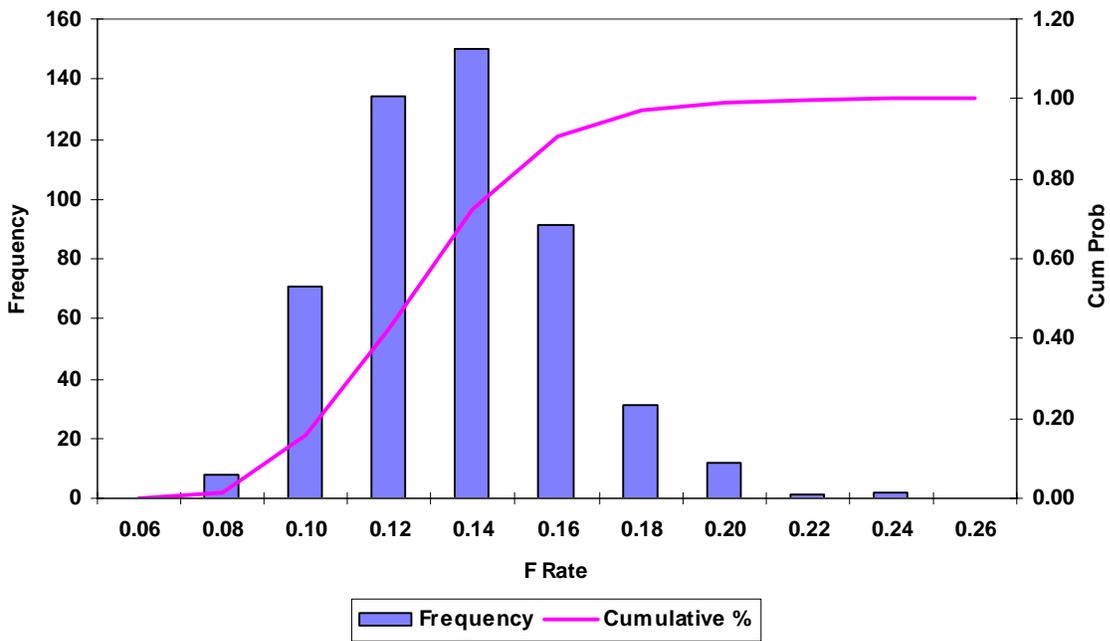
Fig.18- Bootstrap Distribution for RI Tautog Fmsy
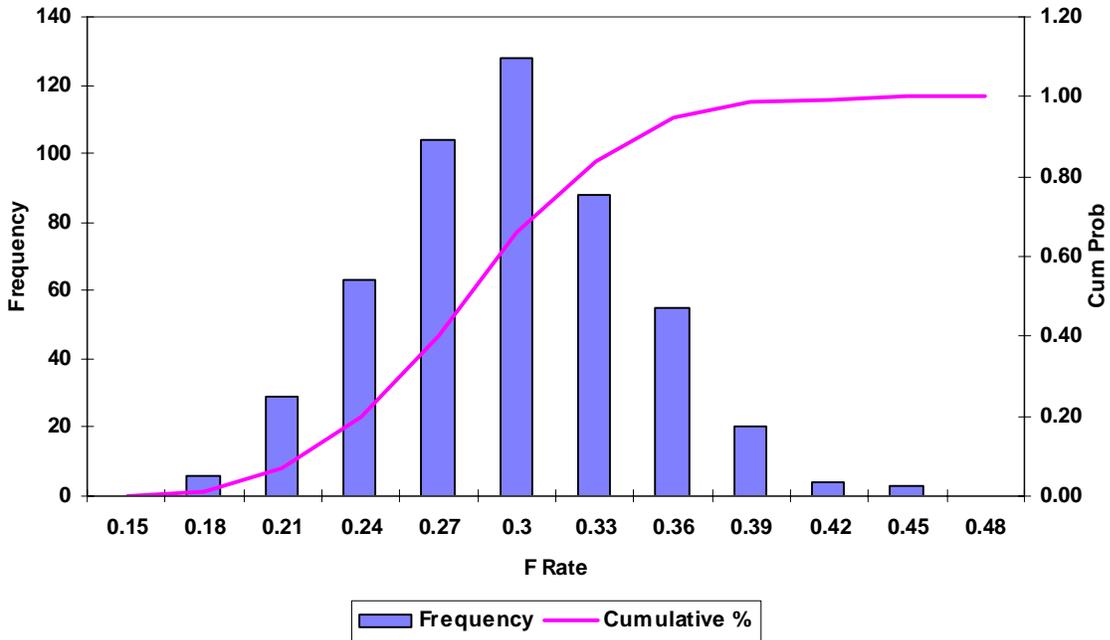
Fig.19- Bootstrap Distribution for Tautog Biomass at MSY
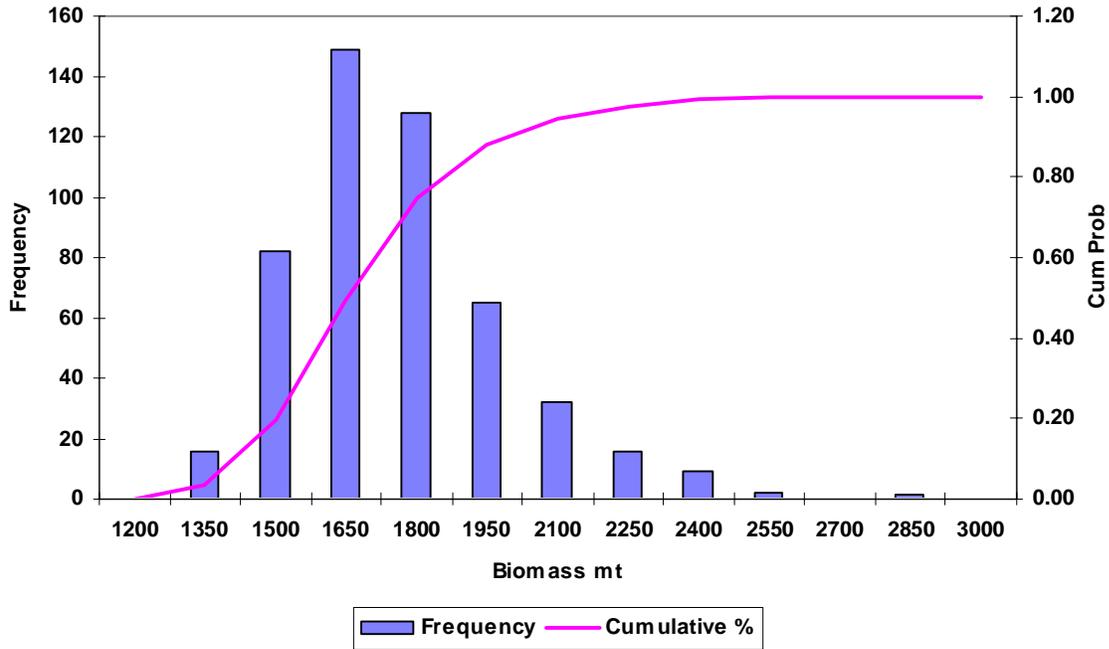
Fig.20- Bootstrap Distribution for Tautog Maximum Sustainable Yield

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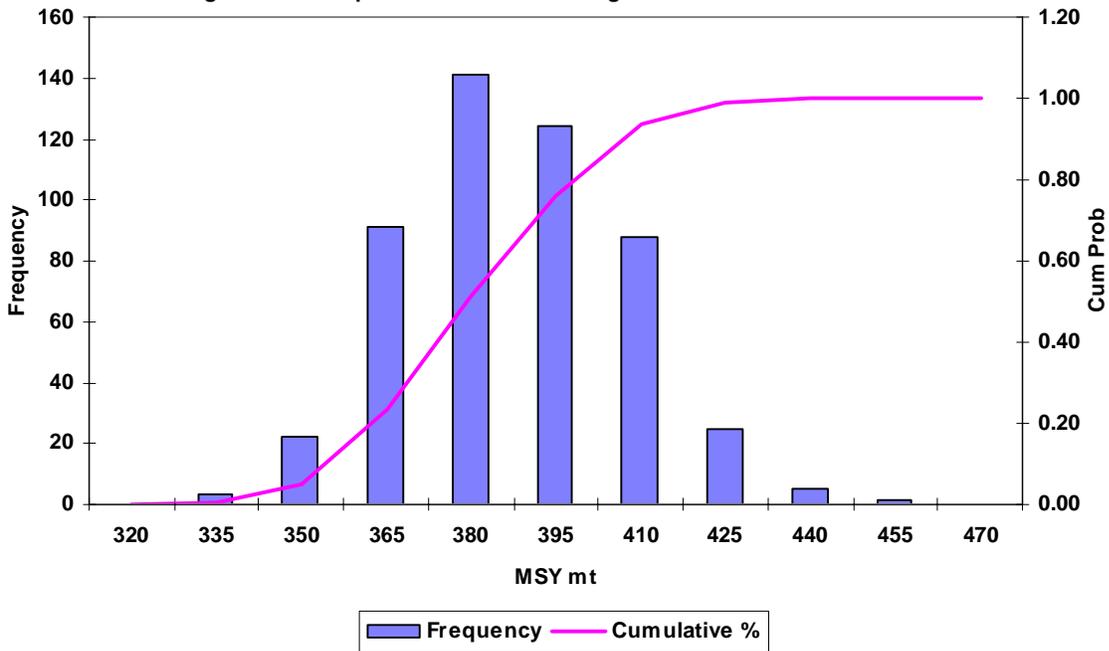
Fig.21- RI Tautog Stock Biomass and Fishing Mortality Rate Relative to MSY Levels
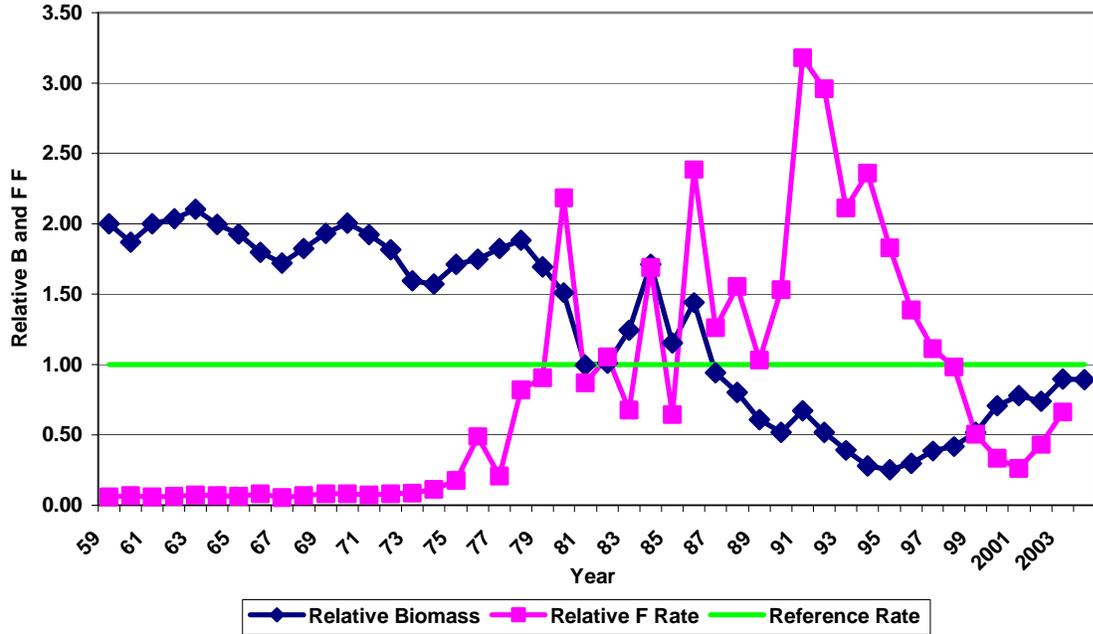
Fig.22- RI Tautog Biomass Dynamic Model Process Errors
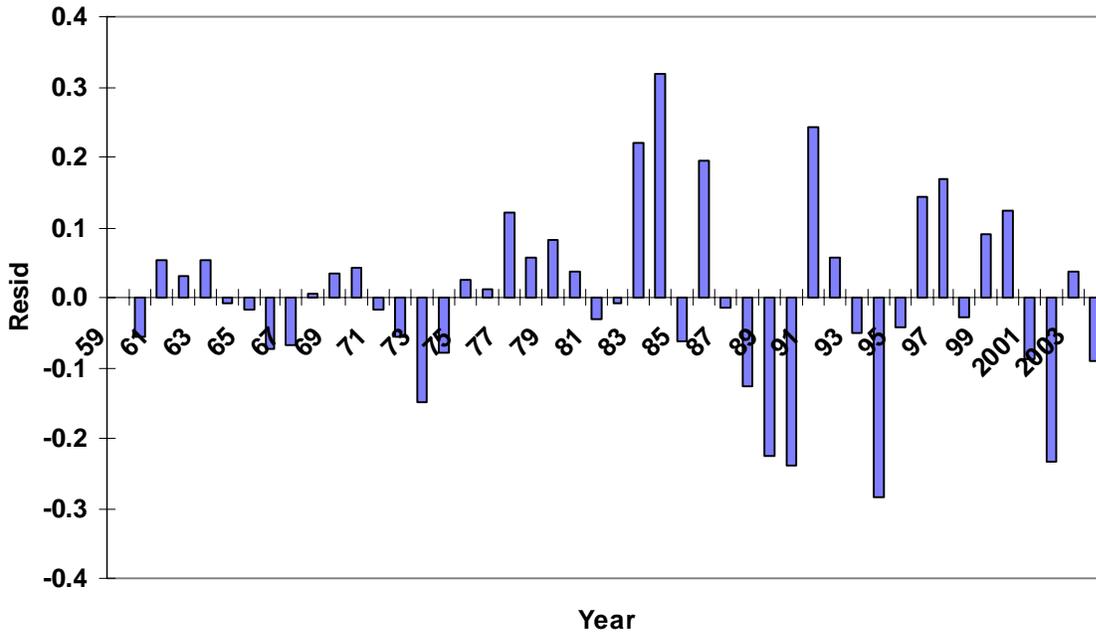
Fig.23- RI Tautog Biomass Dynamic Model URIGSO Index Measurement Errors
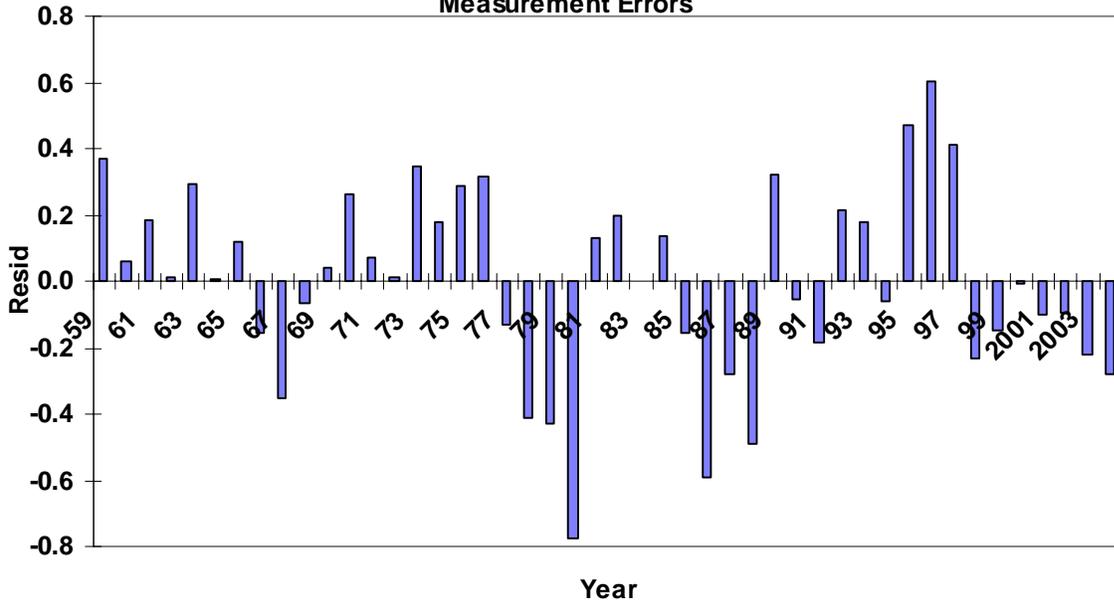
Fig.24- Observed and Model Estimated RIDFW Seasonal Trawl Index for Tautog
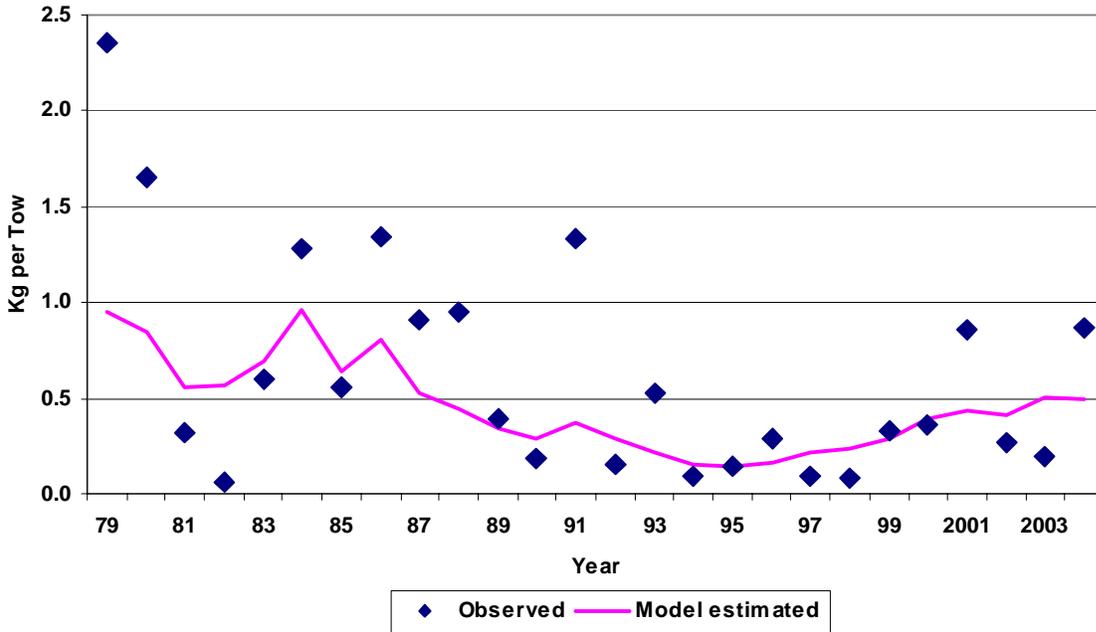
Fig.25- RIDFW Seasonal Tautog Trawl Index Residuals
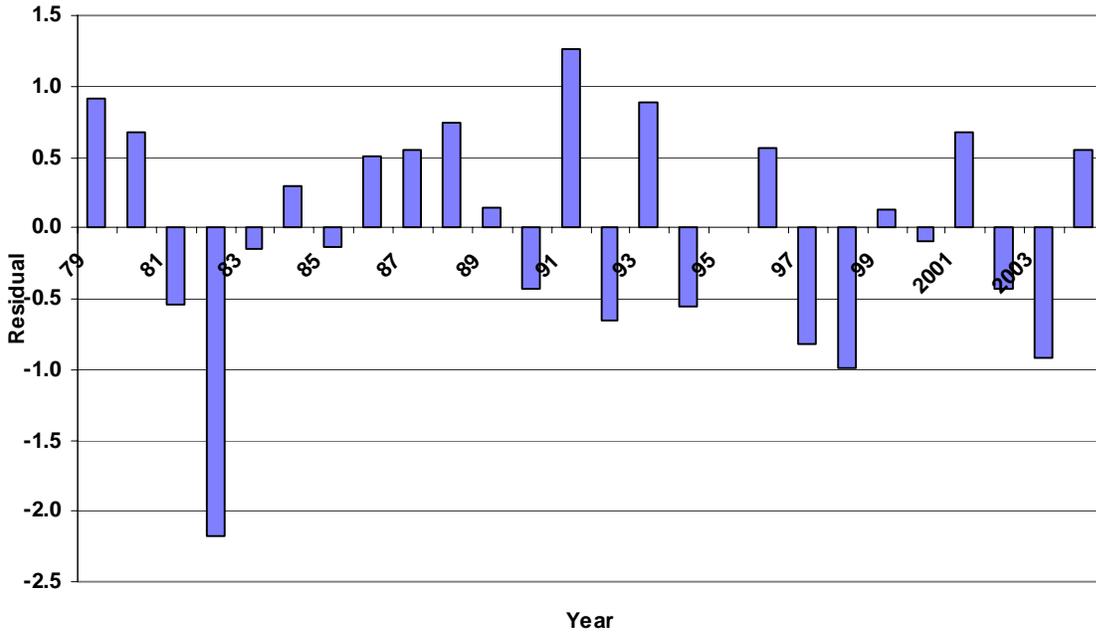
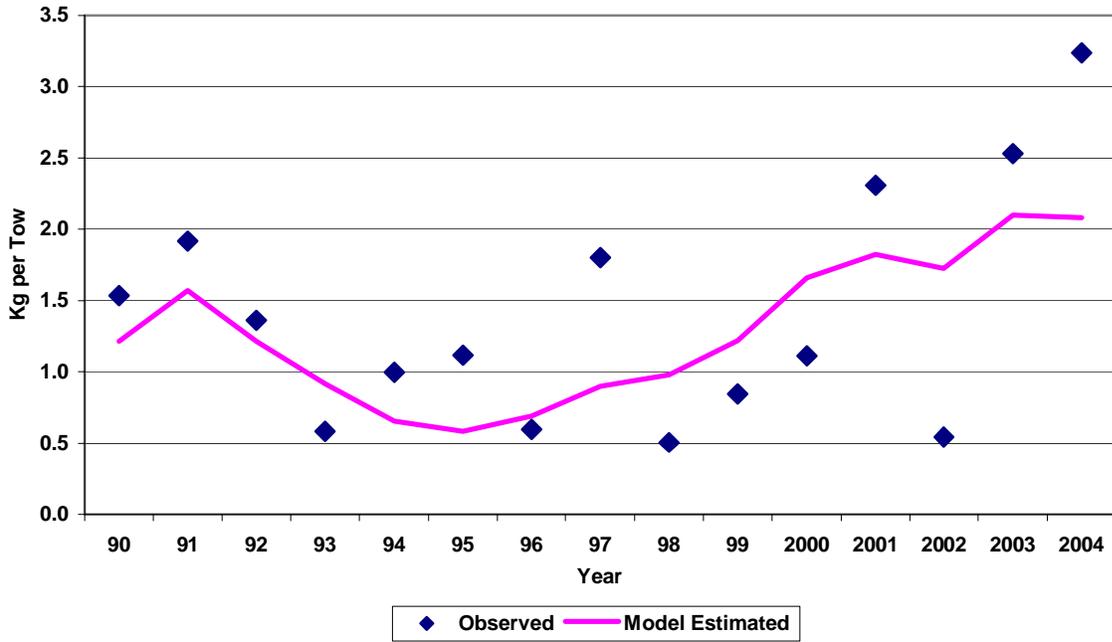Fig.26- Observed and Model Estimated RIDFW Summer Trawl Index for Tautog

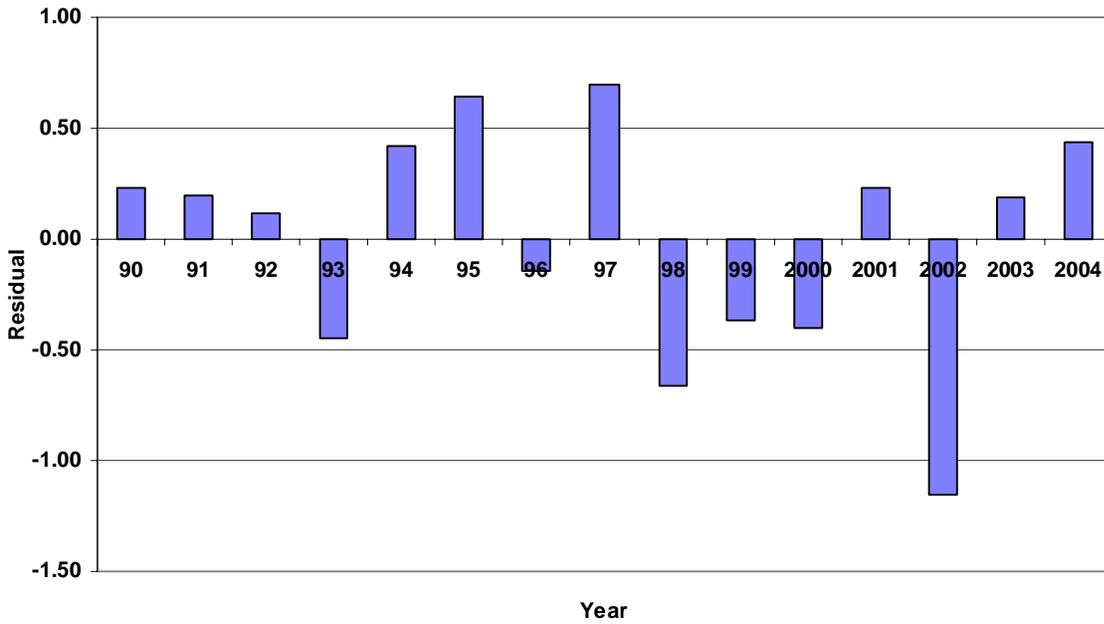Fig.27- RIDFW Summer Tautog Trawl Index Residuals

108

Fig.28- Observed and Model Estimated Recreational CPUE Index for Tautog
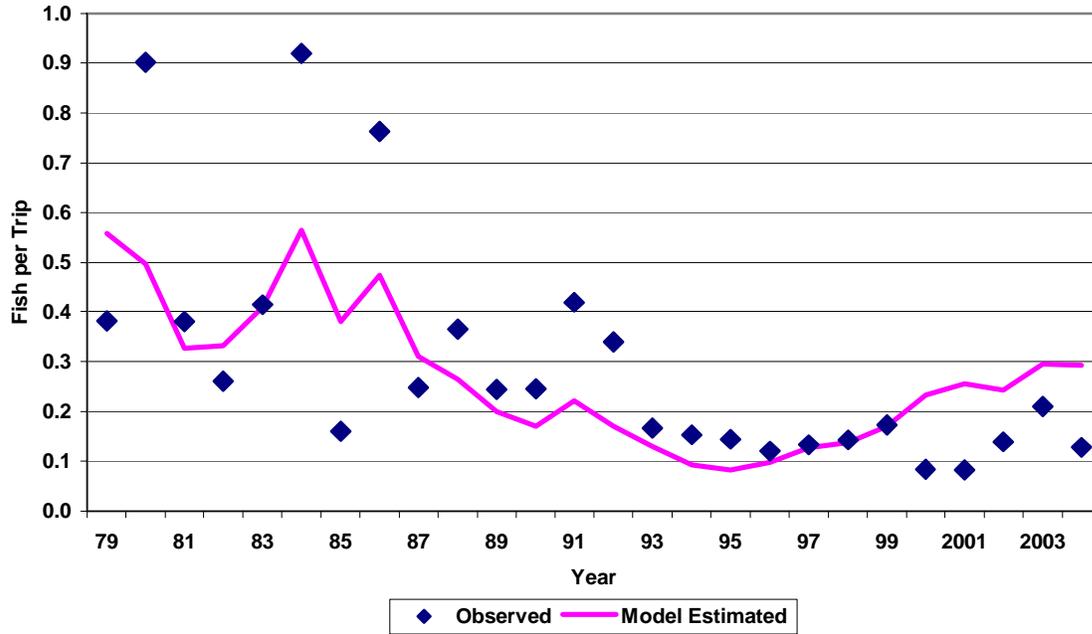

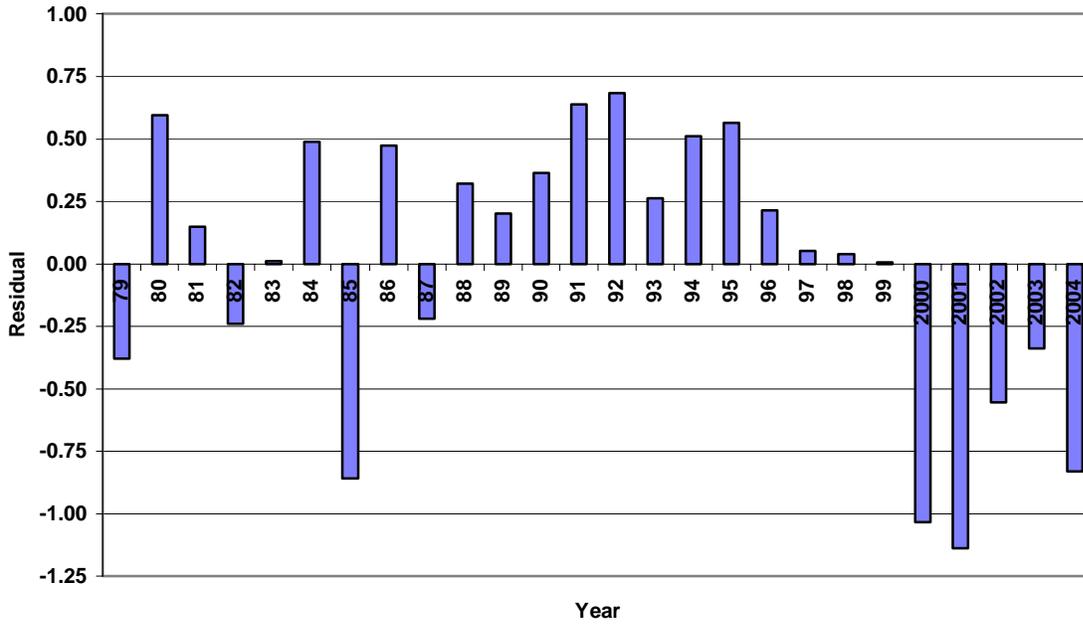**Fig.29- RI Tautog Recreational CPUE Index Residuals**

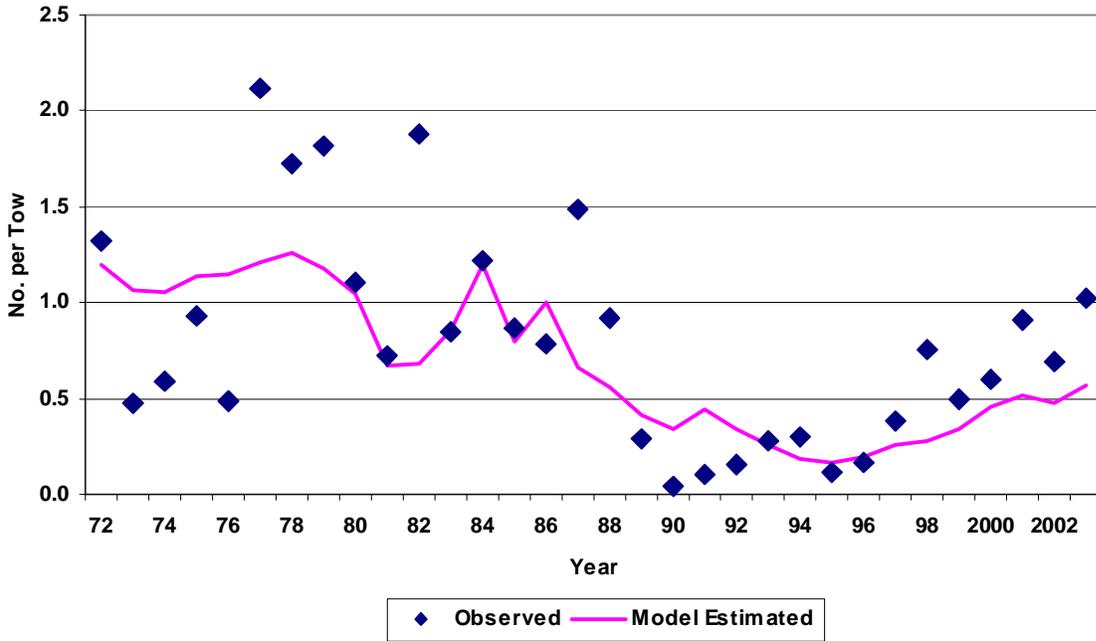Fig.30- Observed and Model Estimated MRI Mt. Hope Bay Tautog Index

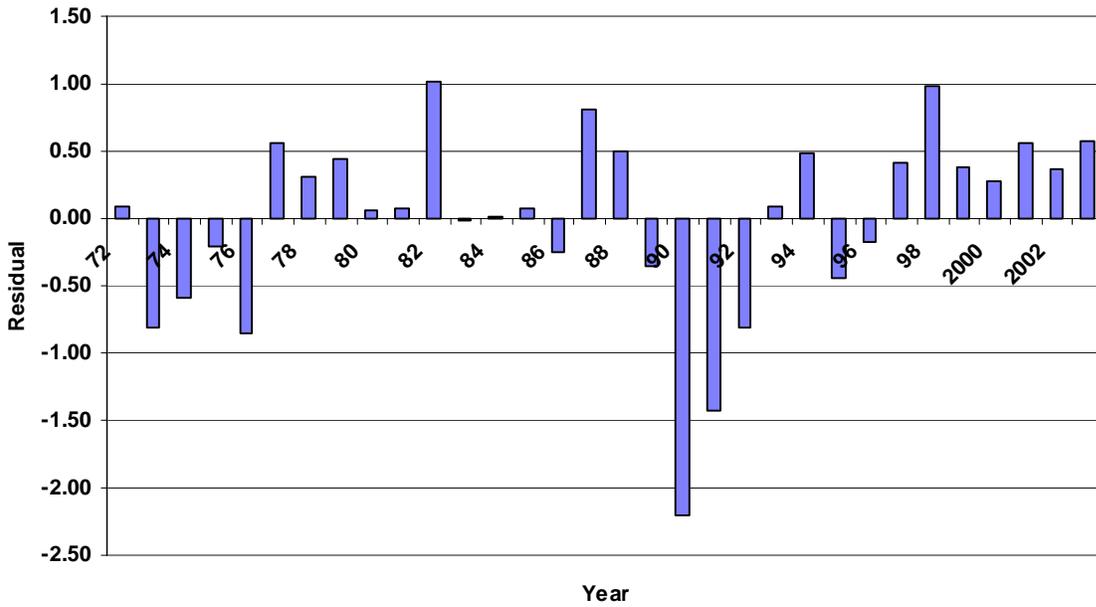Fig.31- MRI Mt. Hope Bay Tautog Index Residuals

Fig.32- Observed and Model Estimated Narragansett Bay Tautog YOY Index
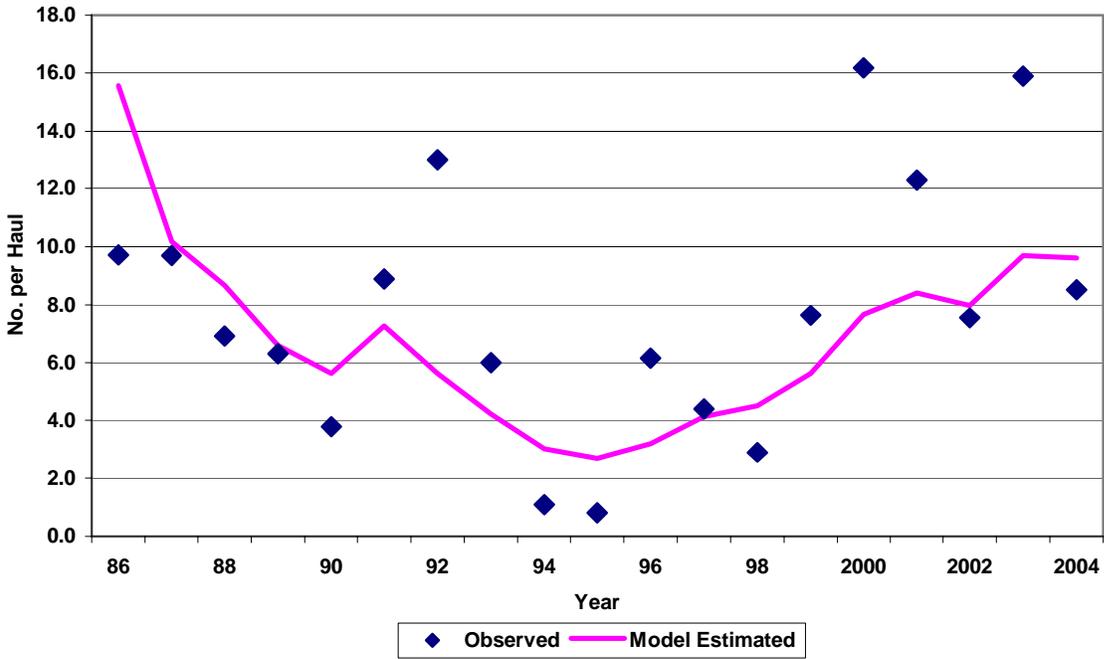

Fig.33- Observed and Model Estimated Coastal Pond Tautog YOY Index

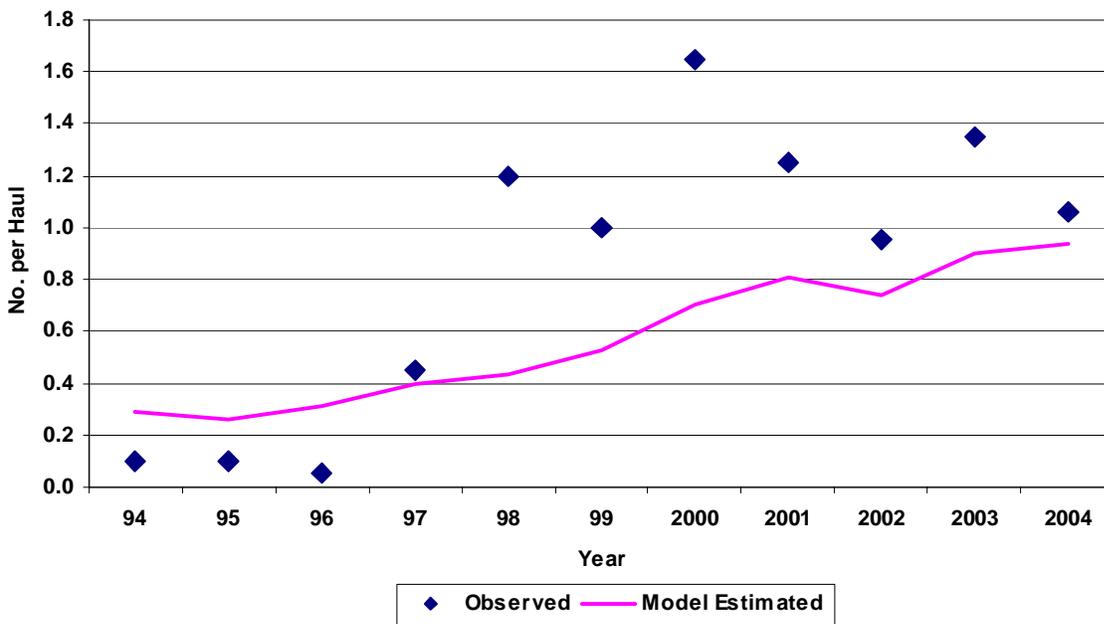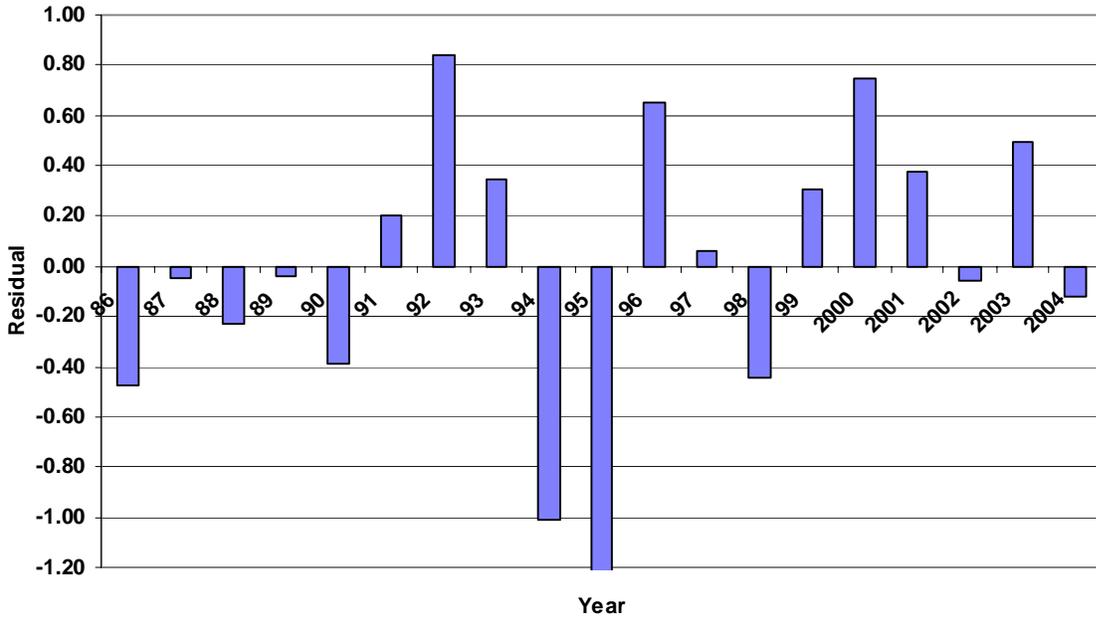Fig.34- Narragansett Bay Tautog YOY Index Residuals

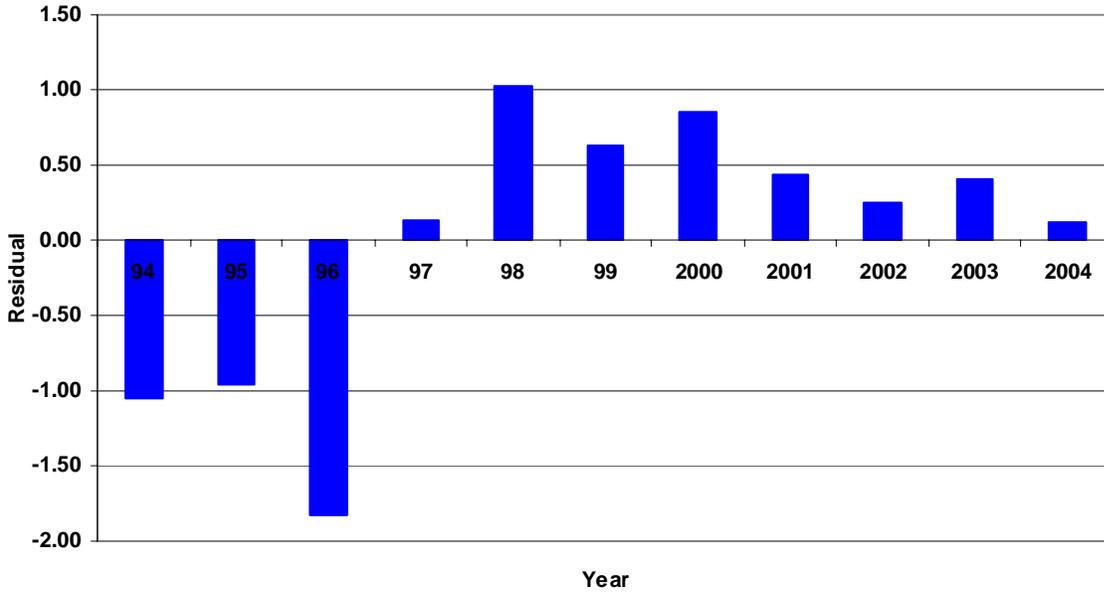Fig.35- Coastal Pond Tautog YOY Index Residuals

Fig.36- RI Tautog Stock and Recruitment Using Bay Seine Index
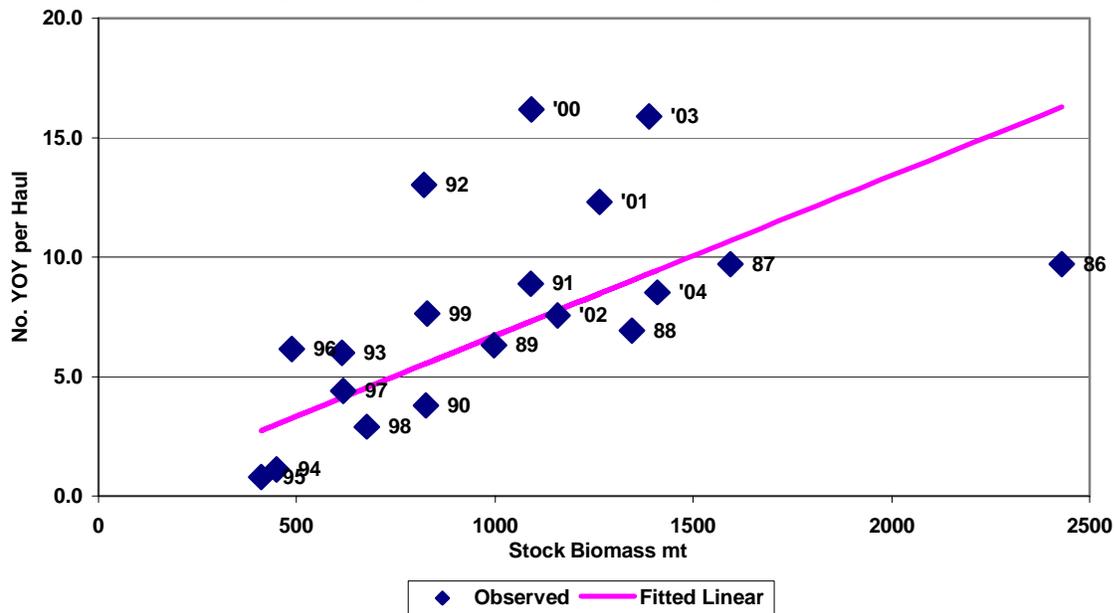

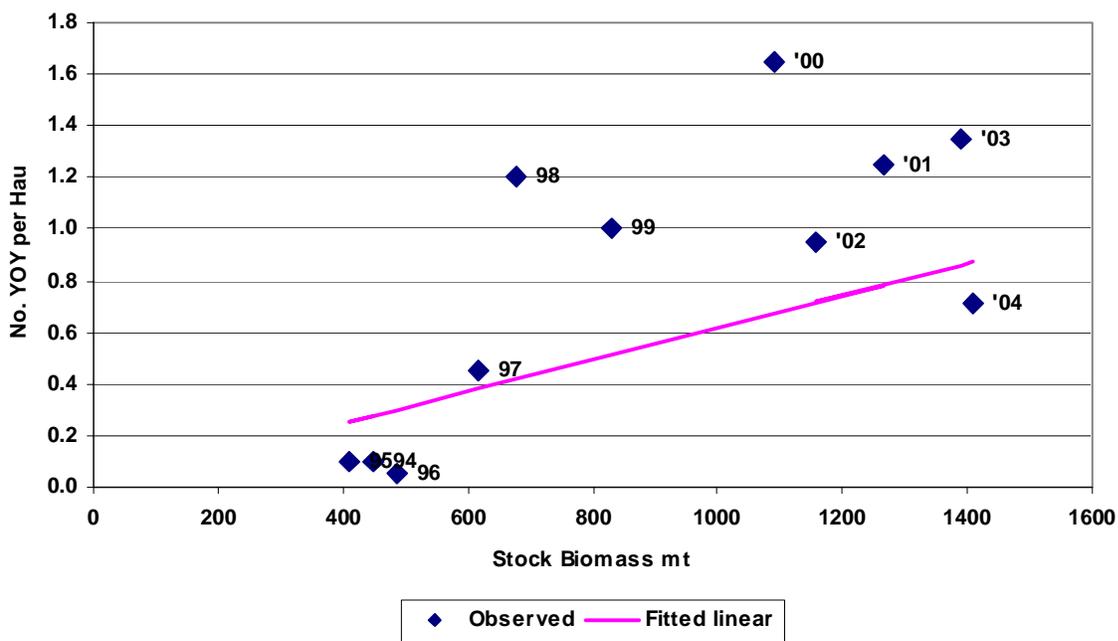Fig.37- RI Tautog Stock and Recruitment Using Coastal Pond Seine Index

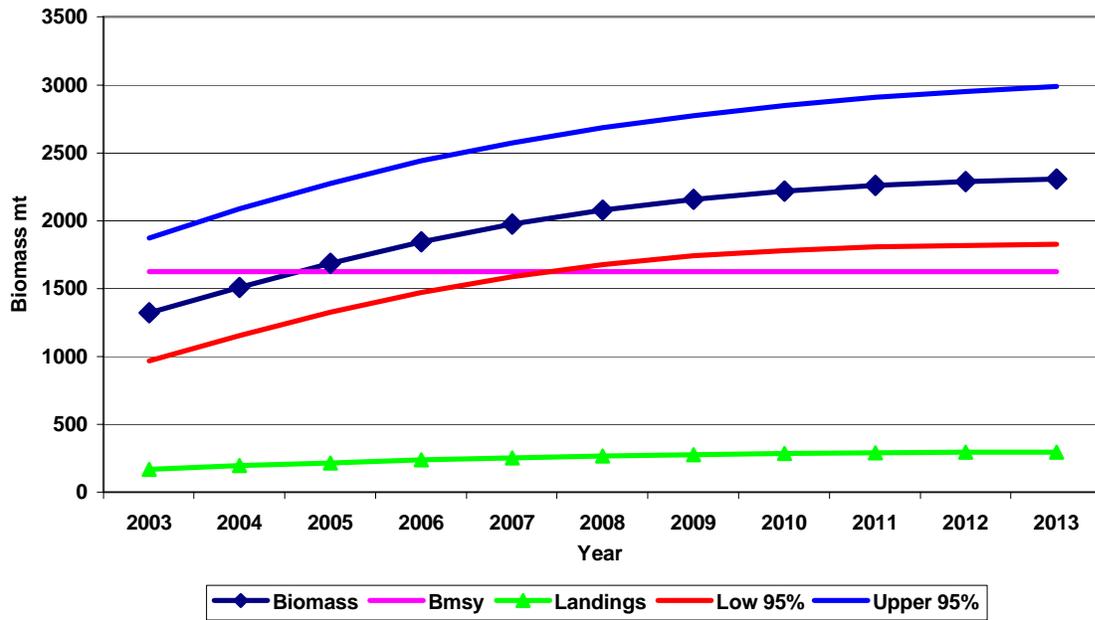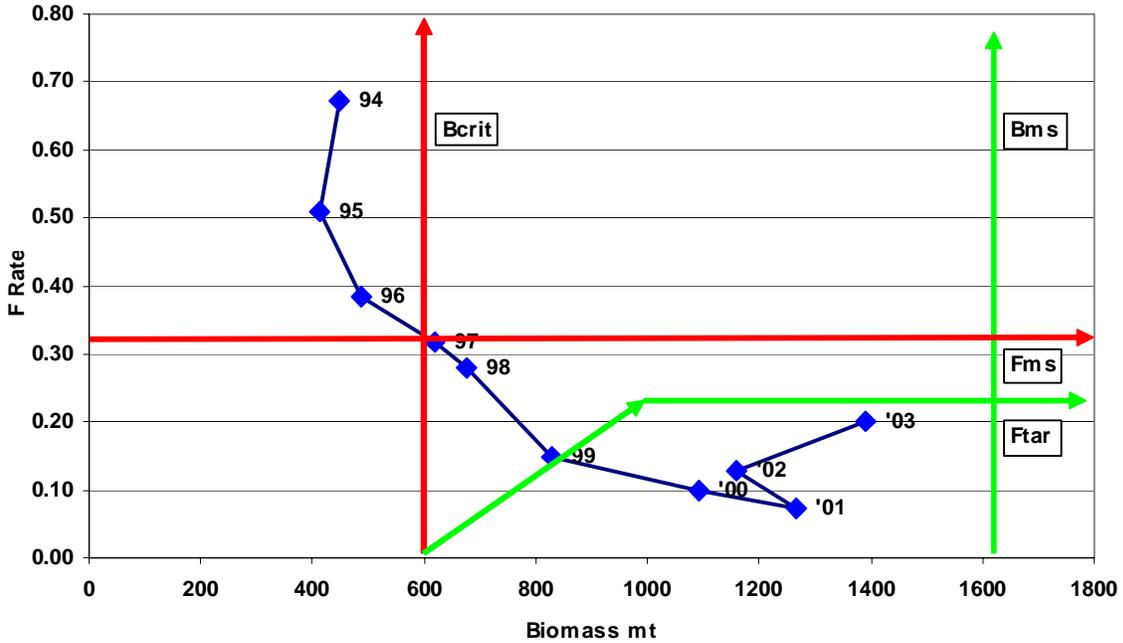**Fig.38- Rhode Island Tautog Stock Biomass and Landings Projection Under Status Quo F**

Fig.39- Proposed Control Rule for RI Tautog and Stock Trajectory 1994-2003

Appendix D. Connecticut Status Report

Management History

Prior to 1995 Connecticut had a 12-inch size limit that was increased in 1995 to 14 inches. In 1996 Connecticut implemented a 4-fish possession limit in the recreational fishery, various gear-specific possession limits in the commercial fisheries, and a seasonal closure from May 1 to June 14 for both sectors. To fulfill the requirements of Addendum III, a seasonal closure from November 24-December 31 was added in 2003. In 2004, the extended closure was amended to include September 8-21 and December 14-31.

Fisheries Dependent Data

The CT DEP has mandatory monthly reporting requirements for commercial license-holders (fishermen and dealers). These data are provided to NMFS for inclusion in their commercial statistics. In the past, two gear types, handlines and otter trawls, accounted for the majority of pounds landed commercially. However, in 2004, 50% of the landings were reported from fish pots while only 38% were reported from handlines and otter trawls combined. Several other gears contributed to the remaining harvest.

Commercial non-harvest losses are unknown, but presumed to be small for this species based on the November 1999 ASMFC Stock Assessment. In this assessment, commercial discard mortality was considered to be negligible and therefore assumed to be zero.

The CT DEP Marine Fisheries Division conducts a Volunteer Angler Survey to supplement MRFSS length measurements, particularly for fish that are released alive. Lengths of tautog have been collected from participating anglers since 1997.

Recreational non-harvest losses were estimated at 2.5% of the discards based on the recreational discard mortality rate used in the most recent stock assessment. Based on 385,997 fish caught and released (B2) recreationally in 2004, this yields a non-harvest loss estimate of 9,650 fish for the year.

Recreational landings account for the majority of total landings in Connecticut and have ranged from 70-90% of the total since 1982. Both recreational harvest and commercial landings have increased in the past 2-3 years.

Recreational harvest and commercial landings in CT

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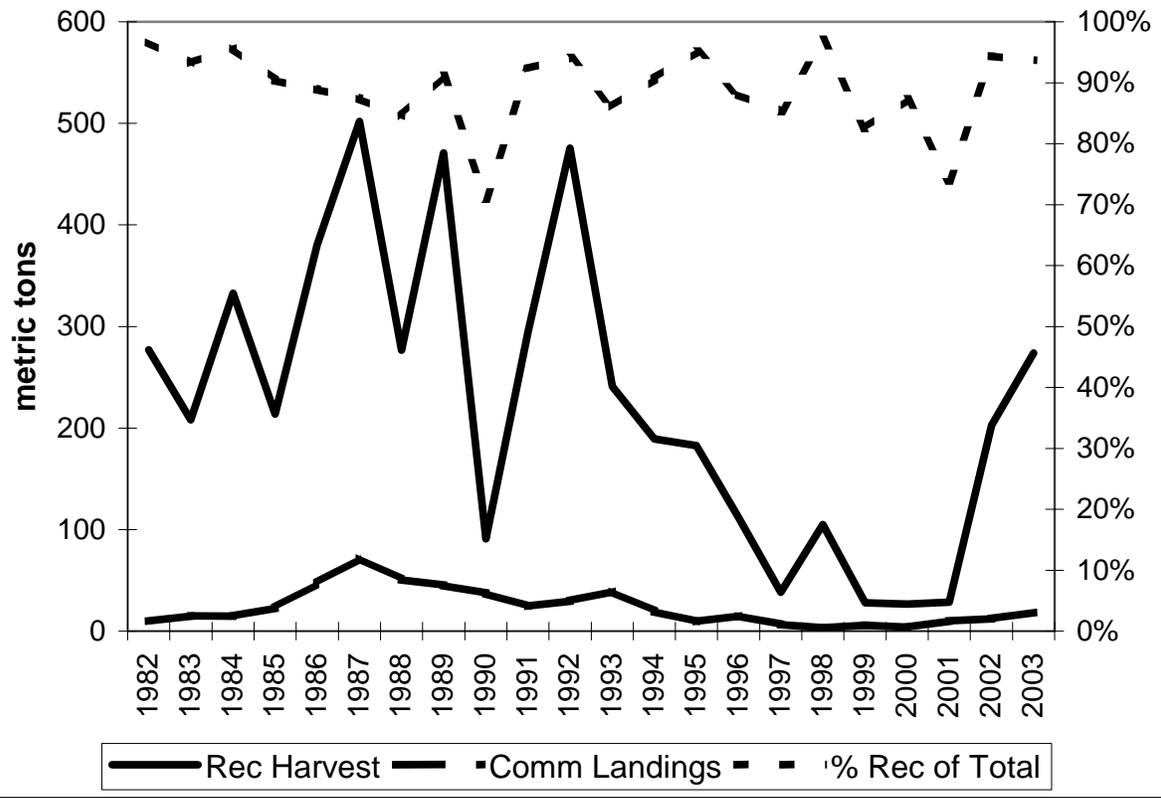
The recreational fishery has been releasing a higher percentage of their catch in the past few years.

Tautog recreational harvest versus releases in CT
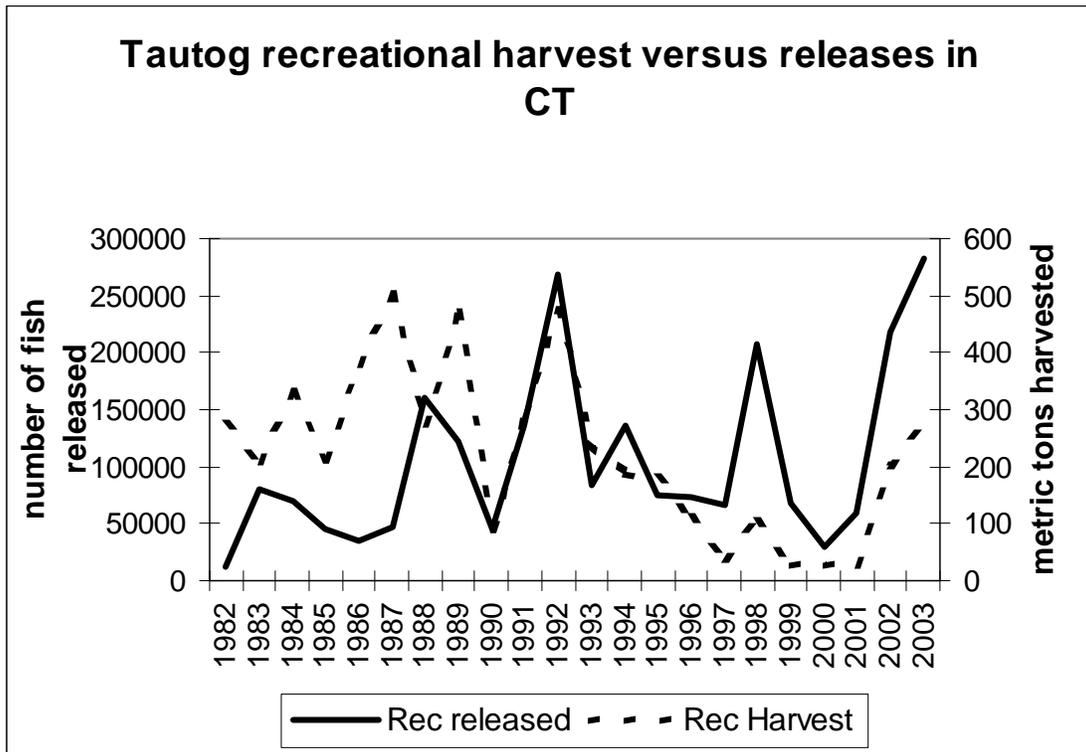
A comparison plot of Lists indices of abundance versus combined recreational and commercial landings show that exploitation remained high from 1986-1993 while abundance steadily declined. Since then, landings have declined in response to lower abundance and more restrictive regulations. This decline continued until 2002, when landings returned to 1993 levels.

CT Index and landings

117
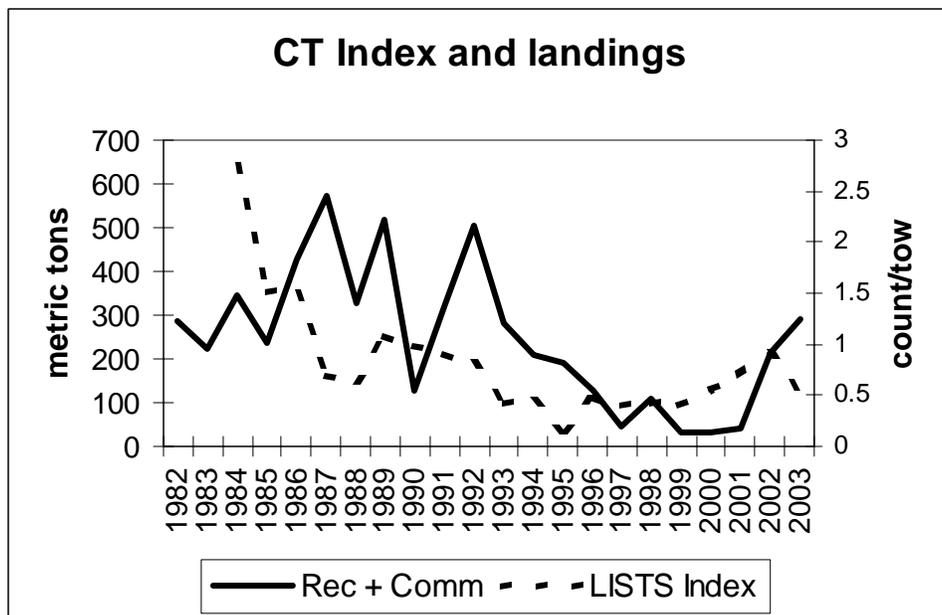
Fisheries Independent Data

The Connecticut DEP has conducted the Long Island Sound Trawl Survey (LISTS) in the Connecticut and New York waters of Long Island Sound since 1984. Sampling occurs at 120 randomly selected sites each spring (April-June) and 80 sites each fall (September-October) between Groton and Norwalk. In the early years (1984-1990), sampling was also conducted in the summer (July-August) and winter (late October-November) months (Table CT1). For each tow, an aggregate weight for tautog is recorded, as well as individual length measurements. A relative index of abundance (geometric mean count per tow) is calculated for both spring and fall surveys, however, the spring index is considered a better indicator of relative abundance in Long Island Sound than the fall index.

Survey indices of abundance from the LISTS are calculated as geometric mean number per standardized tow for each spring survey. The spring 2004 index of 0.54 (gm count/tow) was similar to the 2003 index of 0.52. This is the second consecutive year the index has been below the time series mean of 0.82. The 2002 index (0.91) was the highest value recorded since 1991 and marked the third consecutive year of increasing abundance indices for this species. Indices from 1993-1999 generally ranged from 0.40 to 0.49. Indices improved in 2000 to 0.5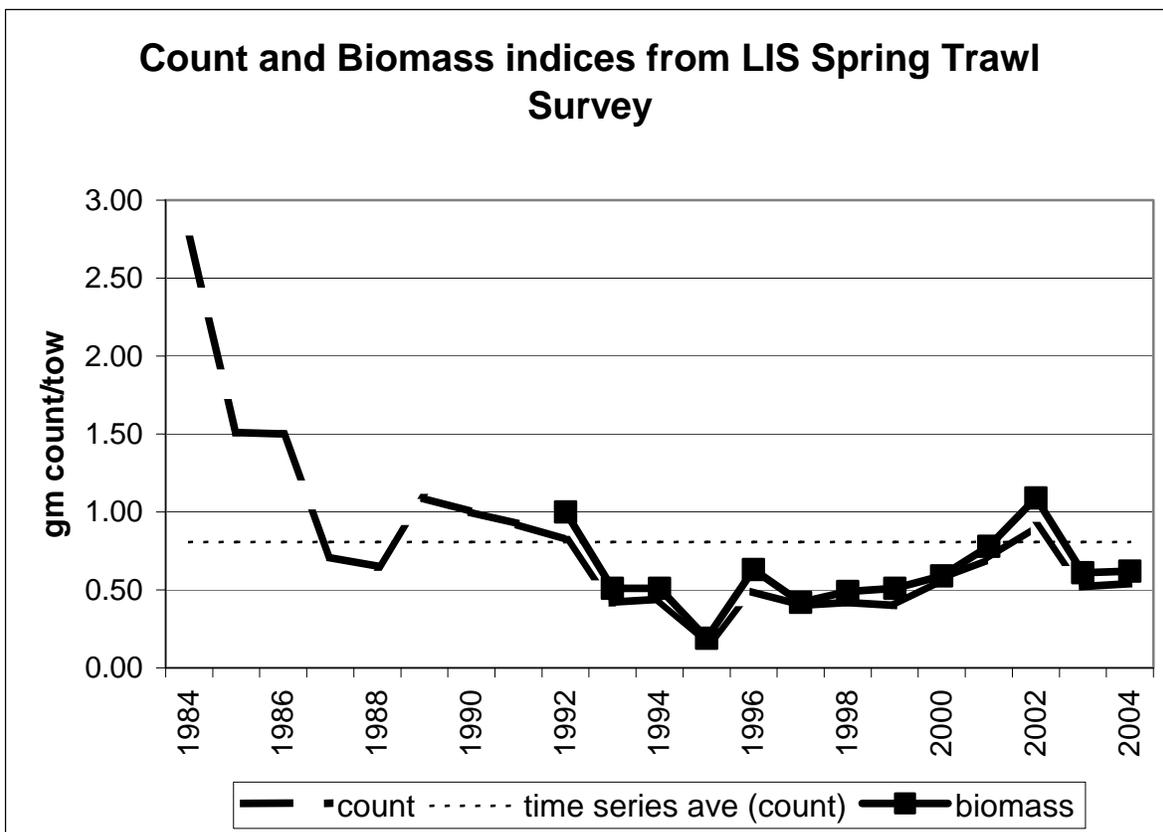7, and again in 2001 to 0.70 before reaching 0.91 in 2002. Indices of abundance have not been above 1.00 since the mid-1980s.

Operdes have been collected from LISTS-caught fish since the Survey's inception (Table CT2). In recent years, opercles have been collected for ageing purposes from almost every tautog captured. In fact, an item of concern is the high percentage of tautog being sacrificed for ageing purposes. The ASMFC compliance requirement to age a minimum of 200 tautog per year requires the sacrifice of most of the fish caught each year through the LISTS.

Year and season specific age keys from LISTS samples were used to convert LISTS length frequencies to ages. Indices-at-age were then determined for each season by apportioning the spring and fall overall indices to the percentage of fish in each age, then summing the spring and fall indices-at-age. Due to the paucity of older ages in the samples (only 29 fish ranging from 20-31 years of age), an age-20+ category is used. The age frequency appears to be truncating. From 1984-1994, 20-30% of the fish were estimated to be older than 10 years of age; however, from 1995-2004, only 10% of the fish are estimated to older than 10 years.

Percent of tautog index- at- age at ages 1-10, LISTS 1984-2004
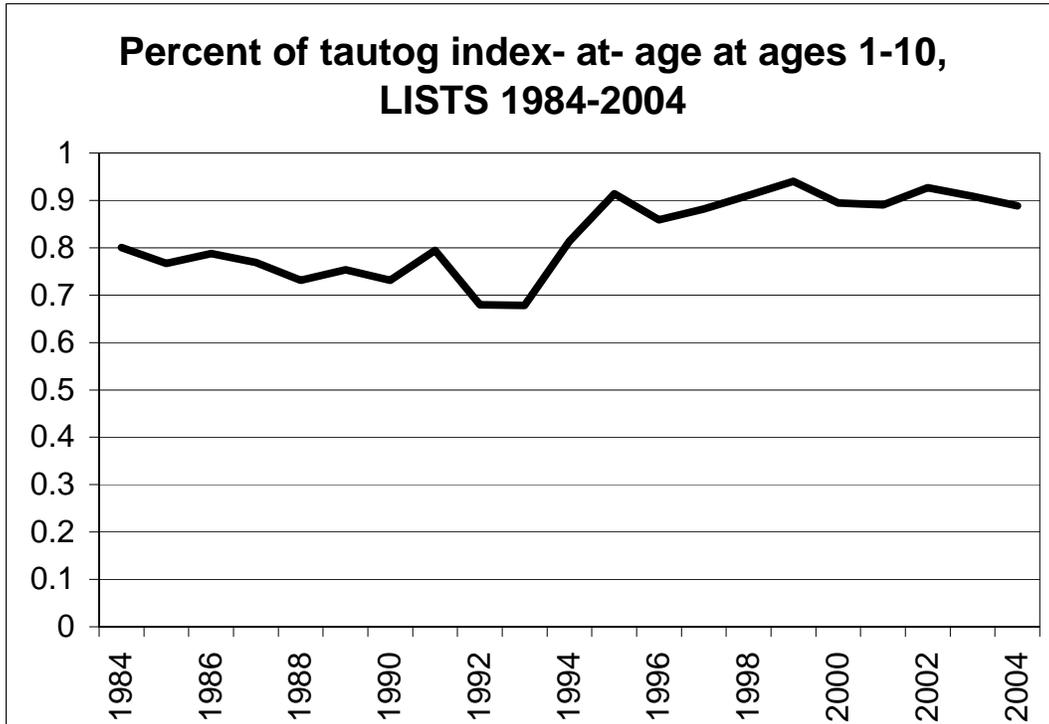
The CT DEP also conducts an Estuarine Seine Survey (ESS) each September that focuses on the abundance of young-of-year and juvenile finfish, as well as forage fish, at eight subtidal locations along the Connecticut shore. An annual index of relative abundance (geometric mean catch per haul) for tautog has been calculated since the ESS began in 1988. Mean catch of young-of-year is highly variable but does shows an increasing trend over course of the seine survey.

Mean catch of tautog young-of-year from Seine Survey

Legend: mean catch — time seriese ave — % occurrence

120
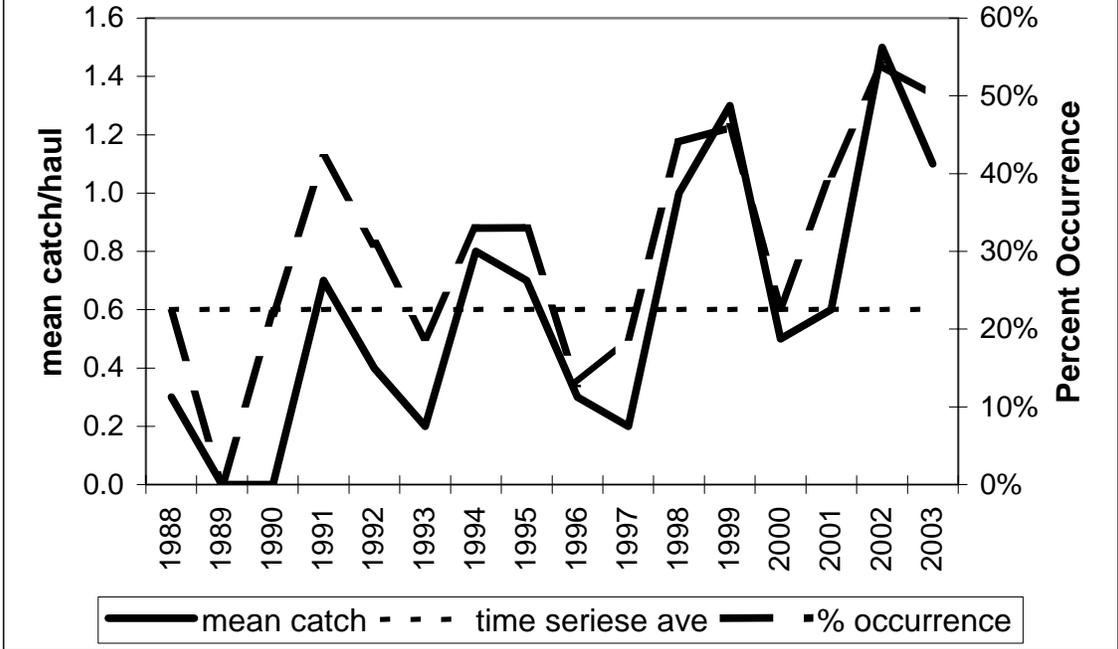
Appendix E. New York Status Report

Management History

Prior to 1991 New York had a 7 inch total length commercial minimum size limit and no recreational size limit. Aside from various area and gear specific closures there were no other commercial or recreational management measures in effect for tautog in New York, and all management measures controlling the harvest of tautog were enacted through legislation. In May of 1991 the New York legislature enacted a 12-inch commercial size limit and a 10 inch minimum size limit for the recreational fishery. The legislation also included an automatic stepwise incremental increase in the recreational minimum size limit over the next two years that would result in common minimum size limits in both fisheries at the end of the period. By January of 1994 both the recreational and commercial fisheries were managed under a 12-inch minimum size.

In response to concerns about large increases in recreational landings the NYSDEC proposed and adopted new regulations raising the recreational size limit to 13 inches, and for the first time implemented a daily recreational possession limit of 10 fish in May 1995. At the same time concerns about the development of a directed market for live tautog resulted in the adoption of new regulations increasing commercial minimum size to 14 inches and a possession limit of 50 fish. NYSDEC was granted complete regulatory authority over tautog in July 1995 and subsequently increased the minimum commercial size limit to 16 inches in January 1996.

In October of 1997, in response to concerns over the continued expansion of the directed fishery for live tautog, the state legislature enacted a law reducing the commercial possession limit to 25 fish per vessel trip and enacted a prohibition on the use of gill or trammel nets for the taking of tautog. The intent of the regulation was to make the commercial fishery a bycatch- only fishery.

Addendum I to the ASMFC FMP required all states to reach the interim fishing mortality target (F= 0.24) and implement a 14-inch minimum size by April 1, 1998. In response to this addendum New York increased the recreational size limit to 14 inches and implemented a 10 fish limit from October 7 to May 31 and a one fish limit the remainder of the year. At the same time the commercial minimum size was lowered to 14 inches and a March 1 to April 8 seasonal closure was implemented. While the 25 fish commercial possession limit remained in place, newly adopted regulations also included a prohibition on the use of rock hopper trawl gear (rollers > 18" diameter) for the taking of tautog and required all fish pots used to take tautog to have a 3 1/8" circular escape vent.

Addendum III to the FMP was approved in February 2002 and required each state to reduce fishing mortality to reach the revised fishing target (F = 0.29) by April 1, 2003. Since the Addendum concluded that recent increases in recreational landings appeared to be the primary cause of increased fishing mortality, reductions in harvest were only required for the recreational fishery. In response, New York implemented an annual recreational possession limit of 10 fish and a seasonal closure of June 1 to September 30 beginning in July 2003.

Fisheries Dependent Data

Recreational harvests (MRFSS A+B1 catch) from 1982 to the present range from a high of 1.2 million fish in 1986 to a low of 46 K fish in 2001, averaging 0.5 million fish over the time series (Figure A). Catches have averaged 189 K fish annually since restrictive recreational fisheries management was implemented in 1994 (14 inch minimum size limit). Since 1996 the released alive proportion of the catch (MRFSS B2 catch) has risen from 46% (1982 - 1995 mean) to 75 % (1996 to 2004 mean). Estimated total recreational removals (harvest plus 2.5% of the B2 catch representing an estimate of release

mortality) follow trends similar to the recreational harvest, since the contribution of release mortality to total mortality is still relatively small.

Recreational CPUE was determined as the harvest numbers from directed trips divided by the number of directed trips, where directed trips are identified when anglers stated tautog as the preferred primary or secondary species sought. The CPUE appears without trend over the time series (Figure B).

Commercial harvest trends are landings averaging 41.5 mt during the 1982 to 1985 time period, rising to a peak harvest in the late 1980s (129 mt in 1989). Harvest declined in the early 1990s, to an average of 32 mt. (Figure C).

Trends in overall fisheries removals closely track the recreational harvest and total recreational removal patterns since, as in the coastwide fisheries, the recreational catch predominates, making up an average 80% of local harvest over the time series.

Fisheries Independent Data

Survey indices are from the New York Peconic Bay Trawl Survey and represent the geometric mean number per tow (Figure D). Survey indices for all ages declined below the time series average (0.29) from 1994 to 1999, rising substantially above the average from 2001 to 2003 (0.43). The 2004 index was just below the time series average. Survey indices are strongly influenced by age-0 and 1 fish over the time series (78% average) and have become more so over time, ranging from 54 % juveniles at the beginning of the time series to 96% at the end of the time series.

Sampling for local age and growth parameters has not taken place since 2001; therefore there is no local age length key. Survey catch was aged based on past sample age keys. Since the survey is heavily influenced by age-0 and 1 fish little bias is expected in aging with this method.

Stock status

A local exploitation history was not determined since the fisheries independent survey targets primarily juvenile tautog and is not geographically comprehensive. The survey catch has become increasingly comprised of age-0 and 1 fish over time, implying that adult biomass may be declining at the eastern end of Long Island. In contrast, recruitment in that area, like in adjoining LIS, appears to be improving.

Based on local recreational harvest and commercial landings trends, fishing mortality is probably down considerably from the peaks of the pre-management years, but like adjoining states, stocks have not increased to the levels seen in those years.

Figure A.

NY Recreational Harvest

Figure B.

NY Recreational CPUE

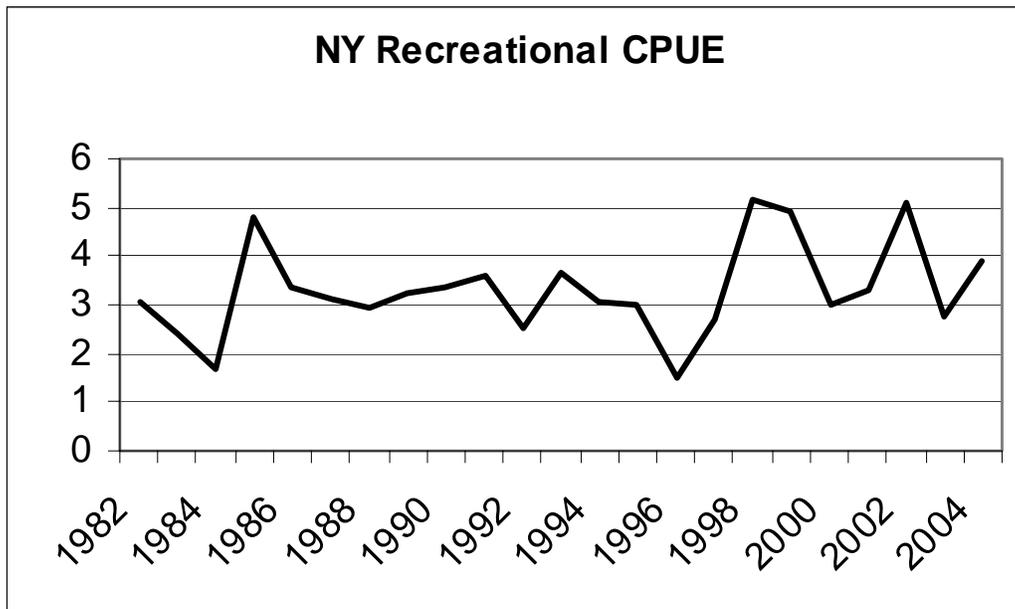123

Figure C.

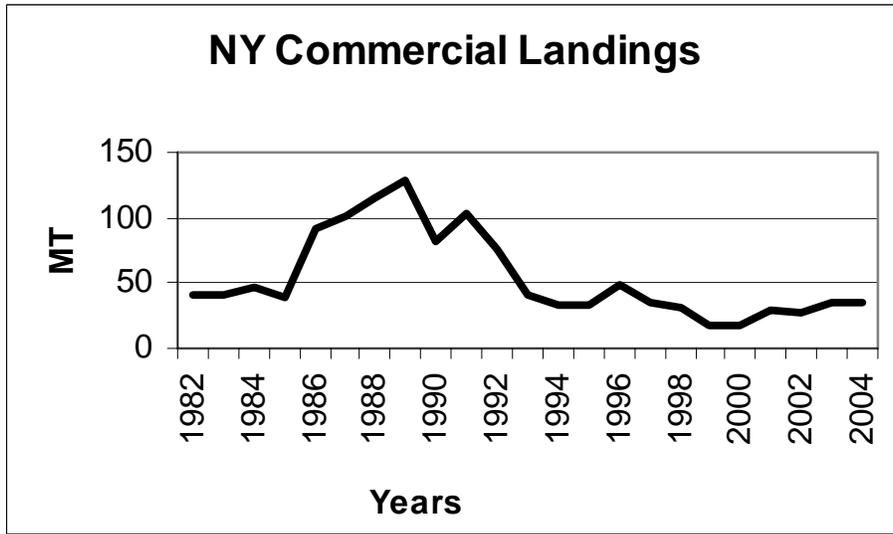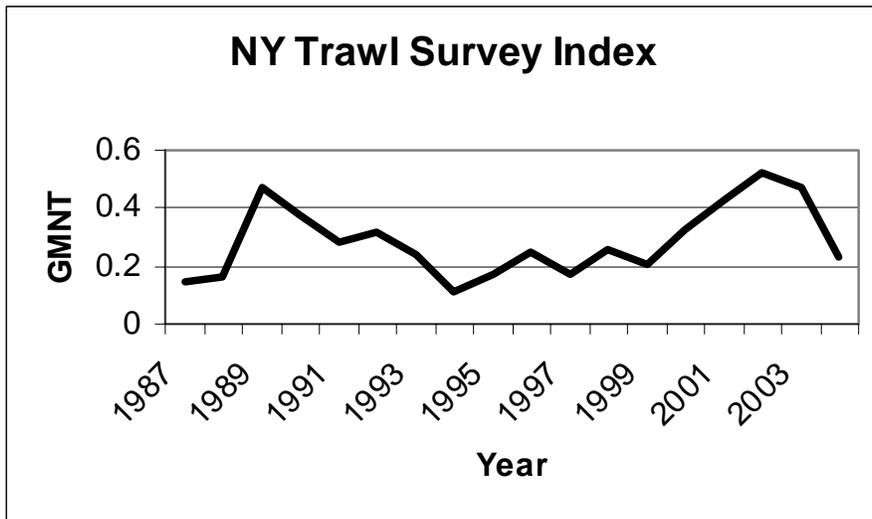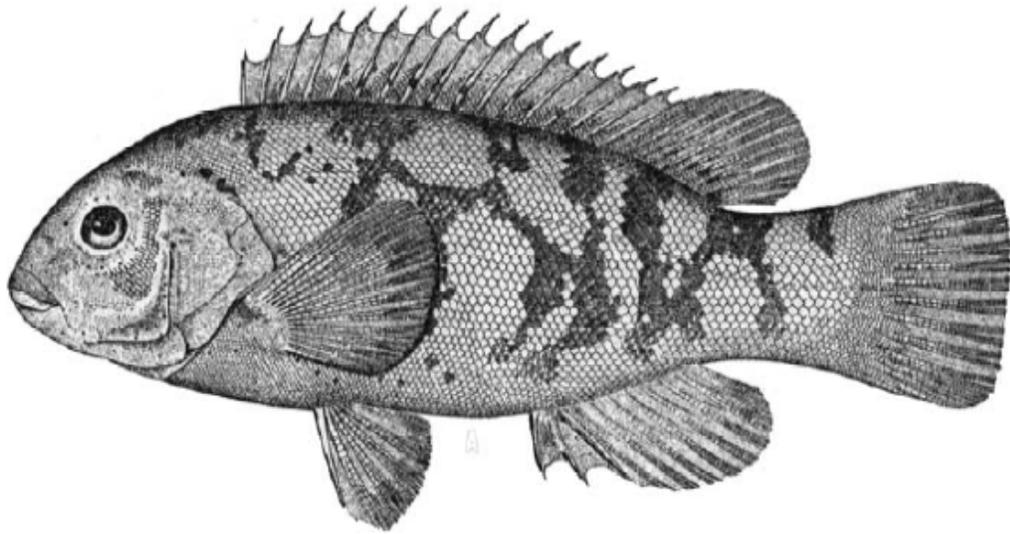**NY Commercial Landings**

Figure D.

NY Trawl Survey Index
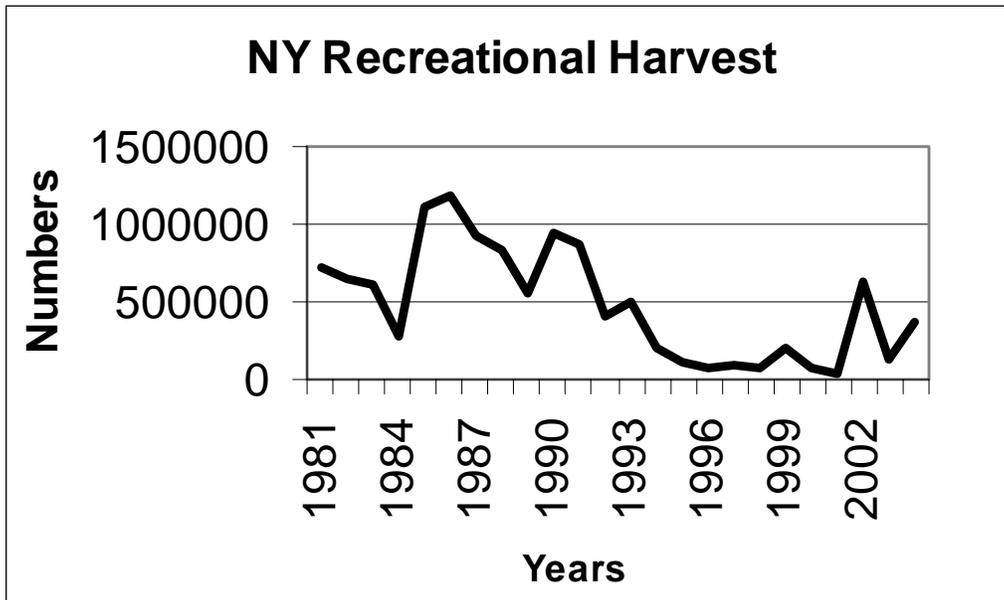
Status Report for Tautog in New Jersey

Jeffrey C. Brust
Research Scientist
New Jersey Division of Fish and Wildlife

July 15, 2005

Introduction

This document is an attempt to determine local stock status of tautog as part of the Atlantic States Marine Fisheries Commission (ASMFC) Tautog Stock Assessment process. The management unit of tautog under the ASMFC is all tautog in state and federal waters between Massachusetts and North Carolina. Previous assessments of the tautog management unit have been conducted using a coastwide virtual population analysis. Recent evidence indicates, however, that the management unit is made up of several discrete spawning populations that have little mixing between them. This suggests that a single coastwide population assessment may not be the most appropriate assessment methodology. The Tautog Stock Assessment Subcommittee reached consensus that the current assessment should use a dual assessment methodology. The coastwide VPA should be updated to allow a comparison of recent stock status with historical assessments that were conducted in a similar manner. At the same time, states should attempt to determine relative stock status in local waters using appropriate methods for the data available. The coastwide VPA will provide information on current levels of fishing mortality and other reference points with respect to management targets stated in the management plan, while the local status reports will evaluate the effectiveness of state management actions.

Management History

Prior to 1994, there were no commercial or recreational management restrictions on harvest of tautog in New Jersey. Beginning in 1994, New Jersey implemented a series of progressively stricter management measures, including a minimum size limit increasing from 11" in 1994 to 14" in 1997 (commercial) and 1998 (recreational) plus a recreational possession limit and commercial quota (Table 1). These measures remained essentially unchanged for several years until 2003, when new recreational possession limits were required to reduce harvest. In the same year, commercial seasons were changed at the request of the participating fishermen. The measures implemented in 2003 are still in effect.

Fisheries Dependent Data

Commercial fishery

Commercial landings data are collected in New Jersey by the National Marine Fisheries Service (NMFS). Data for this report were obtained from the NMFS commercial fisheries data webpage (http://www.st.nmfs.gov/st1/commercial/index.html). Between 1950 and 1966 commercial tautog landings in New Jersey were relatively stable, averaging approximately 35,900 pounds per year (Table 2, Figure 1). Between 1963 and 1966, landings decreased to below 20,000 pounds per year and stayed at this level for several years. In 1972, landings began a gradual increase back to previous levels, exceeding 50,000 pounds in 1980 and 1981. In 1982, landings increased dramatically to over 140,000 pounds and generally remained above 90,000 pounds per year until 1996. Implementation of commercial regulations in 1994 resulted in a rapid decline in landings from 162,600 pounds in 1994 (time series high) to 27,300 pounds in 1999. Since 1999, landings have rebounded to between 35,000 and 65,000 pounds, well below the New Jersey commercial quota of 103,000 pounds.

Landings by gear show that the commercial fishery for tautog in New Jersey is primarily a pot fishery (Table 2, Figure 2). Landings from pots averaged more than 70% of total landings prior to implementation of regulations. Otter trawls are the second most prevalent gear, and appear to be increasing in importance in recent years. Prior to 1994, trawls accounted for approximately 16% of total commercial landings. Since the implementation of regulations in 1994, the proportion of trawl landings has increased to 36% while contribution from pots has declined to 52%. Average annual trawl landings by decade have increased from less than 4,000 pounds per year in the 1960s to over 27,500 pounds per year in the 1990s and 21,500 pounds from 2000 to 2003.

Recreational fishery

Recreational catch and harvest information is collected in New Jersey through the NMFS Marine Recreational Fisheries Statistics Survey (MRFSS). Data for this report were obtained from the MRFSS website (http://www.st.nmfs.gov/st1/recreational/queries/index.html). Between 1982 and 2004, recreational catch (number of A+B1+B2 fish) of tautog in New Jersey has varied widely between years, ranging from approximately 237,000 fish caught in 1998 to almost 2.5 million fish caught in 1986 (Table 3, Figure 3). In general, however, catch appears to have varied without trend over the entire time series, with an average catch of approximately one million fish per year.

Recreational harvest (number of A+B1 fish) ranges from 11,600 fish in 1998 to over 2.3 million fish in 1986 (Table 3, Figure 3). According to MRFSS, the number of tautog harvested in New Jersey increased from approximately 500,000 fish in the early 1980s to around one million fish by the early 1990s. Between 1992 and 2004, there has been a decreasing trend in harvest. Average harvest from 2002 to 2004 was around 189,000 fish – approximately one-fifth of the harvest in the three years before regulations.

In order to evaluate trends in catch and harvest, data were standardized relative to the number of "directed" trips each year, as estimated by MRFSS. A "directed trip is a trip where the interviewee indicated that tautog was the primary or secondary target species for the trip. Between 1982 and 1994, catch per unit effort (CPUE) appears relatively stable, generally ranging between 4 and 6 fish per trip (Table 3, Figure 4). From 1995 to 2001, CPUE increases substantially to between 6 and 10 fish per trip before returning to previous levels in 2002. Overall, CPUE shows a positive slope from 1982 to 2004.

Harvest per unit effort (HPUE) shows a similar pattern as CPUE, with coinciding years of peaks and valleys in both indices (Table 3, Figure 4). However, the overall trend for HPUE is opposite of CPUE. Between 1982 and 1986, HPUE was generally greater than 4 fish per trip. This value decreased to between 2 and 4 fish per trip from 1987 to 1993. Since implementation of harvest regulations, HPUE has declined to around 1 fish per trip in 2003 and 2004.

The differences in these trends are evident in the ratio of harvest to catch. Prior to implementation of management measures in 1994, the ratio of harvest to catch averaged approximately 78% (Table 3). In the first year of management, the ratio dropped to less than 48% and declined to less than 5% by 1998. The ratio rebounded to nearly 43% in 2000, and has declined again to around 21% in 2003 and 2004. Since 1994, the ratio of harvest to catch has averaged 31% - a 60% decrease from the pre-management time period.

Fisheries Independent Data

New Jersey has conducted a stratified random trawl survey in nearshore ocean waters since 1988. The survey is conducted five times per year (January, April, June, August, October) between Cape May and Sandy Hook, NJ. The sampling area is stratified into 5 areas north to south and 3 depth zones (<5, 5-10, 10-20 fathoms) for a total of 15 strata. During each survey, a total of 39 tows are conducted, with the sample size in each stratum determined by stratum area. The sampling gear is a two-seam trawl with a 25 m head rope and 30.5 m footrope. The cod-end has a 6.4 mm liner. Tautog caught in the trawl are counted by tow and measured to the nearest centimeter. An annual index of tautog abundance is determined as the stratified mean number per tow, weighted by stratum area. The total CPUE is then subdivided into CPUE at age using the Southern Region age-length keys used in the coastwide VPA.

In two of the first three years of the survey, total tautog CPUE was greater than one fish per tow (Figure 5). Beginning in 1990, CPUE began a steady decline from the second highest point in the time series (1.1 fish per tow) to the time series low in 1997 (0.04 fish per tow). Since 1997, CPUE appears to have increased slightly to 0.23 fish per tow in 2003 and 0.14 in 2004. However, it appears that relative abundance may be highly influenced by availability of the fish to the gear rather than actual abundance. This is believed because the recent increases in abundance are not restricted to a single cohort (Figure 6). Rather, when total CPUE is high, CPUE for each age is high. Similarly, the decreases in CPUE in the early part of the time series occur on all ages concurrently, instead of on oldest ages first as might be expected if the stock was overexploited. For this reason, there is some concern about the utility of the trawl survey index in assessing tautog population status.

Stock Status

Recreational

Cross sectional (*i.e.* within year) catch curves were conducted using recreational harvest data. The number of fish harvested at each size was determined using length frequency distributions collected by MRFSS (1995 to 2004) and supplemented with length frequencies collected by the State of New Jersey (1995 to1999). The number at length was then converted to number at age using annual age-length keys. Age-length sample sizes from New Jersey alone were not sufficient so age-length data from the entire Southern Region was used. However, since the Southern Region age-length keys used in the coastwide VPA are pooled across years to increase sample size, and since pooled keys can mask interannual variation and thereby dampen signals, the recreational length distributions were aged using annual keys developed from the Southern Region data. Sample sizes were lower than in the pooled keys, but generally sufficient to "fill out" a key. Length categories without age information were filled using an average of the nearest length with data above and below the empty length. The age at full recruitment ranged from age-3 to age-7. For all years except 1999, full recruitment occurred at or before age-6. Instantaneous total mortality (Z) was computed on ages 7 to 12 except in 1999 when ages 8 to 12 were used. Instantaneous fishing mortality (F) was computed as Z minus a constant natural mortality rate of 0.15.

From 1995 to 2003, F generally ranged from 0.1 to 0.2, dropping below 0.1 in 1997 and 2000 (Figure 7). During this time period, there has been no observable trend in F. Unfortunately, the first year that annual keys are available is the second year of management and it is therefore not possible to compare fishing mortality rates before and after implementation of management measures. However, the data suggest that fishing mortality on tautog age-7 to 12 has been well below the management target of $F_{40\%} = 0.29$ since at least 1995.

Longitudinal (*i.e.* cohort specific) catch curves were also estimated using recreational harvest per unit effort data from MRFSS. HPUE by length was determined using the recreational length frequency distributions described above. These were then aged using the annual age-length keys derived from the Southern Region data. Because no age-11 fish were observed in 2003 (1992 cohort), the average HPUE for ages 10 and 12 in 2003 was used. Log(HPUE) for ages 7 to 12 was lagged backwards the appropriate number of years from age-7 to allow estimation of the decline in abundance of each cohort. Lagging the data results in incomplete cohort information for early years and late years. Mortality was only computed for cohorts with information on four or more ages – 1986 (ages 9 to 12) to 1993 (ages 7 to 10).

Cohort fishing mortality decreased from 0.68 in 1986 to 0.2 in 1989 (Figure 8). It remained at low levels (less than 0.11) for several years before increasing dramatically to 0.35 in 1992 and 0.49 in 1993. The two highest points of the time series (1986 and 1993) may be affected by estimating mortality on only four data points. For the cohorts with five or more years worth of data, F has been below the $F_{40\%} = 0.29$

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target except for the 1987 and 1992 year classes. The mortality estimate for the 1992 year class may change if 12 year old fish are observed in the 2004 data when it becomes available. However, it appears that fishing mortality has increased on recent cohorts and may be above the management target.

Trawl survey

Longitudinal catch curves were also developed using the New Jersey trawl survey CPUE at age. For all years except 1998, tautog appeared fully recruited to the trawl gear by age-5. Catch curves were therefore computed using ages 6 to 11 for each cohort that had at least four data points.

As with the longitudinal catch curves for the recreational fishery, estimates of F for the first and last year classes (1980 and 1994) are very different from the remaining years, perhaps due to fewer ages used to compute mortality (Figure 9). Between 1981 and 1985, F was relatively stable, ranging from 0.08 to 0.14. Beginning with the 1986 cohort, the interannual variation in fishing mortality became much more pronounced but remained below the $F_{40\%} = 0.29$ target. However, as mentioned in the discussion of trawl CPUE, there is concern regarding the utility of this data set. Two of the F estimates are negative, which is biologically impossible. The negative F in the terminal year may be due to the fewer number of ages used to estimate mortality. It could be that the pattern in F is correct but not the magnitude. However, there is little correlation with the recreational estimates of cohort F. Given the uncertainty in the trawl index, the estimates of cohort fishing mortality based on the trawl index should be viewed with caution.

Relative Fishing Mortality

Recreational

Fishing mortality can be estimated by dividing annual catch by an average abundance for the year. When absolute abundance is not available, an estimate of the relative amount of fishing mortality can be determined using the average relative abundance index for year t and t+1. For this analysis, an annual index of abundance was determined as the average catch per directed trip in the recreational fishery. Relative F was then estimated as harvest (A+B1) divided by the average index in year t and t+1.

From 1982 to 1985, relative F in the New Jersey recreational fishery was relatively constant (Figure 10) at moderate levels (average 93,000). F increased dramatically in 1986 and 1987, reaching the highest (440,000) and second highest (223,000) in the time series, respectively. Mortality declined in 1988, but was substantially higher than early years, averaging 171,000 from 1988 to 1993. With the implementation of regulations in 1994, F decreased gradually through 1998 to the time series low of 1,250. In recent years, relative F has increased again, averaging around 45,000, approximately half of the value of the early part of the time series.

Trawl survey

Relative F was also estimated using recreational harvest relative to the trawl survey CPUE index (Figure 10). The relative F index using trawl survey CPUE exhibits much more interannual variability than the index based on recreational CPUE. The patterns of the two indices are roughly similar, but correlation between the two indices is moderate (r = 0.22). As noted above, there is some concern regarding the utility of the trawl survey data.

Summary and Conclusions

Available data suggest that fishing mortality on tautog in New Jersey has decreased since the implementation of regulations. Commercial harvest in the last three years is less than 50% of the harvest

in the three years prior to management. Similarly, recreational harvest has decreased nearly 80% over the same time period, while recreational CPUE has remained stable. Relative F estimates using recreational CPUE show a decrease in F in the last decade, while recreational catch curves indicate that fishing mortality on ages 7 to 12 has been below the management target of $F_{40\%} = 0.29$ since 1995. These data suggest that the management measures adopted for the tautog fisheries in New Jersey have been successful in attaining the management objectives.

On a cautionary note, there is some concern that there is no strong evidence of stock rebuilding with decreased fishing pressure. Trawl survey CPUE has increased in recent years, but it was shown that the increase was concurrent on all ages, rather than consecutively as one or more strong year classes recruited to the gear. Recreational CPUE increased in the late 1990s, but has since decreased again. In addition, some trends suggest a recent increase in fishing mortality, including the commercial harvest, recreational CPUE, recreational catch curves, and relative F using trawl survey CPUE. These indicators should be watched over the next few years to determine whether these indices are showing true increases in fishing mortality or are simply a function of interannual variability.

Table 1. History of Tautog Management in New Jersey

YEAR	RECREATIONAL	COMMERCIAL
1994	11 inch minimum size limit	11 inch minimum size limit
1995	12 inch minimum size limit (effective 1/1/95)	12 inch minimum size limit (effective 1/1/95
1996	12 inch minimum size limit	12 inch minimum size limit
1997	13 inch minimum size limit	14 inch minimum size limit; annual quota established at 103,000 pounds; limited entry system implemented with Directed Fishery Tautog Permits
1998	14 inch minimum size limit; seasonal possession limit established of 1 fish from June 1 through Oct 9, and 10 fish from Oct 10 through May 31	A Non-Directed Fishery Tautog Permit is added; annual commercial quota reduced to 61,680 pounds
1999	Same as 1998 measures	Commercial fishery seasons established as per ASMFC mandate as: closed Jan 1 through Mar 30; open Apr 1 through June 15; closed June 16 through Oct 12; open Oct 13 through Dec 31; annual quota raised back to 103,000 pounds
2000	Same as 1998 measures	Same as 1999 measures
2001	Same as 1998 measures	Same as 1999 measures
2002	Same as 1998 measures	Same as 1999 measures
2003	Effective Apr 1, new seasonal possession limits established as: 4 fish Jan 1 through May 31; 1 fish June 1 through Nov 14; 8 fish Nov 15 though Dec 31	Commercial seasons changed at the request of permittees as: closed Jan 16 through Apr 14; open Apr 15 though June 30; closed July 1 through Oct 31; open Nov 1 through Jan 15
2004	Same as 2003 measures	Same as 2003 measures

Table 2. New Jersey Commercial Tautog Landings (Pounds)						
Year	Pots	Trawl	Other	Total	Pct Pots	Pct Trawl
1950	27,700	9,100	1,400	38,200	0.7251	0.2382
1951	26,000	4,600	1,900	32,500	0.8000	0.1415
1952	21,900	22,200	3,000	47,100	0.4650	0.4713
1953	13,700	5,200	3,000	21,900	0.6256	0.2374
1954	21,300	6,600	2,800	30,700	0.6938	0.2150
1955	18,600	3,700	3,000	25,300	0.7352	0.1462
1956	27,600	3,300	2,700	33,600	0.8214	0.0982
1957	16,900	3,500	900	21,300	0.7934	0.1643
1958	40,600	4,200	2,800	47,600	0.8529	0.0882
1959	32,900	4,600	1,800	39,300	0.8372	0.1170
1960	22,000	3,600	1,200	26,800	0.8209	0.1343
1961	19,100	4,100	10,400	33,600	0.5685	0.1220
1962	34,700	6,000	10,800	51,500	0.6738	0.1165
1963	43,000	4,900	5,600	53,500	0.8037	0.0916
1964	25,700	4,700	6,600	37,000	0.6946	0.1270
1965	27,100	5,100	3,700	35,900	0.7549	0.1421
1966	5,600	5,200	6,700	17,500	0.3200	0.2971
1967	12,200	1,400	5,600	19,200	0.6354	0.0729
1968	14,000	2,200	2,200	18,400	0.7609	0.1196
1969	8,200	1,600	2,600	12,400	0.6613	0.1290
1970	16,800	800	2,700	20,300	0.8276	0.0394
1971	11,200	2,000	1,300	14,500	0.7724	0.1379
1972	25,000	1,500	3,800	30,300	0.8251	0.0495
1973	18,500	1,500	3,000	23,000	0.8043	0.0652
1974	18,900	1,200	1,500	21,600	0.8750	0.0556
1975	22,000	9,800	1,400	33,200	0.6627	0.2952
1976	36,600	4,300	3,100	44,000	0.8318	0.0977
1977	27,700	12,200	5,000	44,900	0.6169	0.2717
1978	25,800	8,900	8,800	43,500	0.5931	0.2046
1979	33,800	7,800	4,600	46,200	0.7316	0.1688
1980	51,200	3,800	2,100	57,100	0.8967	0.0665
1981	37,200	9,900	7,300	54,400	0.6838	0.1820
1982	132,400	3,100	12,700	148,200	0.8934	0.0209
1983	82,000	2,400	16,200	100,600	0.8151	0.0239
1984	98,800	21,900	9,000	129,700	0.7618	0.1689
1985	100,700	17,800	7,000	125,500	0.8024	0.1418
1986	77,700	20,800	2,200	100,700	0.7716	0.2066
1987	85,400	7,700	2,100	95,200	0.8971	0.0809
1988	70,600	13,400	4,000	88,000	0.8023	0.1523
1989	37,800	11,500	2,600	51,900	0.7283	0.2216
1990	77,353	17,087	4,672	99,112	0.7805	0.1724
1991	68,028	15,304	9,690	93,022	0.7313	0.1645
1992	46,274	64,495	5,563	116,332	0.3978	0.5544
1993	80,630	54,309	18,535	153,474	0.5254	0.3539
1994	141,141	14,204	7,296	162,641	0.8678	0.0873
1995	68,963	35,689	11,318	115,970	0.5947	0.3077
1996	40,269	30,149	19,017	89,435	0.4503	0.3371
1997	23,186	19,288	7,252	49,726	0.4663	0.3879
1998	23,751	16,769	1,906	42,426	0.5598	0.3953
1999	14,853	9,545	2,909	27,307	0.5439	0.3495
2000	16,049	19,487	4,100	39,636	0.4049	0.4916
2001	20,363	32,968	6,821	60,152	0.3385	0.5481
2002	20,744	9,771	6,090	36,605	0.5667	0.2669
2003	29,106	28,297	7,783	65,186	0.4465	0.4341

|	Catch	PSE	Harvest	PSE	Trips	CPUE	HPUE	H/C
								Ratio of

Table 3. New Jersey Recreational Tautog Catch and Harvest (number of fish) and Harvest to Catch

	Catch	PSE	Harvest	PSE	Trips	CPUE	HPUE	H/C
1982	659,674	24.8	583,550	27.2	152,552	4.32	3.83	0.8846
1983	436,763	26	344,580	31.7	73,747	5.92	4.67	0.7889
1984	541,097	25	516,086	26.1	129,858	4.17	3.97	0.9538
1985	880,574	31.8	840,627	33.3	96,368	9.14	8.72	0.9546
1986	2,490,246	35.7	2,369,852	37.4	428,679	5.81	5.53	0.9517
1987	1,329,927	16.7	1,015,123	18.9	268,195	4.96	3.79	0.7633
1988	827,349	16.1	564,286	18.2	199,565	4.15	2.83	0.6820
1989	979,588	12.2	710,958	13.6	223,558	4.38	3.18	0.7258
1990	1,212,986	9.2	841,770	11.8	329,683	3.68	2.55	0.6940
1991	1,724,211	8.4	1,067,283	10.5	330,596	5.22	3.23	0.6190
1992	1,532,114	10.5	1,018,205	13	235,482	6.51	4.32	0.6646
1993	1,211,518	14.7	773,213	19.9	236,751	5.12	3.27	0.6382
1994	436,141	16.5	208,003	22.7	108,535	4.02	1.92	0.4769
1995	1,585,423	12.8	707,963	18.5	169,024	9.38	4.19	0.4465
1996	1,042,014	16.7	470,431	30.7	142,028	7.34	3.31	0.4515
1997	616,930	12.7	196,724	19.3	96,858	6.37	2.03	0.3189
1998	236,960	41.6	11,667	38.2	29,667	7.99	0.39	0.0492
1999	836,554	19	165,505	28.3	80,290	10.42	2.06	0.1978
2000	1,089,770	15.4	462,371	25.1	122,591	8.89	3.77	0.4243
2001	1,474,199	9.1	467,728	13.9	180,125	8.18	2.60	0.3173
2002	1,184,305	9.2	347,831	13.9	225,072	5.26	1.55	0.2937
2003	496,525	18.4	102,593	19.4	89,035	5.58	1.15	0.2066
2004	531,567	13.1	117,088	16.8	130,294	4.08	0.90	0.2203

Figure 1. New Jersey Commercial Tautog Landings

Figure 2. New Jersey Commercial Landings by Gear
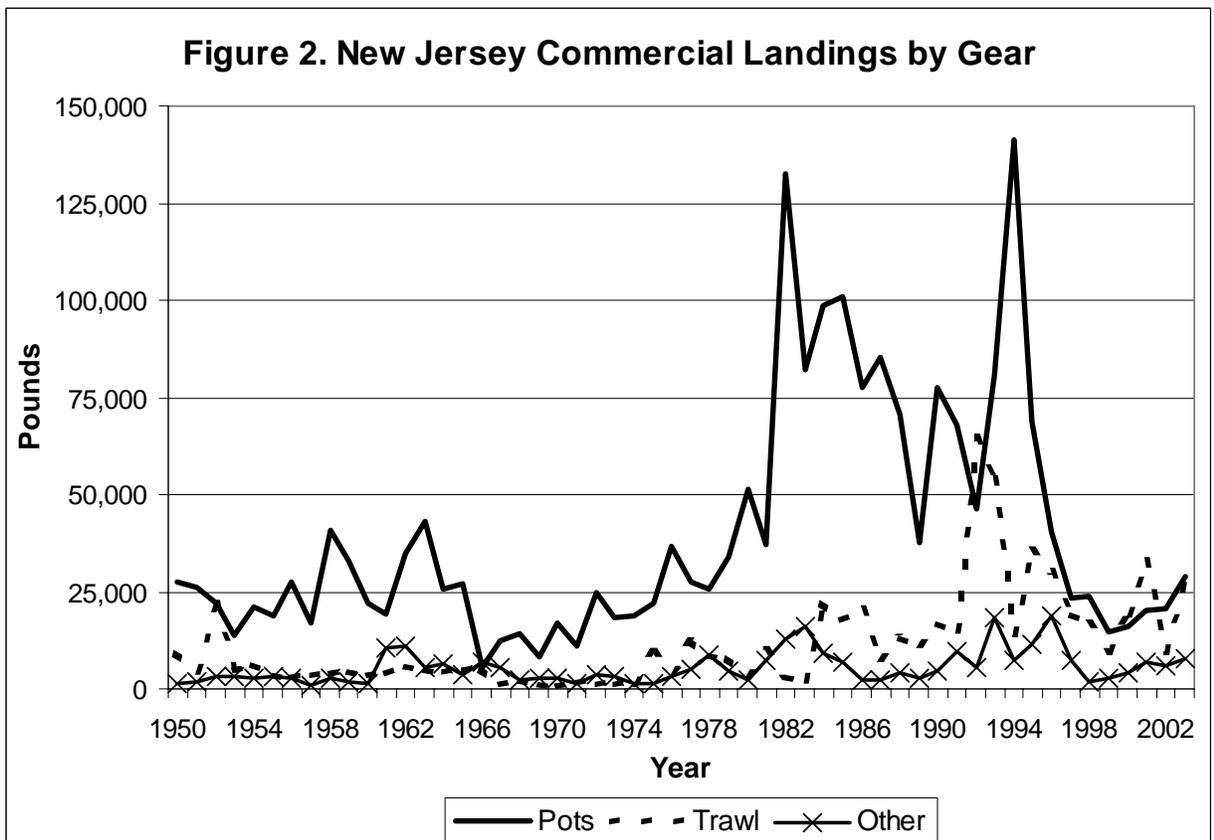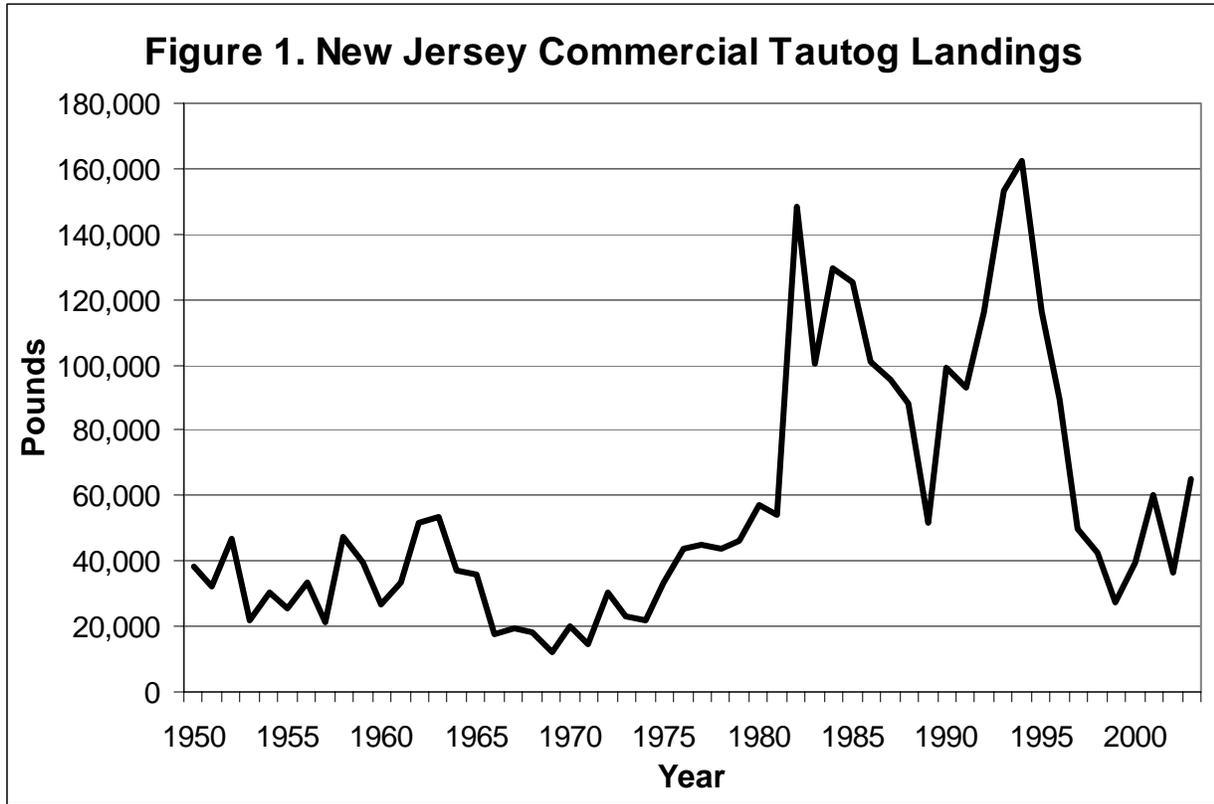
Figure 3. New Jersey Recreational Tautog Catch and Harvest
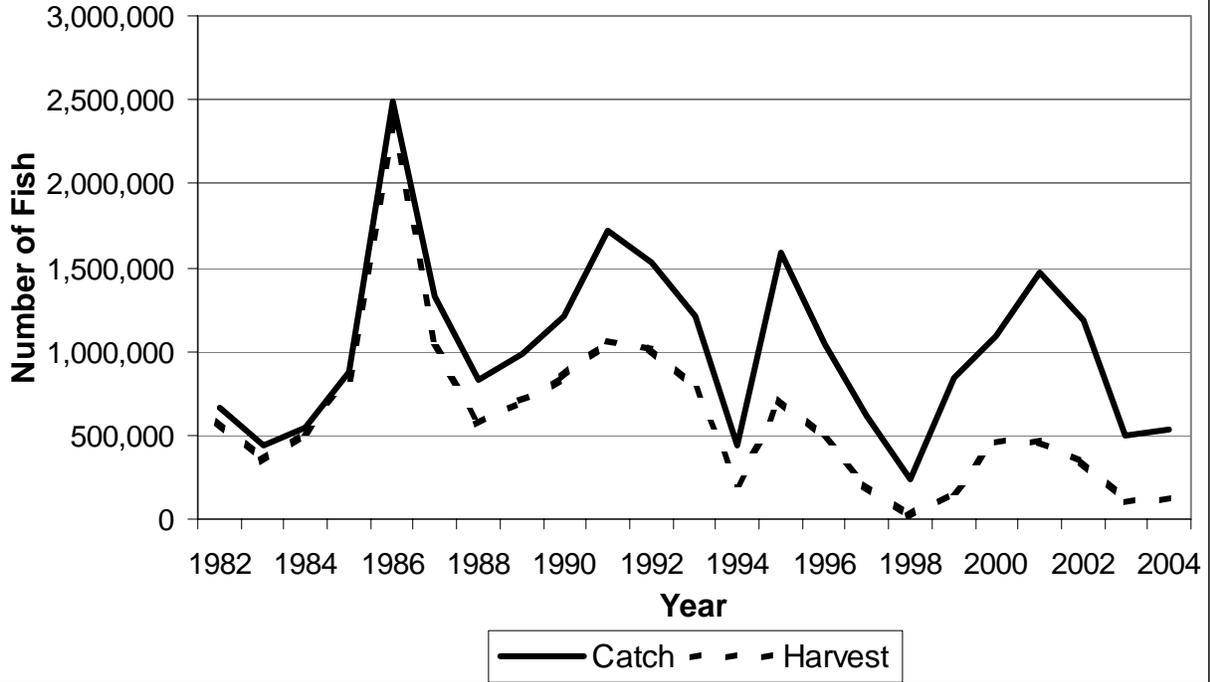
Figure 4. New Jersey Recreational Catch and Harvest per Trip
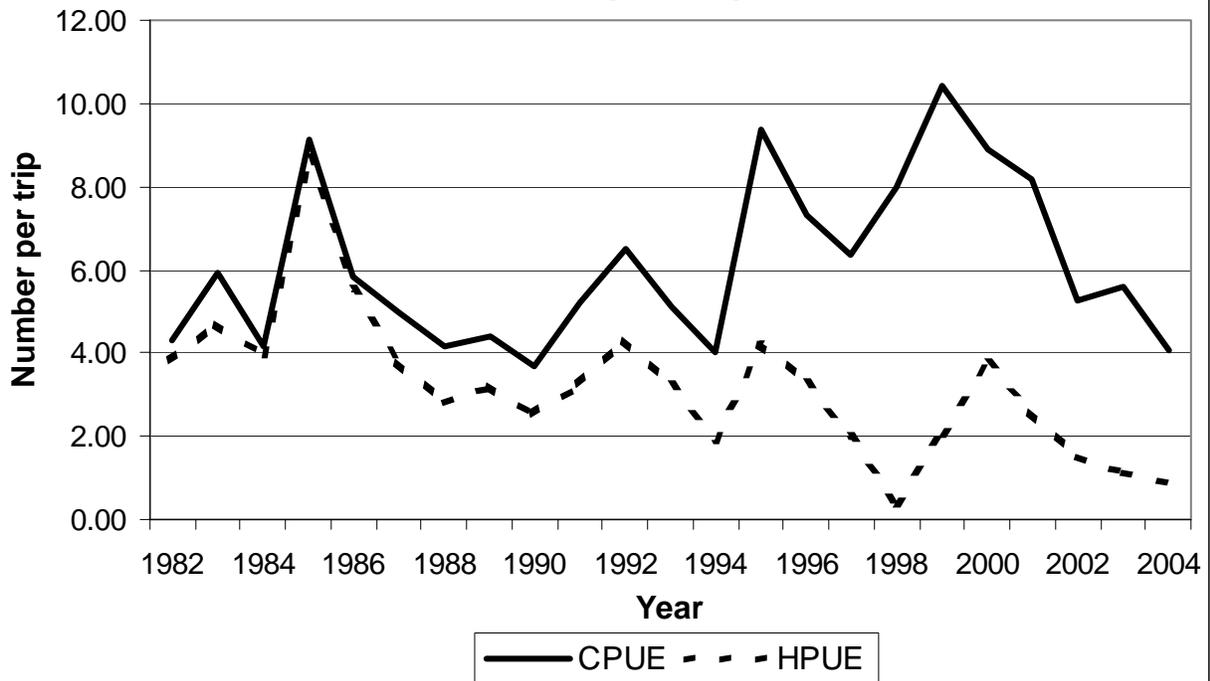
Figure 5. New Jersey Trawl Survey Tautog CPUE
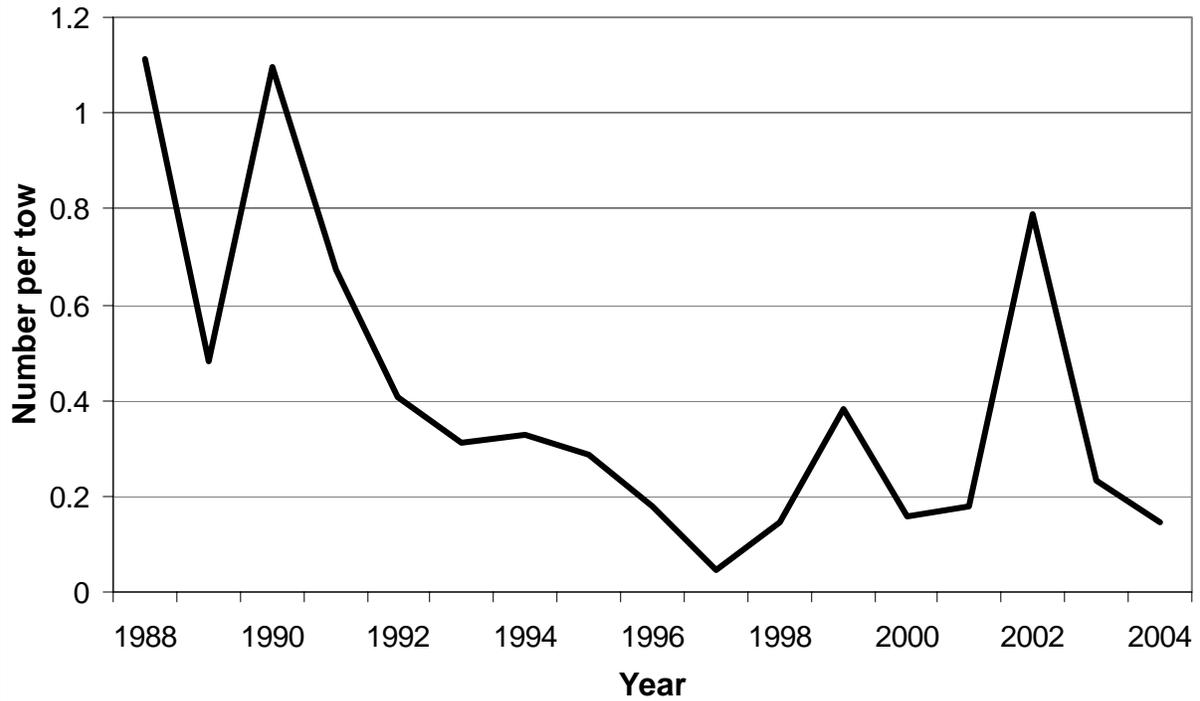
Figure 6. New Jersey Trawl Survey CPUE by Age, Ages 1-10

Legend: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10
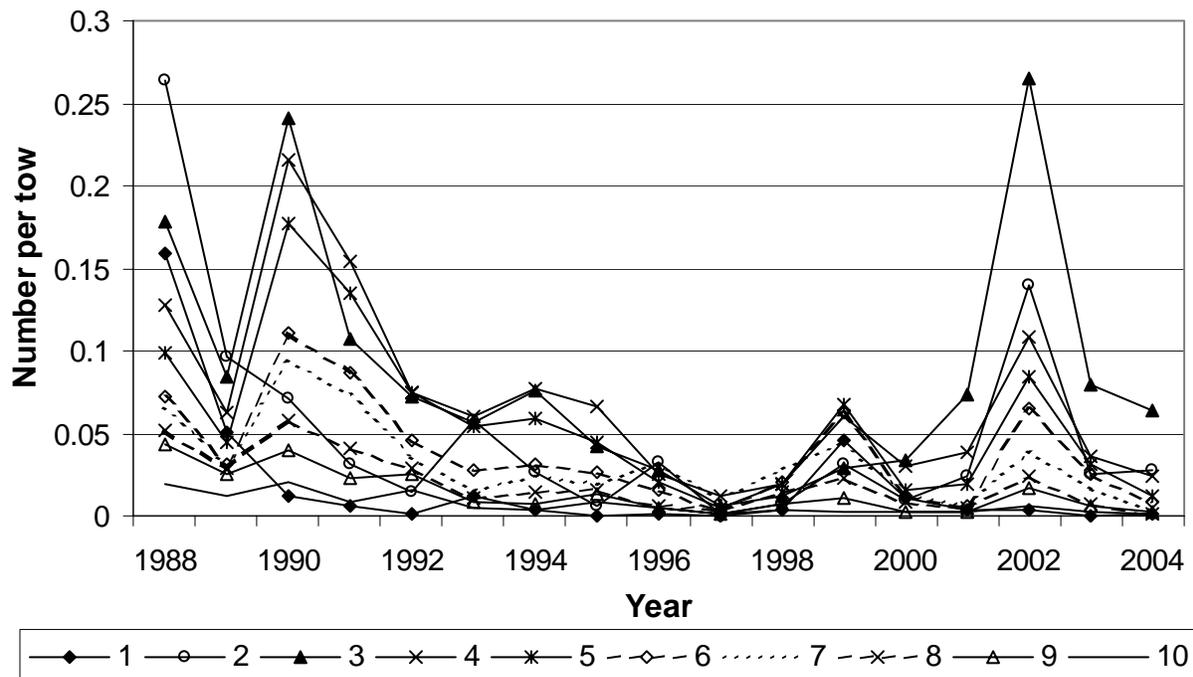
Figure 7. Cross Sectional Fishing Mortality (ages 7 - 12) Estimated from New Jersey's Recreational Fishery
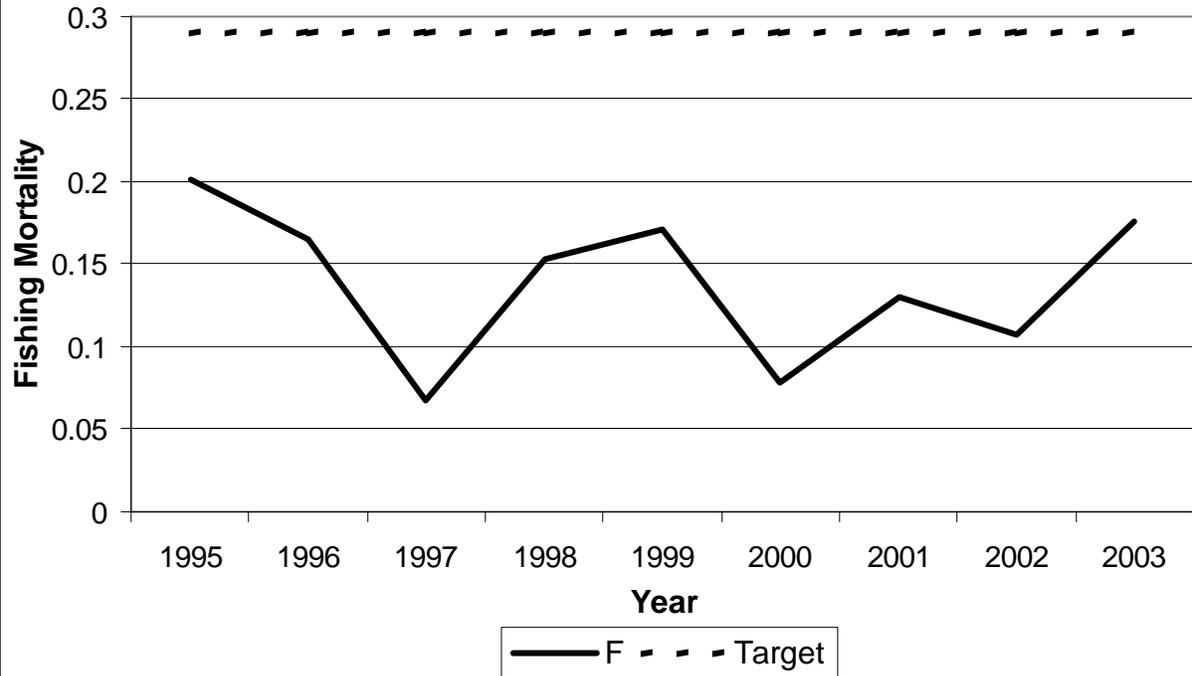
Figure 8. Longitudinal Fishing Mortality (ages 7 - 12) Estimated from New Jersey's Recreational CPUE
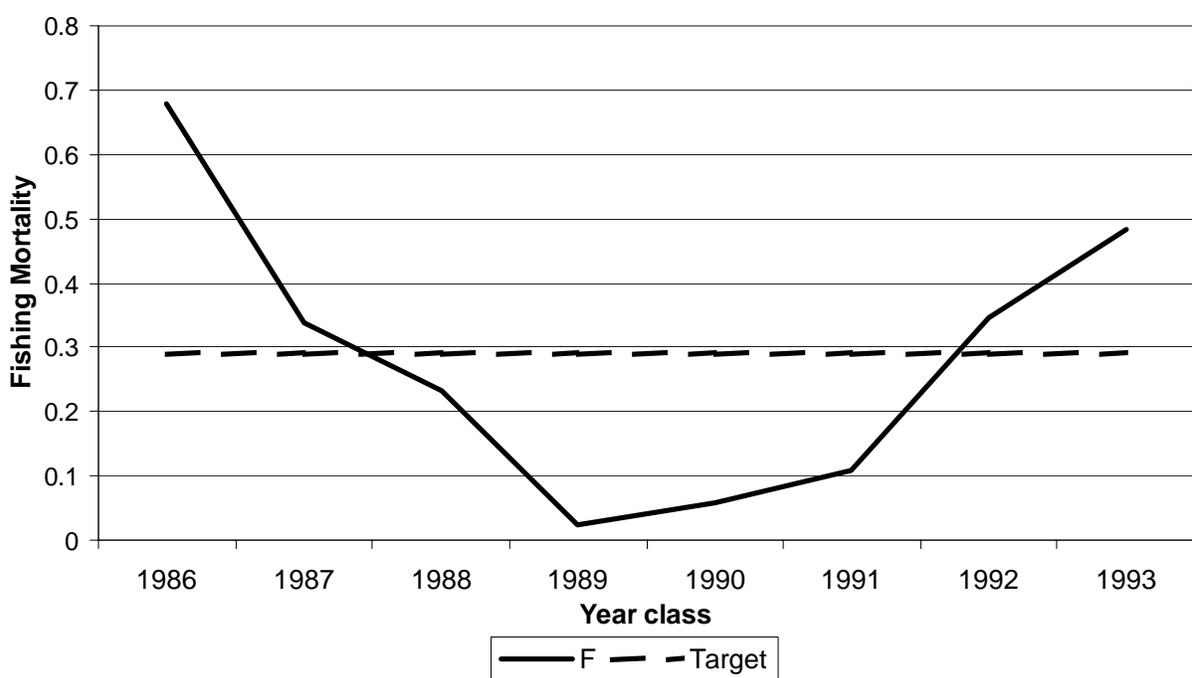
Figure 9. Longitudinal Fishing Mortality (ages 6-11) Estimated from New Jersey's Trawl Survey CPUE

Figure 10. Relative F Estimated From New Jersey's Recreational Fishery Using Recreational and Trawl CPUE

Appendix G. Delaware Status Report

2005 Status of the Resident Tautog Stock of the State of Delaware
Richard Wong
Delaware Division of Fish and Wildlife
Department of Natural Resources and Environmental Control

Introduction

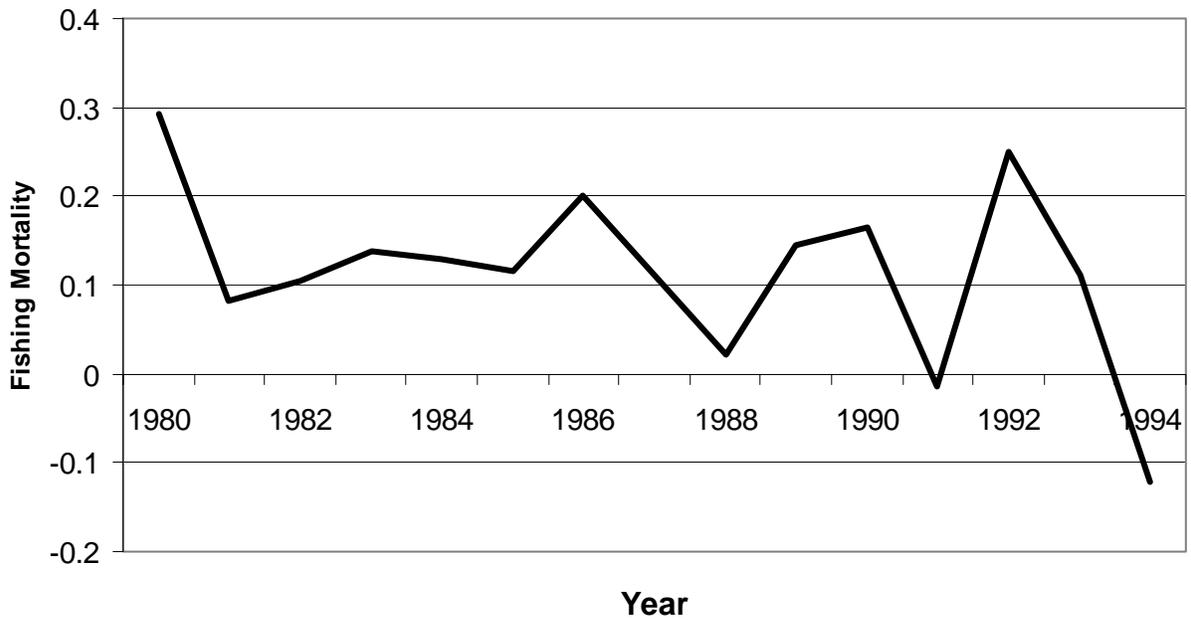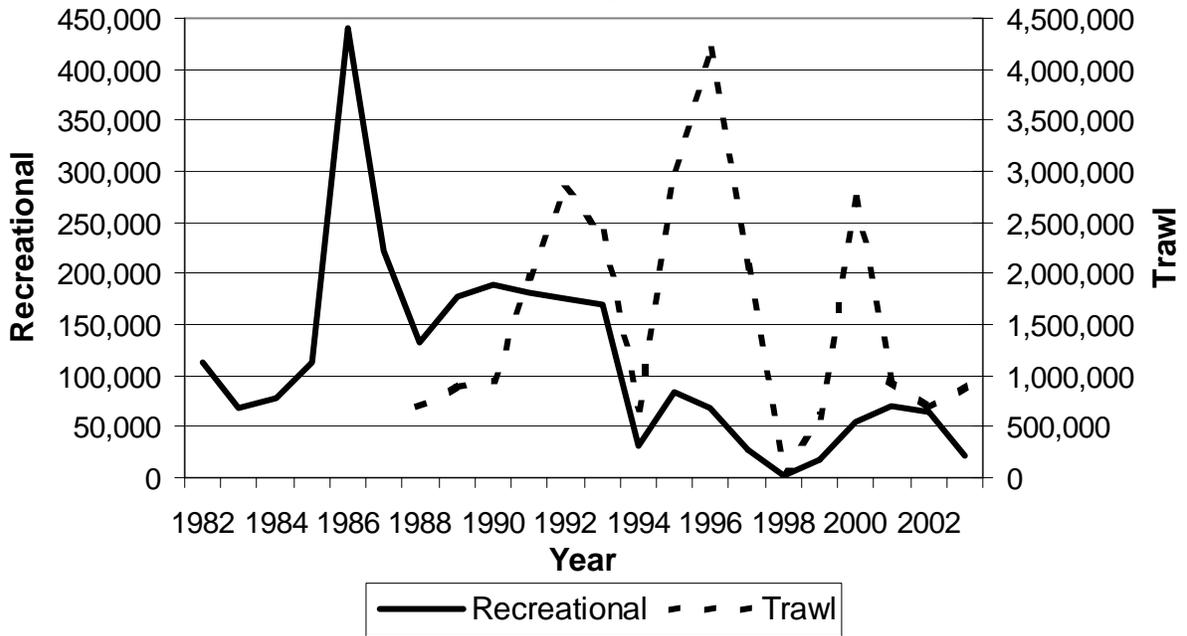Given the localized movement patterns associated with tautog, *Tautoga onitis* (Cooper 1964; Olla et al. 1979; Arendt et al. 2001), a stock evaluation of a discrete portion of the coastwide population was conducted by the State of Delaware. The status of the resident Delaware stock was investigated by examining long-term (1982-2004) fishery trends, and fishery age compositions and mortality rates over the period 1996 to 2004. This analysis is intended to complement the coastwide stock assessment by providing local information about stock trends and mortality rates for the Delaware region of the unit stock.

Recreational Fishery Harvest Trends

Annual recreational landings (Type A+B1) have been erratic since 1982, with sporadic, single-year peaks occurring in 1989 and 1995 (Figure 1). The 1982 to 2004 average was 102,536 individuals (Type A+B1), accounting for 5% of the coastwide average. Recent landings in 2002 and 2004 were slightly larger than normal (Figure 1). Numbers of angler-released fish (Type B2) have increased substantially since recreational harvest restrictions began in 1992 (Table 1).
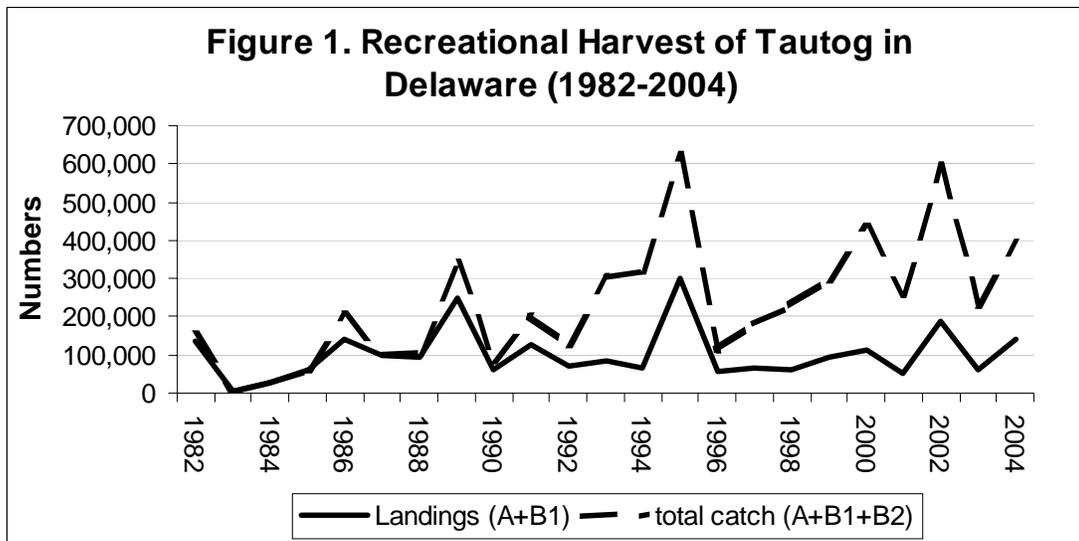
Figure 1. Recreational Harvest of Tautog in Delaware (1982-2004)

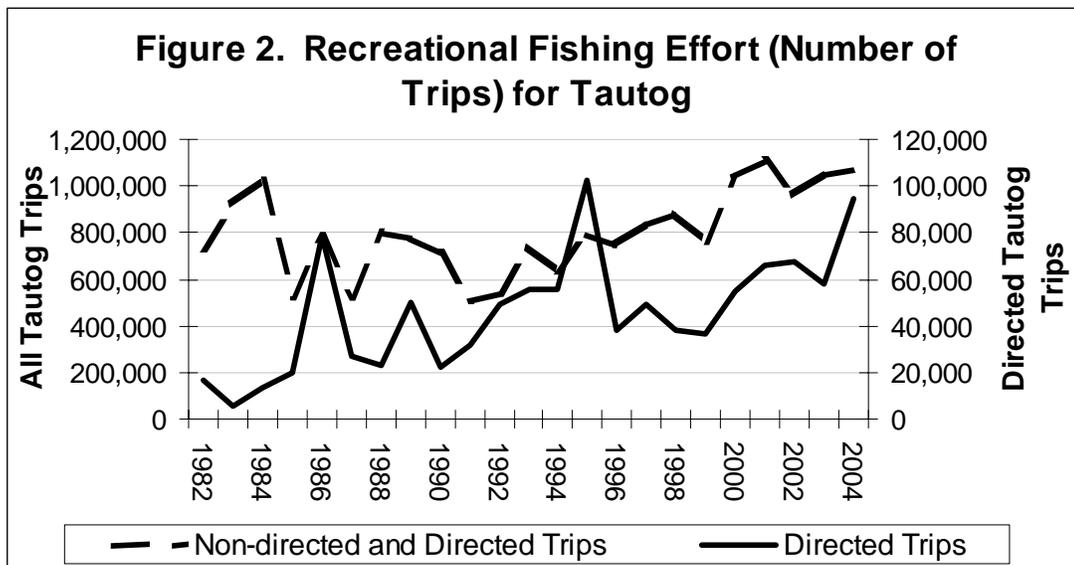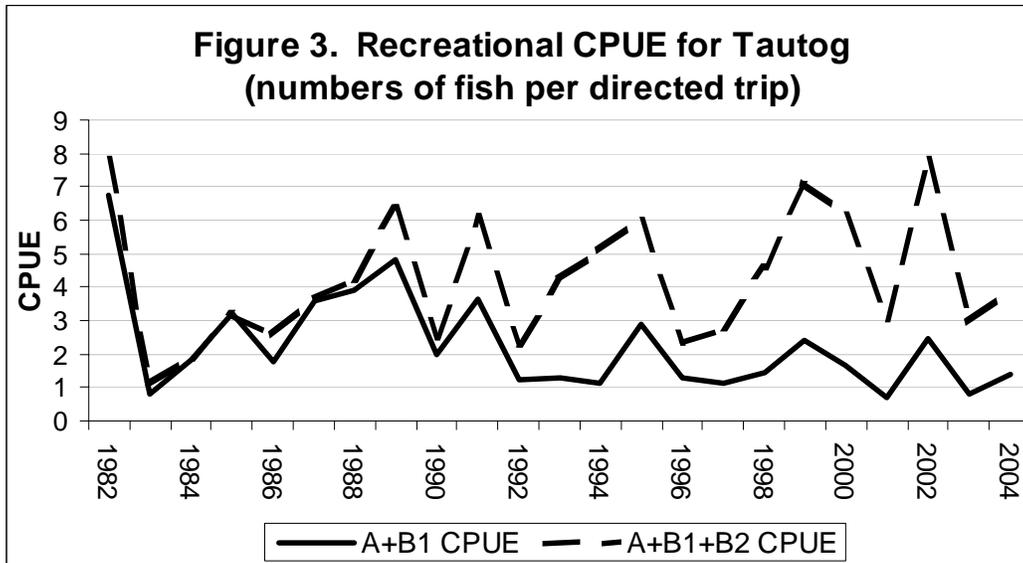Recreational fishing effort has increased over the time series. Directed fishing effort (defined as trips with tautog as the primary or secondary preferred species sought) has climbed since 1982 (Figure 2). Total catch (Type A+B1+B2) per directed trip has regularly fluctuated without directional trend, whereas landings (Type A+B1) per directed trip is generally lower than that seen in the 1980s (Figure 3). The

onset of size and harvest restrictions in the early 1990s coincides with the depressed, yet relatively, stable Type A+B1 CPUE.

Table 1. Chronology of management restrictions on the tautog fisheries in Delaware.

Year	Size Limit	Creel Limit	Season Closure	Limited Entry
1992	15" (Apr - Jun)	3 /day (Apr - Jun); 20 /day (Jul - May)	n/a	n/a
1993	15" (Apr - Jun)	3 /day (Apr - Jun); 20 /day (Jul - May)	n/a	n/a
1994	15" (Apr - Jun)	3 /day (Apr - Jun); 20 /day (Jul - May)	n/a	n/a
1995	15" (Apr - Jun)	3 /day (Apr - Jun); 20 /day (Jul - May)	n/a	commercial hook & line
1996	15" (Apr - Jun)	3 /day (Apr - Jun); 20 /day (Jul - May)	n/a	commercial hook & line
1997	15" (Apr - Jun)	3 /day (Apr - Jun); 20 /day (Jul - May)	n/a	commercial hook & line
1998	15" (Apr - Jun); 14" (Jul - Mar)	3 /day (Apr - Jun); 10 /day (Jul - Mar)	1-17 Sep	commercial hook & line
1999	15" (Apr - Jun); 14" (Jul - Mar)	3 /day (Apr - Jun); 10 /day (Jul - Mar)	1-17 Sep	commercial hook & line
2000	15" (Apr - Jun); 14" (Jul - Mar)	3 /day (Apr - Jun); 10 /day (Jul - Mar)	1-17 Sep	commercial hook & line
2001	15" (Apr - Jun); 14" (Jul - Mar)	3 /day (Apr - Jun); 10 /day (Jul - Mar)	1-17 Sep	commercial hook & line
2002	15" (Apr - Jun); 14" (Jul - Mar)	3 /day (Apr - Jun); 10 /day (Jul - Mar)	1-28 Sep	commercial hook & line
2003	15" (Apr - Jun); 14" (Jul - Mar)	3 /day (Apr - Jun); 10 /day (Jul - Mar)	1-28 Sep	commercial hook & line
2004	15" (Apr - Jun); 14" (Jul - Mar)	3 /day (Apr - Jun); 10 /day (Jul - Mar)	1-28 Sep	commercial hook & line

Figure 2. Recreational Fishing Effort (Number of Trips) for Tautog

Figure 3. Recreational CPUE for Tautog (numbers of fish per directed trip)

Commercial Fishery Harvest Trends

Commercial fishery landings are minimal in Delaware, accounting for 0.3% of the recreational fishery landings. Annual commercial landings in Delaware have averaged 454 kg and account for 0.16% of the coastwide commercial total from 1982 to 2004. An increase in landings has occurred in the most recent two years (2003-2004 average = 1,241 kg) (Figure 4), equal to 1% of the coastwide total during this period. Commercial restrictions have been consistent with recreational restrictions since the onset of tautog management in 1992. Limited entry into the commercial hook and line fishery began in 1995.

Figure 4. Commercial Landings (kg) of Tautog in Delaware (1982-2004)
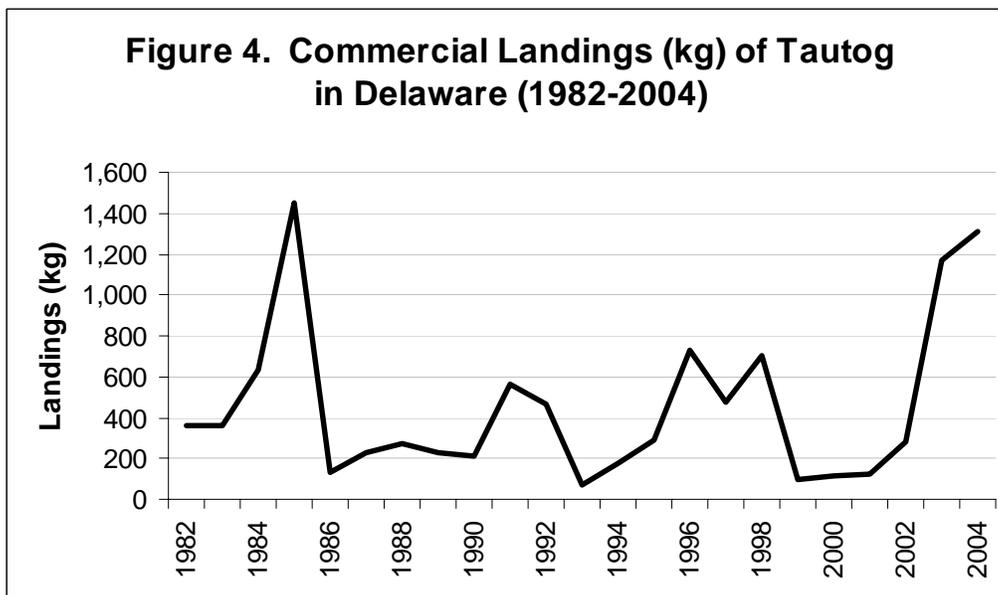
Recreational Fishery Age Compositions

Yearly, fishery age compositions were determined from opercles sampled directly from recreational charter boat landings. Annual collections of opercles occurred in two discrete periods, from May to June

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and September to October, to represent the seasonal pulses of recreational fishery landings in the state (Figure 5).

Figure 5. Percentage of Annual Recreational Landings by Wave (1996-2004)
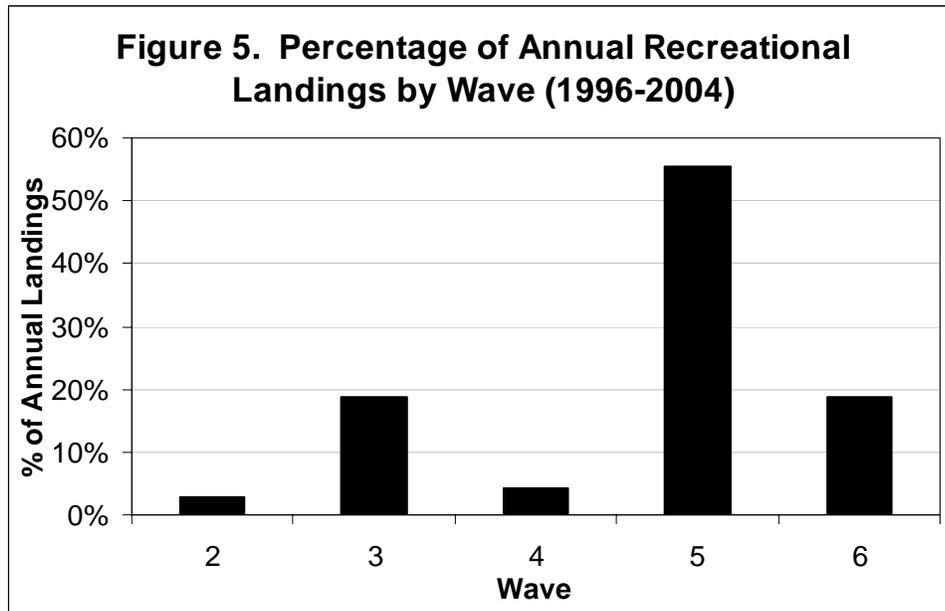
There is a wide age distribution in the fishery, although older age classes appear to decline in frequency through time (Table 2). Reduced sample sizes, however, may have affected the truncated age distribution observed in 2001 to 2003. Also, an unusually smaller proportion of the charter fishery landings occurred in offshore areas (relative to inshore waters) in 2002, which currently has an unbeknownst effect on the age distribution.

Table 2. Annual age compositions of the recreational charter boat fishery (DE Div. Fish & Wildlife).

Age	1996	1997	1998	1999	2000	2001	2002	2003	2004
2	6								
3	33		1		131	33		5	8
4	25	2	13		74	75	50	29	113
5	19	29	57	40	91	30	113	55	180
6	14	154	166	81	60	14	53	47	102
7	5	134	117	167	82	8	27	38	51
8	4	87	79	116	50	3	15	21	14
9	1	39	33	59	14	5	9	13	15
10		23	27	27	8		4	10	7
11	1	13	18	15	4		2	9	6
12		5	4	8	4		3	3	8
13		8	3	2				3	3
14	1	3	3	1	1			1	2
15		3	1					1	1
16		1		1					2
17		2							
18		1				1			
19		1	1						
20	1	1	1						
21		1		1					
23		1							
n	110	508	524	518	520	168	276	235	512

Calculations of Z from Catch Curves

Instantaneous total mortality rates (Z) were calculated from catch curve analyses of the recreational fishery catch-at-age distributions from 1996 to 2004. Two catch curve approaches for calculating Z were employed based on the declining log-transformed catch-at-age (descending limbs) across 1) multiple cohorts within a single year (hereby referred to as cross-sectional catch curves), and 2) across adjacent years following a single cohort through time (hereby referred to as longitudinal catch curves). The descending limb of the catch curve was composed of ensuing ages to the right of the age of maximum catch (Ricker 1975; Hilborn and Walters 1992), and further restricted to sample sizes of at least 5 aged specimens (Pauly 1984). Annual recreational catch per unit effort (Type A+B1 landings per directed trip) was used in order to standardize effort across years in the longitudinal catch curve analysis.

<u>Cross-sectional catch curve analysis</u>

Annual instantaneous total mortality rates averaged Z=0.49 from 1996 to 2004. Given the management target of Z=0.44 (based on $(F_{target} + M) = 0.29 + 0.15$), the Delaware portion of the coastwide population appears to be near its recommended mortality rate (Figures 6, 7). Instantaneous fishing mortality rates, assuming a constant natural mortality rate (M =0.15), have averaged F =0.34 (Table 3). Unfortunately, no information about annual recruitment or fishing vulnerability across fully recruited ages is available.

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Also, the age distribution in some years may have been spuriously affected by low collection numbers of age samples. These caveats should be considered when interpreting these results.

Figure 6. Annual Instantaneous Total Mortality Rates Based on Within-Year Catch Curves (1996-2004)
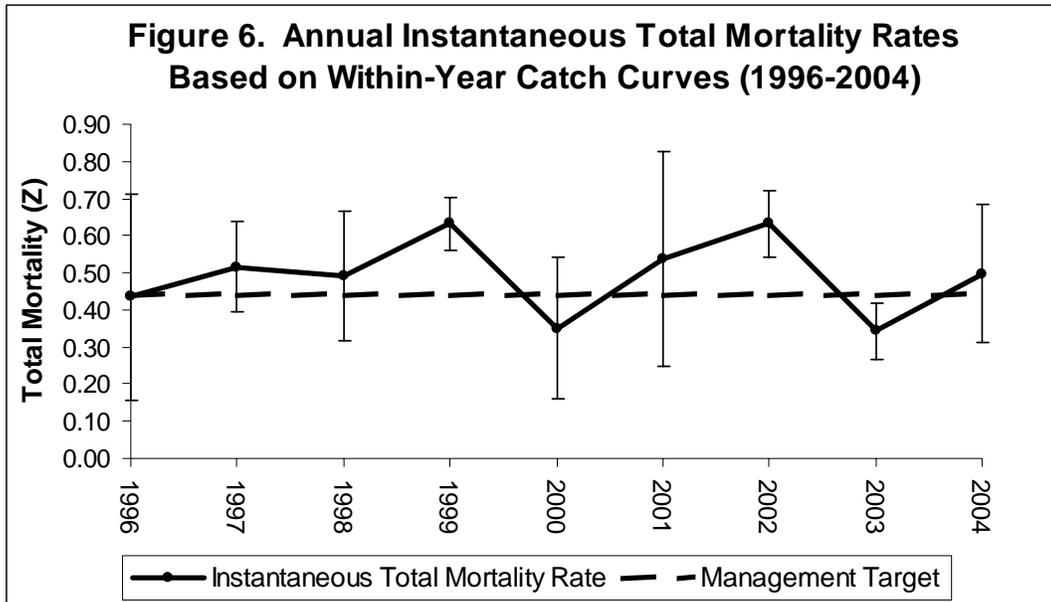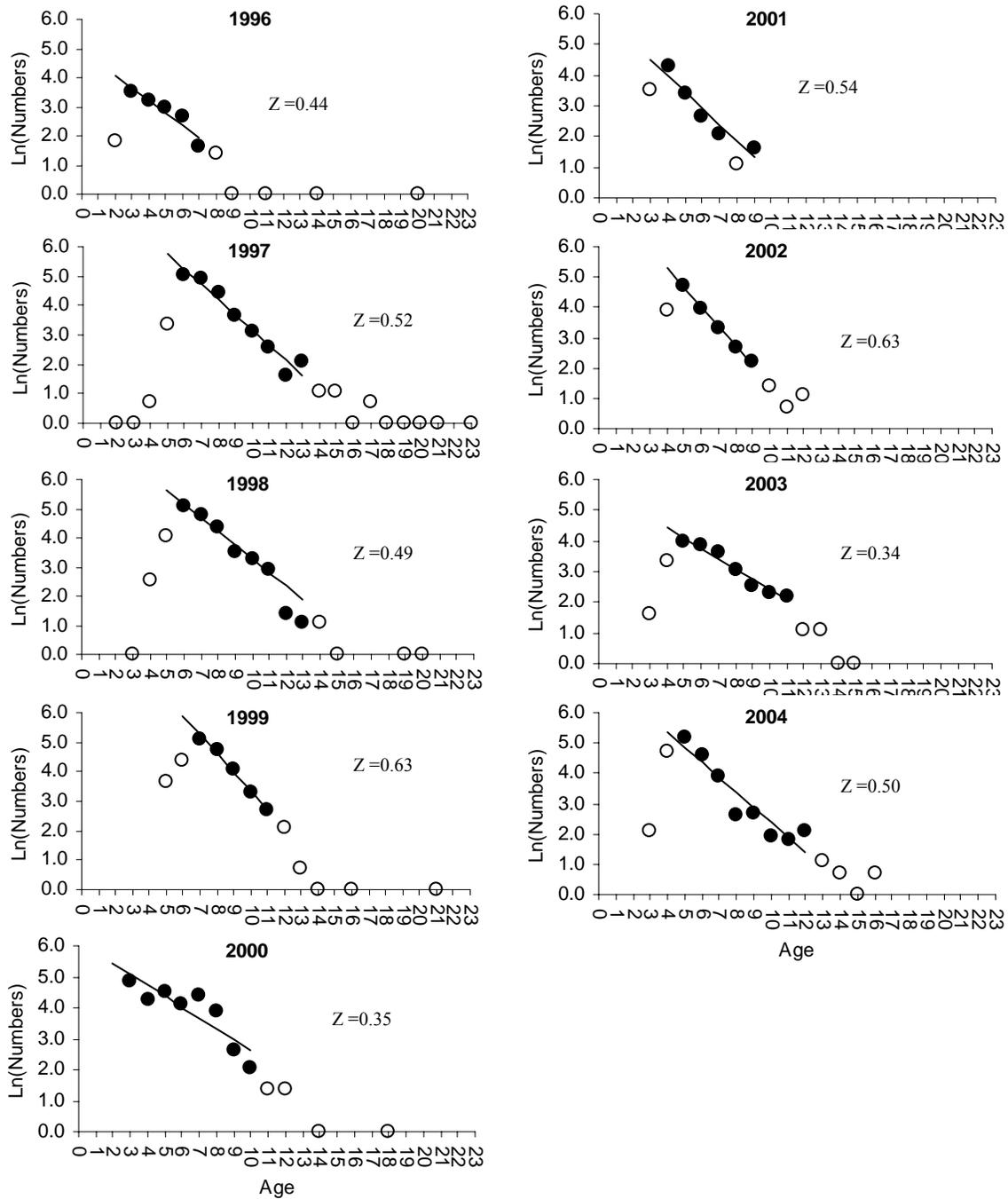
Figure 7. Cross-sectional catch curves for years 1996 to 2004. Dark circles describe the descending limb. Open circles indicate data points not used in the slope calculations.

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Table 3. Cross-sectional catch curve statistics and Z and F calculations.

Year	Descending limb	Slope	Lower 95.0%	Upper 95.0%	R 2	Regression Significance (P value)	Z	F
1996	3 to 7	-0.44	-0.71	-0.16	0.89	0.015	0.44	0.29
1997	6 to 13	-0.52	-0.64	-0.39	0.95	0.0001	0.52	0.37
1998	6 to 10	-0.49	-0.66	-0.32	0.96	0.003	0.49	0.34
1999	7 to 12	-0.63	-0.70	-0.56	0.99	0.00002	0.63	0.48
2000	3 to 10	-0.35	-0.54	-0.16	0.77	0.004	0.35	0.20
2001	4 to 7, 9	-0.54	-0.83	-0.25	0.92	0.010	0.54	0.39
2002	5 to 9	-0.63	-0.72	-0.54	0.99	0.0002	0.63	0.48
2003	5 to 11	-0.34	-0.42	-0.27	0.96	0.0001	0.34	0.19
2004	5 to 12	-0.50	-0.68	-0.31	0.88	0.001	0.50	0.35

Limiting the results of the longitudinal catch curve analysis to cohorts with at least four data points in its descending limb produced Z values that appear to decline across the 1990 to 1995 cohorts (Figure 8). The average Z calculation for these six cohorts was Z =0.55, albeit with considerably high uncertainty associated with individual slopes and low coefficient of determination R^2 values (Table 4; Figure 9). The non-linearity of these catch curves suggests that either mortality is not constant across age classes, vulnerability to the fishery changes across age classes, or perhaps data are too sparse or unreliable for this analysis.

Figure 8. Calculations of Instantaneous Total Mortality Rates (Z) for the 1990 to 1995 Cohorts.
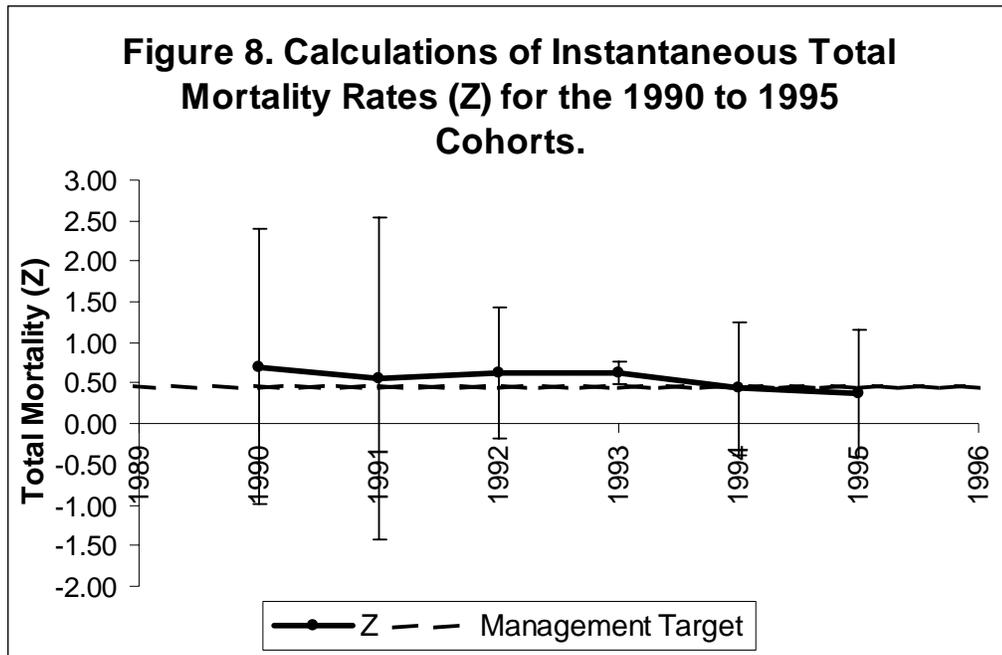
Table 4. Longitudinal catch curve statistics and Z and F calculations.

Cohort	Descending limb	Slope	Lower 95.0%	Upper 95.0%	R 2	Regression Significance (P value)	Z	F
1990	7 to 10	-0.71	-2.40	0.99	0.62	0.22	0.71	0.56
1991	6 to 9	-0.55	-2.53	1.43	0.42	0.35	0.55	0.40
1992	7 to 9, 11 to 12	-0.63	-1.44	0.18	0.67	0.09	0.63	0.48
1993	6, 7, 9 to 11	-0.64	-0.78	-0.50	0.99	0.0007	0.64	0.49
1994	6 to 10	-0.43	-1.25	0.39	0.49	0.19	0.43	0.28
1995	5 to 9	-0.37	-1.15	0.41	0.43	0.23	0.37	0.22

Figure 9. Longitudinal catch curves for the 1990 to 1995 cohorts. Dark circles describe the descending limb. Open circles indicate data points not used in the slope calculations.

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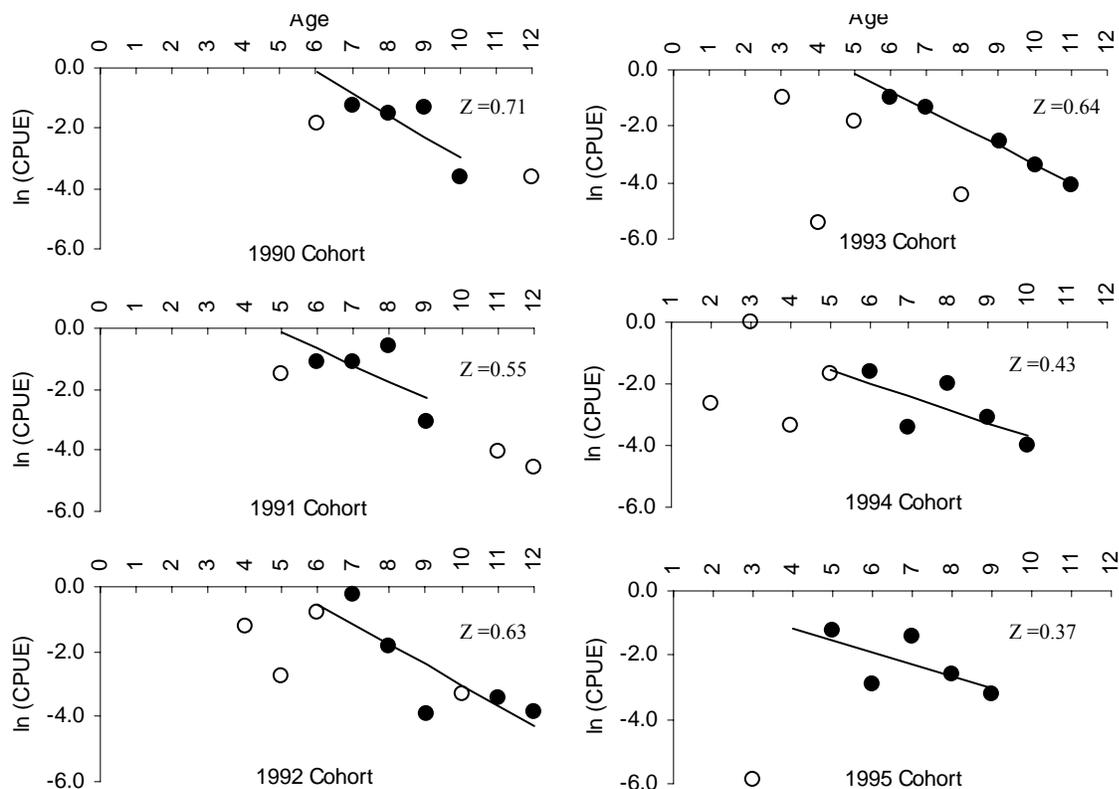
Results from the longitudinal catch curve analysis can be strongly affected by the quality of the annual MRFSS estimates of directed CPUE, potential age distribution biases associated with low sample sizes in certain years, and unknown age-related catchability patterns across fully-recruited age classes.

Summary

The status of the resident tautog stock of Delaware is uncertain given only fishery-dependent information, yet positive signs of unexpanded long-term fishery landings, regularly fluctuating (yet non-declining) recreational total catch CPUE, and consistent (if not declining) short-term mortality rates near the management target lessen imminent concern for the stock. However, the decline of older age classes (>6 years old) in recent years and rising fishing effort might be indicators of potential overfishing on the stock. Larger sample sizes taken from the recreational fishery landings in upcoming years should illuminate whether this observed age truncation was a sampling artifact or perhaps a true sign of overfishing and/or an overfished state.

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**Tautog (*Tautoga onitis*) Stock Status in Maryland Waters,
Report to the Atlantic States Marine Fisheries Commission – 2004**

by

**Harry T. Hornick
and
Lisa D. Warner**

FISHERIES SERVICE

July 2005

Introduction

This document is an effort by the Maryland Department of Natural Resources to determine local stock status of tautog (*Tautoga onitis*) as part of the Atlantic States Marine Fisheries Commission (ASMFC) Tautog Stock Assessment process.

Tautog are caught primarily in the Atlantic ocean off Maryland and rarely in Chesapeake Bay. In 1998, Maryland imposed a daily harvest limit of five fish per day and a minimum size limit of 14 inches total length (TL) for both the commercial and recreational fisheries. In 2003, a regulation change by the Maryland Department of Natural Resources (MD DNR) was enacted to comply with Amendment 2 to the Tautog Fisheries Management (FMP) Plan. This action closed the recreational fishery during the month of December. These regulations remained for 2005.

Fisheries Dependent Data

Recreational Fishery

Maryland has a relatively limited tautog fishery, ranked 8th coast wide in recreational harvest. Recreational harvest and release totals, in numbers, for Maryland is presented in Table 1. Mean number of harvested and caught and released tautog was 44,539 fish per year. Further analysis will be conducted on tautog recreational CPUE for Maryland.

Trends

Landings presented in Addendum III to the FMP indicated that Maryland ranked 8th coast wide in recreational harvest.

Commercial Fishery

The dominant gear type for Maryland commercial fishermen are fish pots/fish traps, which average over 95% of the harvests. Other gear types used are spear fishing, trawls and hook & line. Harvest from all gears combined for Maryland commercial fishermen averaged 2,913 pounds from 1993 to 2004, and ranged from 33 pounds to 10, 608 pounds (Figure 1). Biological samples were collected mainly from fish pots and by spear fishing (Table 2). Length frequencies and age frequencies for data collected from the commercial fishery are presented in Figures 2 and 3.

Trends

Landings presented in Addendum III to the FMP indicated that Maryland ranked 7th coast wide in commercial harvest. The commercial fishery for tautog in Maryland waters averaged approximately 2,213 pounds between 1993 and 2003. The 2004 fishery had the highest commercial landings for the past twelve years with 10,608 pounds. Preliminary commercial CPUE estimates from the fish pot fishery were fairly low from 1993 through 2000 (Figure 4). In 2001, CPUE increased dramatically, while the concurrent commercial harvest was actually near the ten-year average.

Regulation Changes

In 1998, Maryland imposed a daily harvest limit of five fish per day and a minimum size limit of 14 inches total length (TL) for both the commercial and recreational fisheries. In 2003, a regulation change by the Maryland Department of Natural Resources (MD DNR) was enacted to comply with Amendment

2. This action closed the recreational fishery during the month of December. These regulations remained for 2004 with no proposed management changes for 2005. The current regulations are:

An individual may not catch or possess:

        A tautog less than 14 inches total length;
        More than five tautog per day; and
        A tautog in the month of December.

Gear Restrictions: A pot or trap used to catch tautog shall have hinges or fasteners on one panel or door made of one of the following degradable materials:

        Untreated hemp or jute string 3/16 inch in diameter or smaller;
        Magnesium alloy fasteners; or
        Ungalvanized or uncoated iron wire of 0.094-inch diameter or smaller.

Fisheries Independent Data

MD DNR has conducted a fish population monitoring project in Maryland's coastal bays and near-shore Atlantic Ocean since 1972. Sampling was conducted along Maryland's coastal bays in areas greater than 1.0 meter (m) (3ft.) deep using a 4.9m (16 ft.) semi-balloon otter trawl with mesh sizes of 31.5mm (1.25") and 38.1 mm (1.5") and 13.0mm (0.50") mesh liner. Trawls were towed for six minutes at a speed of 3.0 knots at 20 fixed sites monthly from April through October.   The annual geometric means for juvenile tautog sampled from 1972 through 2004 are presented in Figure 5.   This survey may not be suitable for providing an accurate indication of Maryland tautog recruitment or stock size due to the near-shore nature of the survey.

However, further examination of the data will be conducted to determine the potential utility of this survey and its impact on Maryland tautog stock assessment activities.

Table 1. Recreational harvest and release totals, in numbers, for Maryland from 1982 through 2004.

YEAR	MD RECREATIONAL HARVEST
1982	35,105
1983	2126
1984	42835
1985	486
1986	5476
1987	90523
1988	107,570
1989	34,709
1990	45,467
1991	26,770
1992	106,255
1993	60,231
1994	157,260
1995	43,542
1996	9,695
1997	85,682
1998	6,512
1999	20,180
2000	20,129
2001	23,715
2002	42,038
2003	13,555
2004	19,977
MEAN HARVEST	**44,539**

Table 2. Tautog stock assessment sample collection summary for Maryland, 1999 – 2004.

Gear Type	1999	2000	2001	2002	2003	2004
Fish Pots	132	294	233	160	380	297
Spear	103	54	19	104	---	41
Trawl	---	---	---	---	---	---
Hook/Line	---	---	---	---	---	---
Gillnet	---	---	---	---	---	---
TOTAL	235	348	252	265	380	338

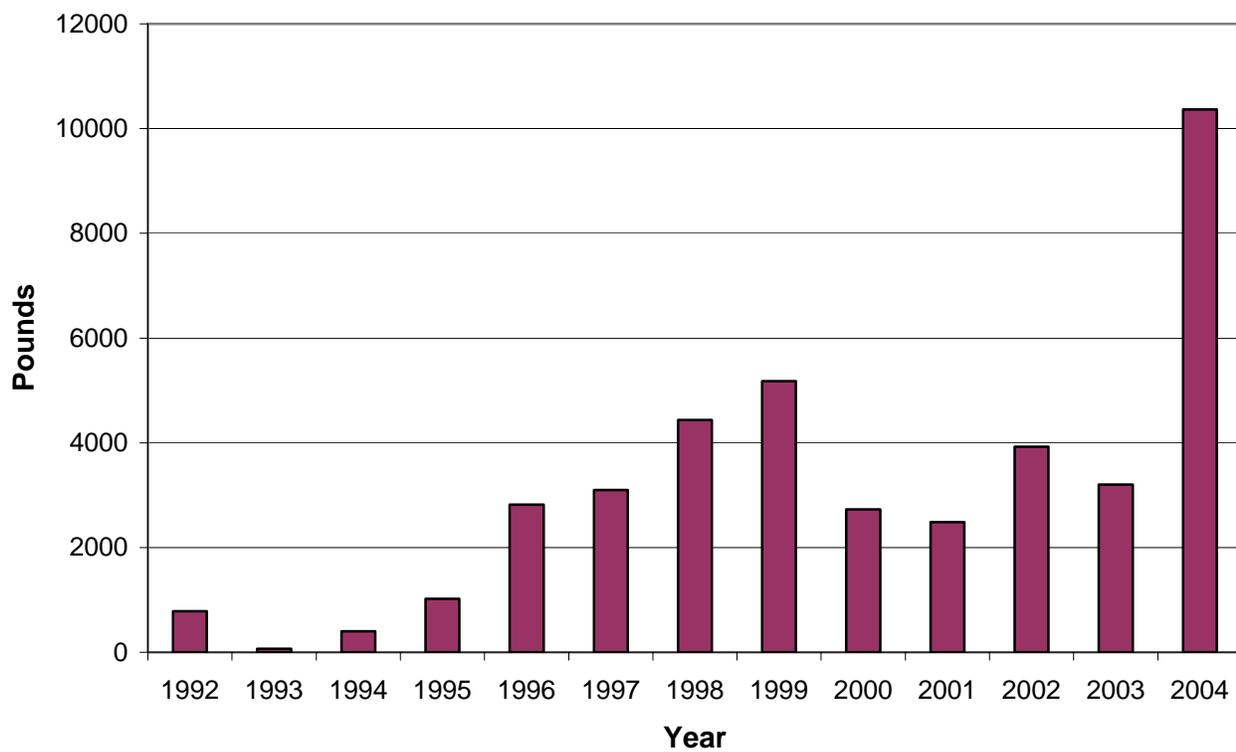# Figure 1. Commercial tautog landings reported to Maryland DNR, 1992-2004

Figure 2. Annual length frequency distributions of tautog sampled from Maryland commercial fishermen, from 1999 to 2004.
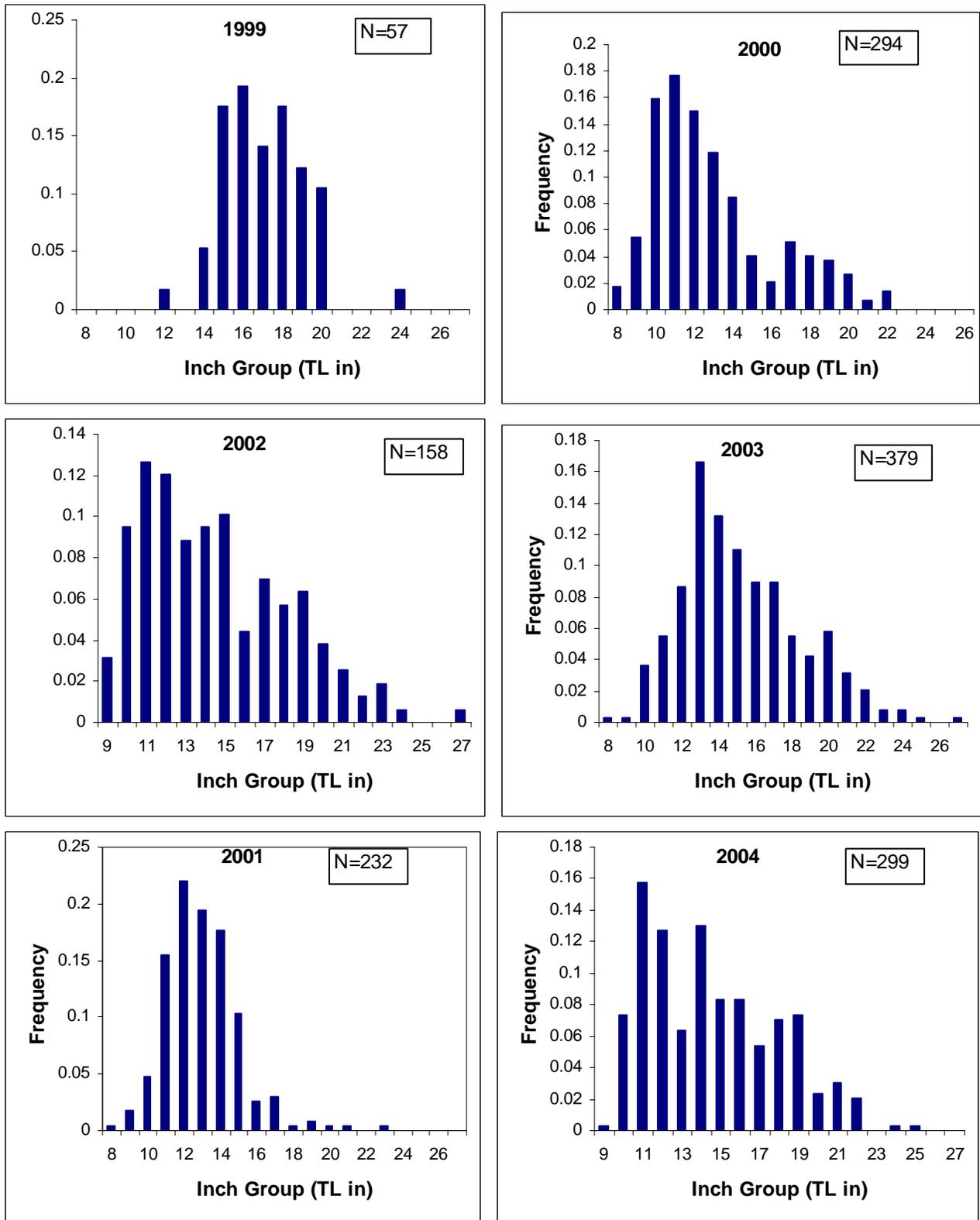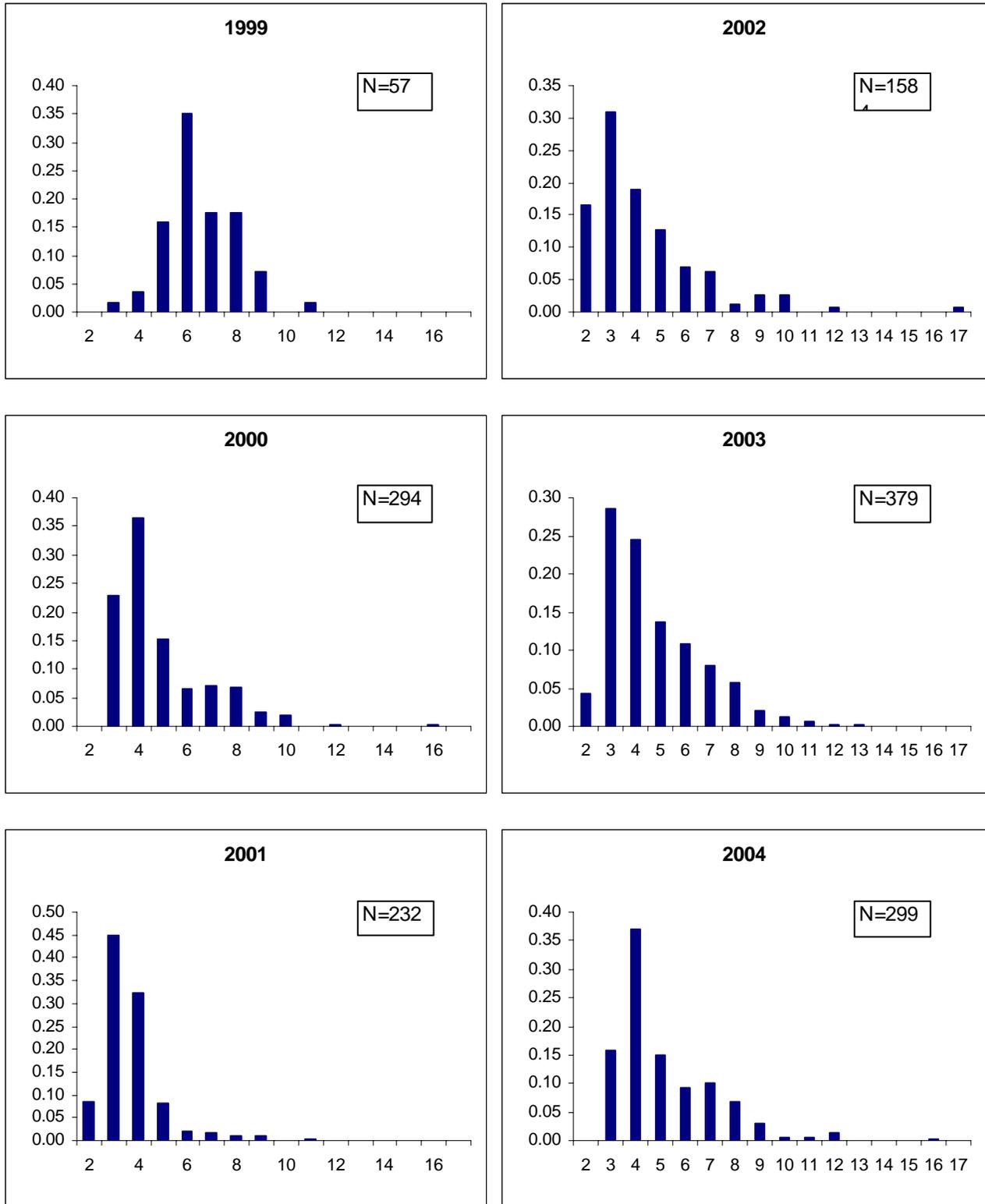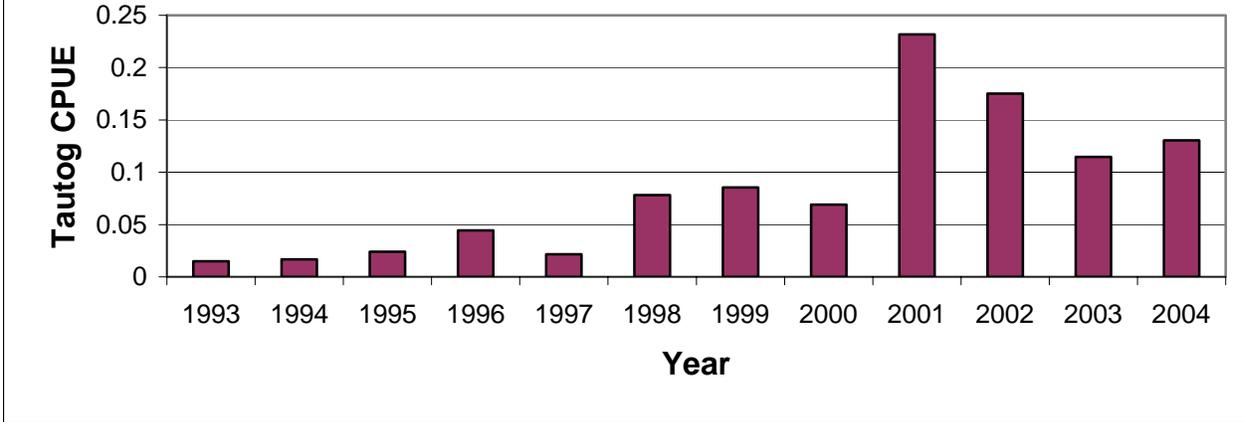
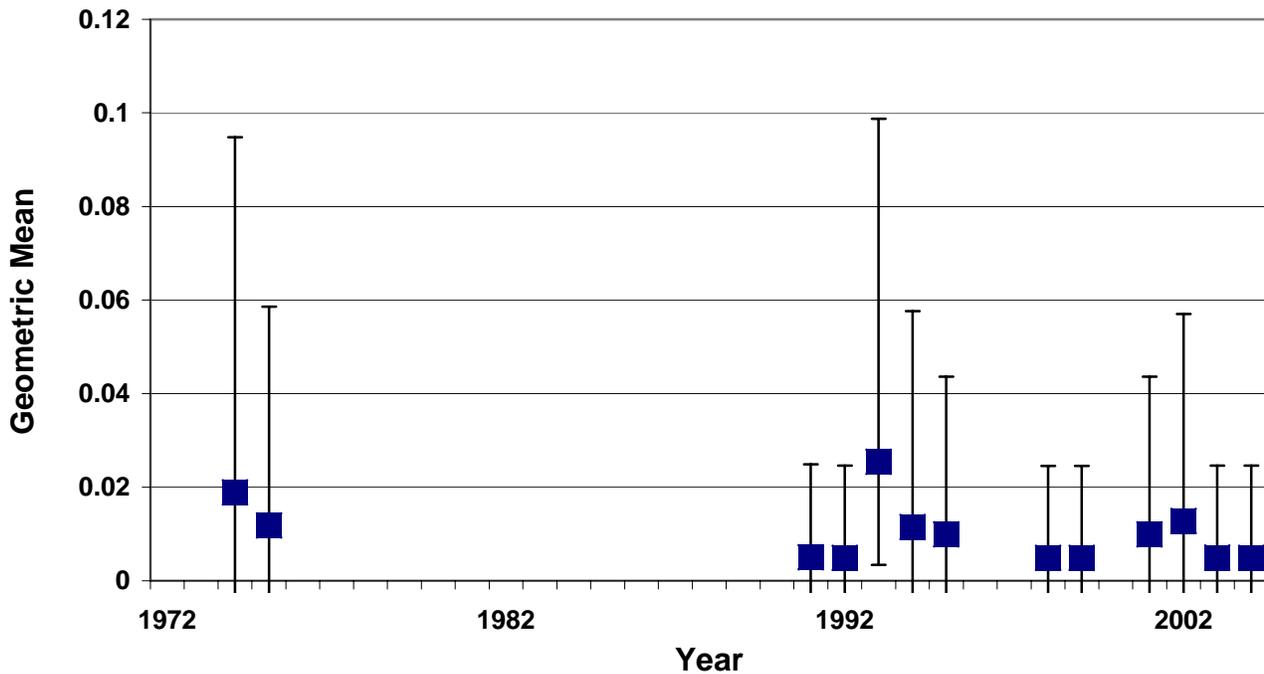Figure 3. Annual age frequency distributions of tautog sampled from Maryland commercial fishermen, from 1999 to 2004

Figure 4. Commercial Fish Pot CPUE Estimates For Tautog By Year For Maryland, 1993 to 2004

Figure 5. Maryland Coastal Bays geometric mean s(GM) catch per haul and 95 % confidence intervals (+/- 2se) for juvenileTautog 1972 to 2004

Appendix I. Virginia Status Report

Introduction

This document is an attempt to determine local stock status as part of Atlantic States Marine Fisheries Commission (ASMFC) Tautog Stock Assessment process. Previous assessment of the tautog stock was done under a coast wide VPA. Although the VPA will be updated with the upcoming stock assessment, it is the general consensus of the Technical Committee and Stock Assessment Sub-committee that tautog populations are regionally discrete. Tautog recapture rates from the Virginia Game Fish Tagging Program (VGFTP), as well as, a Virginia Institute of Marine Science (VIMS) acoustic telemetry tagging study confirm this assumption.

Fisheries dependent data

Recreational fishery

Prior to regulations imposed by the ASMFC FMP in 1996, recreational harvests (A+B1 catch) averaged just over 228,000 fish per year for the period 1982-1995 (1982 has the lowest landings at 71,599 fish and 1983 the highest at 579,795 fish). The average harvest of the years 1984-1996 (94-96 landings very similar) is 212,424 fish. The harvest average for 1997-2004 is 65,505 fish. 2003 and 2004 have shown large increases in MRFSS numbers.

Trends

Addendum III to the FMP illustrated that from 1996 through 2000, Virginia ranked in the top 3 of the 9 states included in the FMP for recreation landings (A + B1). According to MRFSS data for that period Virginia ranked 2nd by poundage and 3rd by number of fish. A ranking of the 9 states for the years 1998 through 2004, again using MRFSS data, shows that Virginia's rank has dropped to 7th.   As noted in Addendum III there are several other factors that may play a role in following recreational harvest and effort trends, including but not limited to: changes in restrictions to harvest alternate target species (such as striped bass) and the imprecision of recreational fisheries data.

Commercial fishery

The commercial fishery averaged 1.4 mt between 1980 and 1993. The fishery saw an increase in the mid-1990s that has remained consistent through to the present. 1994- 2004 mean of 8.2 mt. 1995 had the highest commercial landings for the 25-year period (27,760 pounds).

Trends

The increased commercial landings that began in 1994 are directly associated with an increase in hook and line landings, and do not show any effect from the regulations that went into place with the FMP. Using VMRC mandatory reporting data for the period 1994-2004, landings from hook and line account for an average of 80% of total commercial landings. Due to the opportunistic nature of the fishery, seasonal closures and possession limits may not be a constraint for commercial landings.

Regulation changes

In May 1997 Virginia established a 13" minimum size for both fisheries. The commercial fishery was closed from May 1 through August 31; also a gear restriction was added that any fish pot must include a door or panel fastened with degradable materials. In accordance with FMP requirements, Virginia

increased the minimum size to 14", effective April 1 1998. The recreational season was closed from May 1 through June 30 with a 10 fish possession limit. Effective January 1, 1999 the recreational fishery went to a 7 fish possession limit and no closed season. The 7 fish possession limit with no closed season has remained in effect since 1999; the commercial closed season and gear restriction have stayed the same since 1997. (Table 1)

Table 1. History of Tautog Management in Virginia.

IMPLEMENTATION DATE	FISHERY	SIZE LIMIT (inches)	POSSESSION LIMITS	CLOSED SEASONS	GEAR RESTRICTION
1 MAY 1997	RECREATIONAL	13"			ANY FISH POT/TRAP MUST BE CONSTRUCTED WITH HINGES AND FASTENERS ON ONE PANEL MADE OF DEGRADABLE MATERIALS
1 MAY 1997	COMMERCIAL	13"		1 MAY - 31 AUGUST	
4 APRIL 1998	RECREATIONAL	14"	10	1 MAY - 30 JUNE	
4 APRIL 1998	COMMERCIAL	14"	10	1 MAY - 31 AUGUST	
1 JANUARY 1999	RECREATIONAL	14"	7		
1 JANUARY 1999	COMMERCIAL	14"		1 MAY - 31 AUGUST	

Fisheries Independent Data

In accordance with FMP sampling protocol, Virginia's Stock Assessment Program (SAP) has been collecting biological data on finfish since 1988. In 1998, the SAP, in cooperation with Old Dominion University's Center for Quantitative Fisheries Ecology Laboratory, initiated removal of otoliths from 13 important finfish species, including tautog, in order to obtain age data. During 1998-1999, otoliths from over 400 tautog caught by commercial gear were collected to be analyzed for age information. Stock assessment has gone beyond compliance mandate in the past few years attaining more than 500 samples for 2003 and 2004. The aging samples also represent the fishery by gear and spatially. Assuming the vast majority of Virginia's recreational landings for tautog are hook and line as are the majority of commercial landings, the samples collected reflect this (Table 2).

Table 2. Stock Assessment Tautog Sample Collection Summary.

STOCK ASSESSMENT TAUTOG SAMPLE COLLECTION SUMMARY						
GEAR	1999	2000	2001	2002	2003	2004
HL	315	168	287	189	390	476
AGN	16	13	16	131	48	25
PN	4		16	42	13	5
FPOT				12	43	
UNK					16	
TOTAL	335	181	319	374	510	506

The Virginia Game Fish Tagging Program (VGFTP), started in 1995, is a cooperative effort of the Virginia Marine Resources Commission (VMRC) and the Virginia Institute of Marine Science (VIMS). Recreational anglers tag targeted species of marine game fish in order to provide scientific information

about the movements and biology of these fish. From 1995 through 2004, only three-recaptured tautog have been reported outside Virginia waters. Two fish were reported around Ocean City, MD and the mouth of the Delaware Bay and one at rock jetties at Oregon Inlet. Since 1995 there have been nearly 8,900 tautog tagged (over 3,000 greater than or equal to 14") and 1,410 recaptured tautog (individuals have remained at large for periods ranging from weeks up to four years) (Hoenig and Lucy 2004). The issue of stock discreetness is also supported by a 1998-1999 VIMS study of 27 tautog tagged with ultrasonic transmitters. The results show that the fish by and large exhibit fidelity to sites of initial capture. 15 of the 16 tautog released in fall 1998 remained inshore within the Bay during winter and 10 of 11 released in spring 1999 remained inshore within the Bay during summer (Ardent, Lucy, and Munroe).

VIMS has been conducting a fishery independent juvenile trawl survey since 1955 but does not collect enough tautog to derive an index of abundance. Currently, the survey samples approximately 35 Bay stations and 60 river stations. Between 1955 and 2003 there were a total of 311 tautog captured in the survey (average length of fish captured in this period is 289mm/11.4in). From 2000 through 2002 there were only 12 tautog captured. In 2003, seven individuals were captured. Data for 2004 is not available.

Stock status

Catch curve analyses have been used to show mortality rates in Virginia have remained below the target F=0.29, over the past seven years. Equilibrium cross-sectional catch curve analysis suggests a slight reduction in total mortality in recent years relative to the 1980s and early 1990s. Non-equilibrium catch curves were also constructed for the years (1997, 1999-2004) assuming that mortality may have changed over time. Without local independent data to confirm steady recruitment for Virginia's tautog stock, cross sectional catch curves cannot definitively demonstrate total mortality rates (Hoenig et al, 2005). However, recruitment estimates from the VPA do not show any decreasing trend over time throughout the northern management area and actually show an increase in biomass and recruitment in recent years (ASMFC 2002). An index of recruitment would be valuable for assessing cross-sectional catch curves. However, the absence of such an index should not preclude the use of a catch curve. Recruitment patterns from adjacent areas or even from the VPA might be useful in assessing if there is a recruitment problem. This is because for marine species the spatial correlation of recruitment is expected to extend over a considerable region (see Myers et al. (1997) who assert "Generally the spatial scale of recruitment correlations for marine species is approximately 500 km".). The results from the VPA concerning recruitment are consistent with the idea that recruitment in Virginia has not declined. Additionally, the MRFSS effort data showing lower fishing mortality in recent years (with a notable increase in only the last two years) supports the conclusion that fishing mortality has not risen above the target level. Fishing effort has risen in the last two years and, coincidentally, the extreme left-most two points of the (descending limb of the) catch curve are steep. This suggests that effort and mortality should be monitored to look for a sustained change.

Evaluating Localized vs Large-scale Management for Virginia Tautog (*Tautoga onitis)*

John Hoenig, Jon Lucy, Troy Tuckey and Noëlle Yochum

Virginia Institute of Marine Science, College of William and Mary, P.O. Box 1346, Gloucester Point, VA 23062

and

Robert O'Reilly and Joseph Cimino
Virginia Marine Resources Commission, 2600 Washington Avenue, Newport News, VA 23607

Abstract

The tautog stock complex from Virginia to Massachusetts has been assessed as one stock using a virtual population analysis. Estimated mortality of the stock has exceeded the target and resulted in mandated reductions in fishing effort. However, two states (Virginia and Rhode Island) have argued that mortality rates in their jurisdictions in recent years are below the target value and thus these states should be exempted from the reductions. In Virginia, cross-sectional catch curve analyses since 1996 consistently show mortality rates are less than the target and that the average mortality is slightly lower than it was in the 1980s and early 1990s. Tagging data show that Virginia tautog essentially do not move to other states thus providing a mechanism for localized mortality rates. Fishing effort estimates for Virginia from the Marine Recreational Fisheries Statistics Survey show a lower sport fishing effort over the last eight years than in previous years, consistent with Virginia having a decline in mortality rates. Ordinary catch curves are based on the assumption of equilibrium. A change in mortality rate is reflected in the catch curve only gradually (leading Ricker to observe that catch curves reflect "ancient history"). However, non-equilibrium catch curves have the potential to demonstrate changes in mortality over time. A change in mortality is reflected in the catch curve as a bend in the curve that moves progressively to the right over time. The slope of the catch curve at the extreme right provides an estimate of the previous mortality rate whereas the slope at the left (of the descending limb) reflects the new mortality rate. Non-equilibrium catch curves for 1997 and for 1999 through 2004 show recent mortality rates (left part of the curve) in Virginia to be consistently below the target. The catch curve results are also consistent with an alternative explanation that recruitment has declined in Virginia; however, there is no reason to suspect a long-term downturn in recruitment as recruitment estimates from the VPA do not show a decline and, additionally, the apparently lower mortality rates in Virginia in the period since 1996 are consistent with lower fishing effort. It might be argued that because of the theoretical possibility that recruitment has declined it would be conservative to impose a reduction on Virginia fishing effort. However, if Virginia mortality rates are lower than the stock-wide average, imposing a reduction in Virginia causes a loss of legitimate yield (yield consistent with the management goals) while failing to alleviate the overfishing elsewhere. Failure to alleviate overfishing where it is most pronounced is not conservative. Simple models used for localized assessment can thus have an advantage over a sophisticated model applied to an entire stock complex.

Introduction

The choice of management spatial scales is a critical step of any stock assessment. That decision depends upon the biology and behavior of the species and the operational considerations of the management policy. There are advantages and disadvantages of any choice of management unit that are strongly affected by the movement patterns of the species. We begin by reviewing the tradeoffs associated with few, large management units (large-scale management) compared with a greater number of small management units (localized management) and then discuss the tautog (*Tautoga onitis*) resource in Virginia.

Trade-offs associated with large-scale vs. localized assessment and management

There can be clear advantages to assessing a stock on a large-scale basis, i.e. treating a stock complex as a single unit for assessment and management (Table 1). When there is no significant spatial variability in population characteristics due to the fact that the stock is well mixed, large-scale analysis is appropriate and requires possibly less work since data compilation and analysis only need to be done once. A single stock management unit, when appropriate, also enables data from subunits to be used for estimating parameters for the whole stock complex. For example, to tune a Virtual Population Analysis (VPA) to obtain fishing mortality (F), it is appropriate to use a survey index of abundance from a portion of the species' range *provided* the index is representative of the entire stock complex. Additional advantages of defining a single stock unit arise from the aggregation of data from subunits within the management area. This results in potentially lower costs to gather data and possibly more precise parameter estimates.

If the stock-complex is managed as a single unit, but is comprised of sub-stocks that have real biological differences in terms of population parameters, then potential problems arise. The aggregation of data from the entire stock-complex results in estimated parameter values that represent averages spread across the spatial scale used in the analysis. If mangers use the average value as the target for all sub-stocks, then for some sub-stocks the restrictions will be too stringent, while in others the restrictions will not be sufficient to meet management goals, which will result in a loss of yield in both cases. Management regulations lacking spatial detail can potentially lead to localized serial depletion and lower recruitment.

One way to address the risks of large-scale single-stock analysis is to partition the management area into smaller spatial scales that reflect biologically meaningful units. While data requirements increase as stocks are separated into smaller spatial scales, the potential of localized serial depletion is reduced. Localized management may also result in stability of the fishery and help to maintain genetic diversity and productivity in sub-stocks. However, if the spatial scale is too small, external forces (immigration and emigration) may overwhelm any management effort. For example, if unlimited fishing of a mobile species were allowed in a small management area, immigration into the area may dominate over depletion due to fishing, resulting in a constant catch rate and leading to the incorrect conclusion that fishing has no effect on population density. An additional consideration is that parameter estimates from smaller spatial scales may have more variance and the reduction in data availability could make localized management unwarranted.

Tautog in Virginia

Fisheries dependent data

Recreational fishery (harvest and effort data based on MRFSS)

The majority of Virginia tautog landings (greater than 90%) result from the recreational fishery (ASMFC 2002). Prior to regulations imposed by the ASMFC fishery management plan (FMP) in 1996, recreational harvests (A+B1 catch) averaged just over 228,000 fish per year for the period 1982-1995 (1982 has the lowest landings at 71,599 fish and 1983 the highest at 579,795 fish) (Figure 1). The average harvest of the years 1984 to 1996 (1994-1996 landings are very similar) is 212,424 fish. The harvest average for 1997-2004 is 65,505 fish. 2003 and 2004 have shown large increases in MRFSS numbers.

Commercial fishery

The commercial fishery accounts for less than 10% of the landings. The commercial fishery was stable throughout the 1980s and early 1990s, averaging 1.4 mt between 1980 and 1993. From 1994 to 2004, the mean was 8.2 mt. 1995 had the highest commercial landings for the 25-year period, followed by 1996 (with the second highest) and 1997. 1998 saw a drop to 6.7 mt from 11.6 mt in 1997, which was associated with changes in the regulations. 2002 showed a spike, with landings exceeding 10 mt. 2003 and 2004 landings were similar to those of the 1980s and early 1990s.

Trends

Addendum III to the FMP illustrated that from 1996 through 2000, Virginia ranked in the top 3 of the 9 states included in the FMP for recreation landings (A + B1). According to MRFSS data for that period Virginia ranked 2nd by poundage and 3rd by number of fish. A ranking of the 9 states for the years 1998 through 2004, again using MRFSS data, shows that Virginia's rank has dropped to 7th.

Regulation changes

In May 1997, a 13" minimum size was established for both fishery sectors. The commercial fishery was closed from May 1 through August 31. In April, 1998, the minimum size was increased to 14". The commercial fishery kept the same closed season and the recreational season was closed from May 2 through June 30. Effective January 1, 1999, the recreational fishery went to a 7 fish possession limit and no closed season. This regulation has remained in effect (the commercial closure has stayed May 1-August 31).

Assessment and stock status

Beginning in the mid-1980s, tautog stock size began to decrease due to fishing pressure. To facilitate management of the stock, the Atlantic States Marine Fisheries Commission (ASMFC) adopted a fishery management plan for tautog in 1996 to rebuild spawning stock biomass by reducing fishing mortality. The ASMFC split the management region into two zones: a northern zone (MA, RI, CT, NY, NJ) and a southern zone (DE, MD, VA, NC). Since 1996, three addenda have been added to the management plan to reduce F and rebuild spawning stock biomass by creating minimum size and possession limits, gear restrictions, and closed seasons.

The ASMFC used a VPA to examine tautog stocks on a coast-wide basis (Table 2). Fisheries dependent data from MA to VA (and fisheries independent data from MA to NJ only) are aggregated and the entire stock is assessed resulting in annual estimates of abundance and fishing mortality by age and in annual estimates of recruitment (ASMFC 2002). If tautog are well mixed throughout the range and if the assumption that natural mortality (M) is constant throughout the stock is warranted, then extending the results of the VPA to include the southern zone is appropriate. However, if sub-stocks exist, then the VPA may mask real localized differences in estimated population parameters. For example, VPA will average F across the entire stock and not appropriately allocate mortality rates among sub-stocks. The result would be an overestimate of F in one area and an underestimate in another area that could lead to

ineffective management decisions and potentially to sub-stock collapse. The F calculated for the entire stock complex is not an unbiased estimate of the stock average because the estimate depends on which sub-stocks supply tuning indices and how those indices are weighted.

The most recent VPA (2001) using data from 1981 to 2000 showed that fishing mortality rates declined from 0.71 to 0.41 between 1993 and 2000. Despite the decrease, the estimated fishing mortality rate remained above the ASMFC target of F=0.29 ($F_{40\%SSB}$) established by the Tautog Plan Review Team (ASMFC 2002). As a result, the ASMFC mandated a reduction in fishing effort for all states in 2003. However, the age composition data used in the analysis were from the northern zone and a lack of sufficient data from states south of NJ prevented a regional assessment based on VPA for this zone.

The Virginia Marine Resources Commission (VMRC) believed that tautog in Virginia experienced a lower fishing mortality rate compared with northern populations (White et al. 1997). Catch curves were constructed using samples collected primarily from the commercial fishery in Virginia to derive an age-length key that was applied to landings data obtained by the Marine Recreational Fishery Statistics Survey (MRFSS) and the VMRC. The estimated total instantaneous mortality rates (Z) varied between 0.26 and 0.58 yr^{-1} from 1985 to 1996 and were lower than the coast-wide VPA average of Z = 0.73 yr^{-1} at that time (Fig. 2).

Furthermore, tagging studies conducted by the Virginia Saltwater Gamefish Tagging Program since 1995 showed that 3 out of 1,328 tag returns (0.23%) from tautog tagged in Virginia were caught outside of the State of Virginia; one was from Ocean City, Maryland, one from Delaware Bay, and the other from Oregon Inlet, North Carolina (Hoenig and Lucy 2004). The majority of tagged fish were caught near the tagging location although there was some inshore-offshore migration as well. Similar migration patterns for tautog have been found in Rhode Island (Cooper 1966) and New York (Olla et al. 1974). Investigations into stock structure based on genetics have shown some limited genetic diversity between Virginia, Massachusetts, Rhode Island, New York, and New Jersey that could be related to low effective population size or historical bottleneck from previous glacial events (Choudhury and Bradley 2005). The supporting evidence that Virginia tautog remain near Chesapeake Bay and show little interstate movement provides a mechanism for localized fishing mortality rates.

Non-equilibrium catch curves

To continue to monitor Virginia tautog mortality rates after the study by White et al. (1997), opercle and otolith samples obtained primarily from the commercial fishery were examined by Old Dominion University for age distributions. Additional samples were collected from recreational catches haphazardly. The resulting aged samples were used to derive cross-sectional catch curves for each year from 1997 through 2004. Cross-sectional catch curve analysis was used because it provides an estimate of total instantaneous mortality rate Z and only requires information on relative abundance of cohorts from a single year (Table 2). Two assumptions of cross-sectional catch curves are: catchability of the cohorts is constant across age and recruitment shows no trend over time for the cohorts being examined, but recruitment may fluctuate randomly about a stationary mean. Another possibility for examining localized mortality rates is the use of a longitudinal catch curve, which assumes that catchability of the fishing gear remains constant from year to year, that catchability of the cohort remains constant as the fish grow larger, and that the catch curve is based on known catch per unit effort. Because longitudinal catch curves follow a single cohort through time, analysis requires landings over multiple years. On the other hand, cross-sectional catch curves can be examined using a single year of catch composition data. An additional assumption of both longitudinal and cross-sectional catch curves is that the stock and fishery are at equilibrium. When there is equilibrium (no change in fishing or natural mortality rates and no trend in recruitment over time), the descending limb of the catch curve is a straight line whose slope reflects the total instantaneous mortality rate. However, for tautog, a stock undergoing rebuilding efforts, changing

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fishing mortality rates should result in non-equilibrium conditions and departures from linearity (bend in the catch curve). Interpretation of the non-equilibrium catch curve can provide insight into changes in stock dynamics, although additional years of data are required. If the bend in a cross-sectional catch curve always occurs at the same point every year, then either catchability changes with age or mortality changes with age, but distinguishing between the two is not possible without further information (Fig. 3). On the other hand, if the bend in the curve moves one time step to the right each subsequent year, then either there has been a change in mortality with time or a change in recruitment with time (Figs. 4 and 5). A fixed percentage decrease or increase in recruitment every year results in a series of catch curves over time that consist of two linear segments (Fig. 5), whereas a one-time permanent change in recruitment results in a complicated pattern evolving in the catch curve over time (Fig. 6). Distinguishing between the different explanations for bent catch curves is not possible without further information, but catch curves do provide a tool for examining non-equilibrium conditions using limited data.

Catch curves for Virginia tautog

Equilibrium cross-sectional catch curve analysis for tautog in Virginia suggests a slight reduction in total mortality in recent years relative to the 1980s and early 1990s (average 0.38 yr^{-1} from 1985 to 1996, average 0.30 yr^{-1} for 1997 and 1999 to 2004) with values that are below the target F of 0.29 yr^{-1} established by the ASMFC (Figs. 2 and 7). To check for the possibility that mortality may have changed over time, non-equilibrium catch curves were also constructed. Total instantaneous mortality rates for younger fish that only experienced recent mortality rates ranged from 0.18 (2000) to 0.41 (2004), while the mortality rate for older fish that experienced prior mortality rates ranged from 0.24 (2003) to 0.51 (1999) (Table 3; Fig. 7). An important point is that the recent total mortality rates are below the ASMFC target F=0.29 (assuming M=0.15). If the entire age range is used in the catch curve analysis (assuming there is no bend in the catch curve), then estimated total instantaneous mortality rates for tautog ranged between 0.26 (2000) to 0.41 (1997) (Table 3, Fig. 7). Thus, the conclusion that mortality rates in Virginia are below the ASMFC target is robust to the interpretation of the shape of the catch curves. In addition, the increase in MRFSS catch and effort estimates observed during 2003 and 2004 (Fig. 1) correspond to a steepening of the catch curve at the extreme left of the descending limb, suggesting that the non-equilibrium catch-curves may be tracking recent changes in mortality rates. Additional years of data could verify this trend.

In theory, another possible explanation for a bend in the catch curve is a violation of the assumption of no trend in recruitment. If recruitment continuously decreased at a constant percentage rate with time, the result would be to pull the left side of the catch curve downward and appear as a reduction in total mortality estimates for younger ages (Fig. 5). Observing a constant decrease in recruitment over time, such as 20% each year, is possible but not likely. Unfortunately, data for recruitment of Virginia tautog are not available and we are currently unable to exclude this possibility definitively. However, recruitment estimates from the VPA do not show any decreasing trend over time throughout the northern management area and actually show an increase in biomass and recruitment in recent years (ASMFC 2002). Inasmuch as recruitment is influenced by regional factors, such as climate (Myers et al. 1997), the results from the VPA concerning recruitment are consistent with the idea that recruitment in Virginia has not declined. Additionally, the MRFSS effort data showing lower fishing mortality in recent years (with a notable increase in only the last two years) supports the conclusion that fishing mortality has not risen above the target level.

Discussion and Conclusions

The argument for using a cross-sectional catch curve analysis versus a VPA does not argue against using a VPA, but rather that different assessment tools may be complementary and show insight into stock dynamics that a single methodology may not reveal. While VPA is superior in providing annual estimates

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of mortality rates and absolute abundances by age, it is inferior in that the parameters are averaged over the entire management unit. If sub-stocks are not well mixed, as appears to be the case for tautog, then mortality rates may not be accurate for any jurisdictions and management decisions may be less effective. For example, if Virginia's fishing mortality rate is below the value obtained using a VPA for northern states, then cutting back fishing effort in Virginia results in unnecessary regulations and loss of yield. Furthermore, there must be higher values of F in another area (or areas) within the management unit that accounts for the overestimated value in Virginia. Therefore, the reduction in effort that is averaged across the management sub-units may not be sufficient to decrease F to the target value established by the ASMFC in all areas and the regulations may not be conservative. On the other hand, if Virginia's mortality rates are the same as values obtained through VPA, then not reducing effort in Virginia may result in sub-stock decline. Managers are faced with the choice between results from a detailed stock analysis (VPA) that may not be applicable in all areas and a less detailed analysis (cross-sectional catch curve) that leaves some uncertainty with respect to the cause of the resulting estimated parameters. (This uncertainty is minimized by considering additional information such as effort data and tag returns). Our contention is that if real biological differences exist between sub-stocks, then applying results obtained from the more sophisticated model are not going to achieve management goals, but that the less detailed analysis may provide additional information and help clarify management options.

We conclude:

1) Catch curve analysis (equilibrium and non-equilibrium) suggest fishing mortality rate for Virginia tautog has been less than the target since 1997 and this is supported by a reduction in fishing effort estimated in the MRFSS.

2) The historical catch curve estimates of tautog mortality in Virginia presented by White et al. (1997) were all below the coast-wide average determined from the VPA (Virginia range = (0.31,0.39), coast-wide average = 0.73).

3) The idea that Virginia may have lower mortality rates than elsewhere is supported by the tagging data that show Virginia tautog remain in Virginia waters.

4) Fishing effort has risen in the last two years and, coincidentally, the extreme left-most two points of the (descending limb of the) catch curve are steep. This suggests that effort and mortality should be monitored to look for a sustained change.

5) Cross-sectional catch curves provide a mechanism for measuring mortality on a local scale and, in the non-equilibrium form, can be used to check for changes in mortality rates over time. It is true that there is a lag between time of change and time the change can be detected in the catch curve but even the use of a VPA entails a lag as the VPA is not performed every year and the most recent results of the VPA are the least reliable.

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Table 1. Advantages and disadvantages of different spatial scales for management units used in stock assessments.

	Possible Management Units Used to Assess the Stock	
	Several Small (Localized)	**Few Large (Large-scale)**
When Appropriate	* When there are real spatial differences	* When there are few spatial differences
Requirements	* Requres fine scale data	* Requires only aggregate data
Advantages	* Will detect localized depletions, maintain reproduction in substocks (genetic diversity), promote stability of fishery (avoid serial depletion)	* Potentially less work and expense to assess and enforce, may be able to "borrow strength" (obtain parameter values) from subunits
Disadvantages	* Possibly more work and expense to assess the stock, may be harder to enforce and identify location of catch, need information regarding recruitment and external factors (ex. Immigration)	* Perhaps biased (if the stock is not well-mixed)
Risk if wrong management unit is chosen	* Additional, unnecessary expense; inappropriate scale may mask effects of management	* Local depletion goes undetected, potential for loss of genetic diversity, potential loss in legitimate yield

Table 2. Comparison of data requirements, assumptions, advantages, and disadvantages of virtual population analysis (VPA) and cross-sectional catch curve analysis.

	VPA	Cross-sectional Catch Curve
Data Requirements	* Catch at age matrix for more years than there are ages, tuning index, need to know natural mortality (M)	* Catch composition
Output	* Get a value for fishing mortality (F), and abundance by age and year, and get recruitment	* Get one (or more) value(s) for total mortality
Assumptions	* M is known and is constant throughout the stock, stock is spatially well mixed, generally need some assumptions about catchability and possibly about a plus group	* F and M are constant across age groups, vulnerability to fishing gear is constant above a given age, no trend in recruitment over time
Advantages	* F can be determined for each age class in each year	* Can be calculated from a single years' data, can give localized estimates
Disadvantages	* Looks at the population from a historic perspective, the dependability of the results is poorest for most recent years	* Provides less detail about the stock than VPA, cannot discriminate between all possibilities (e.g. change in mortality vs change in recruitment)

Table 3. Total instantaneous mortality estimates (Z full) and non-equilibrium total instantaneous mortality estimates for younger ages (Z left) and older ages (Z right) for Virginia tautog from 1997 through 2004. Note that estimates for 1998 are not shown because only 51 fish were aged. Estimated effort comes from Marine Recreational Fisheries Statistics Survey.

Bend located at age	Year	Z full	Z left	Z right	# Aged	Estimated effort (MRFSS)
-	1997	0.41	-	-	~500	45,938
6	1999	0.37	0.22	0.51	267	36,368
7	2000	0.26	0.18	0.48	181	28,499
8	2001	0.39	0.40	0.30	293	33,290
9	2002	0.29	0.37	0.42	372	21,474
10	2003	0.34	0.35	0.24	510	48,890
11	2004	0.32	0.41	0.29	443	82,959
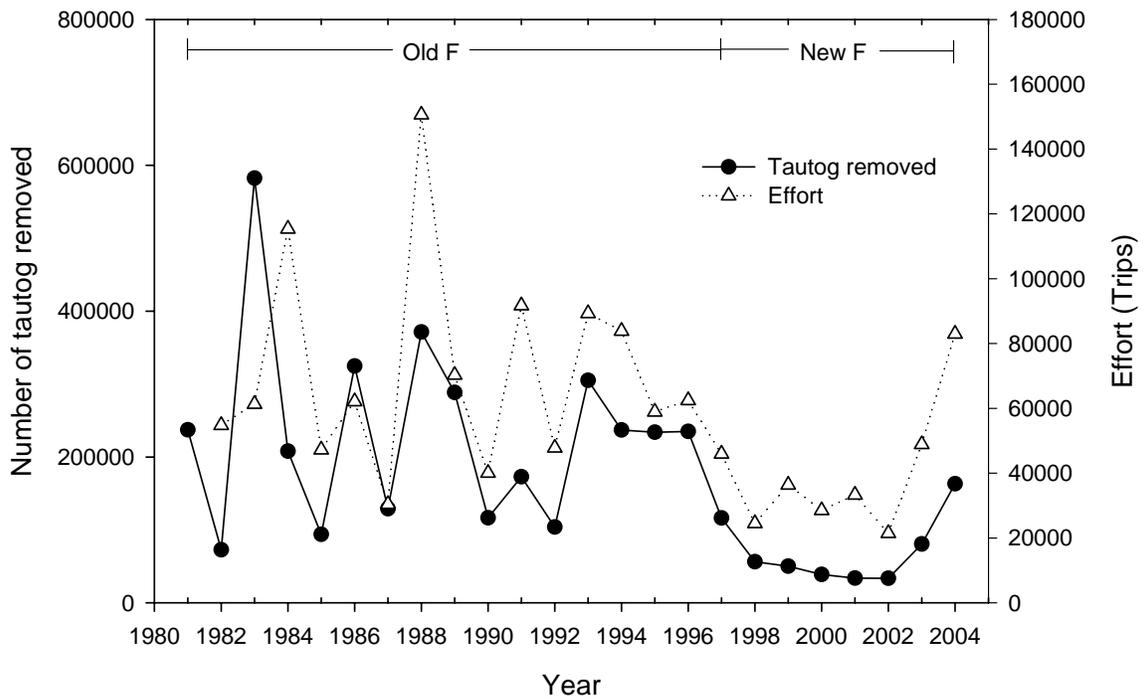
Figure 1. Combined effort and landings data for tautog from commercial and recreational catch from 1981 through 2004. Marine Recreational Fishery Statistic Survey data include an assumed 2.5% post-release mortality.
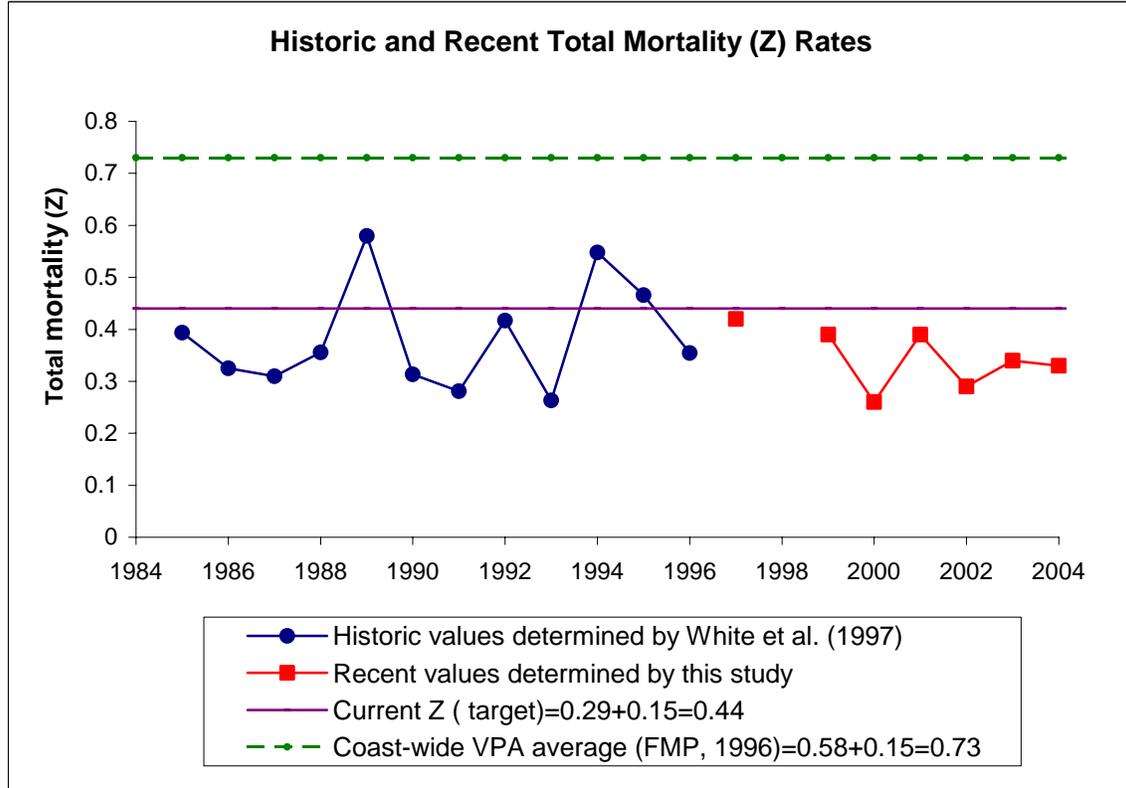

Historic and Recent Total Mortality (Z) Rates

Legend:
- Historic values determined by White et al. (1997)
- Recent values determined by this study
- Current Z (target)=0.29+0.15=0.44
- Coast-wide VPA average (FMP, 1996)=0.58+0.15=0.73

Figure 2. Estimates of total instantaneous mortality rates obtained from cross-sectional catch curves by White et al. (1997, columns 2 and 6 of Figure V.7) and this study.
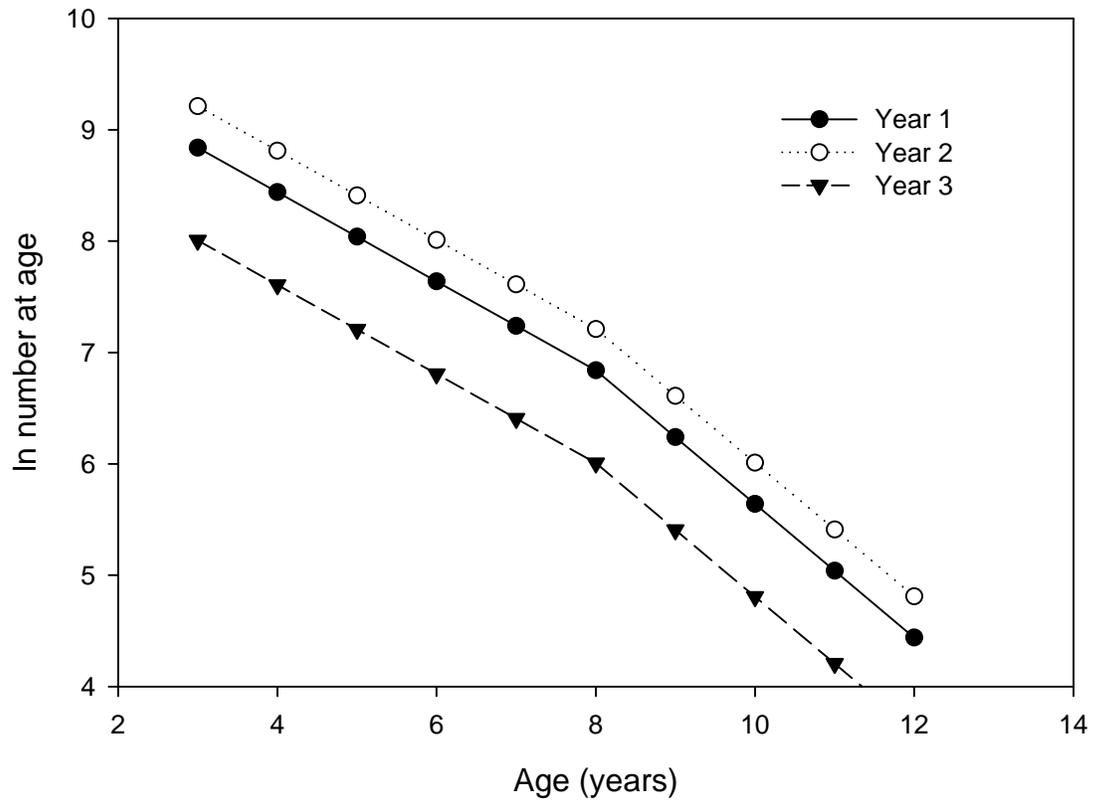
Figure 3. Cross-sectional catch curves for three years of data showing a consistent bend in the curve at age-8. Such a pattern is consistent with mortality increasing with age or catchability decreasing with age.
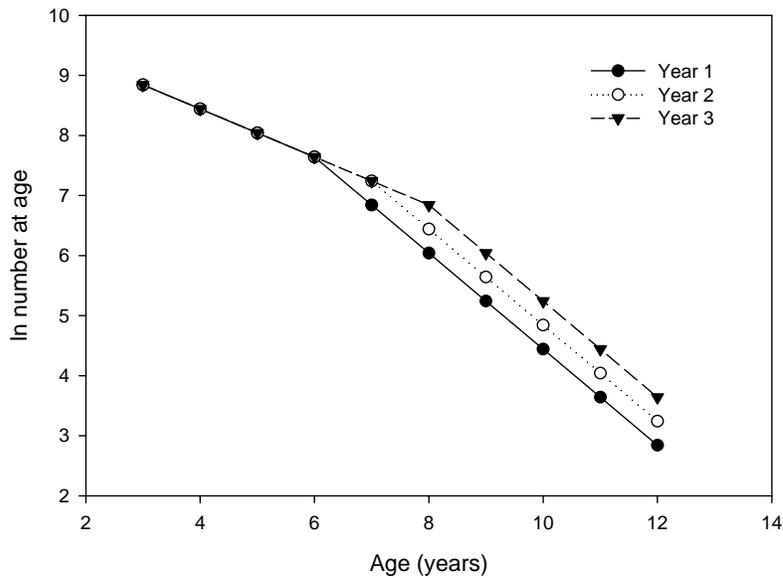

Figure 4. Non-equilibrium cross-sectional catch curve for three years of data showing a migration of the bend to the right. This is consistent with a decrease in mortality with time or a decrease in recruitment. The slope of the line to the left of the bend shows the recent mortality rate if the mortality rate has changed.
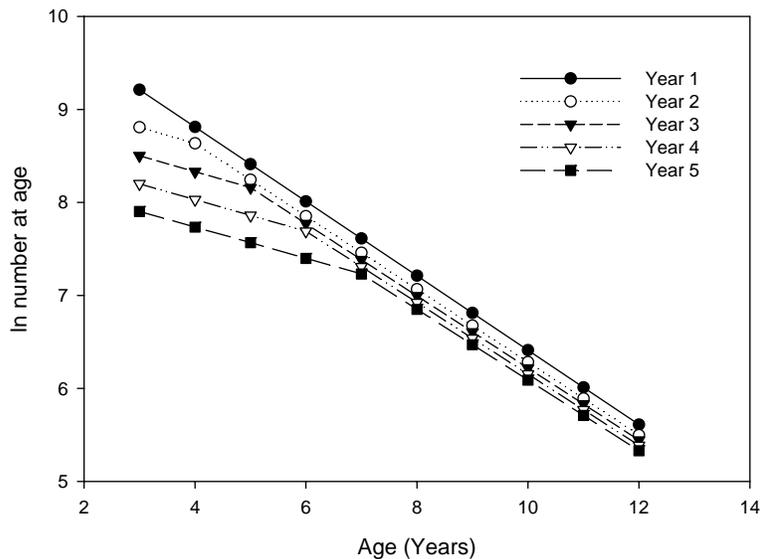
Figure 5. Cross-sectional catch curves over a series of years showing a consistent 20% decrease in recruitment every year. Here total mortality (Z) is constant over all ages and all years and the departure from linearity is due to changing recruitment. The slope to the right of the bend reflects the true mortality rate.
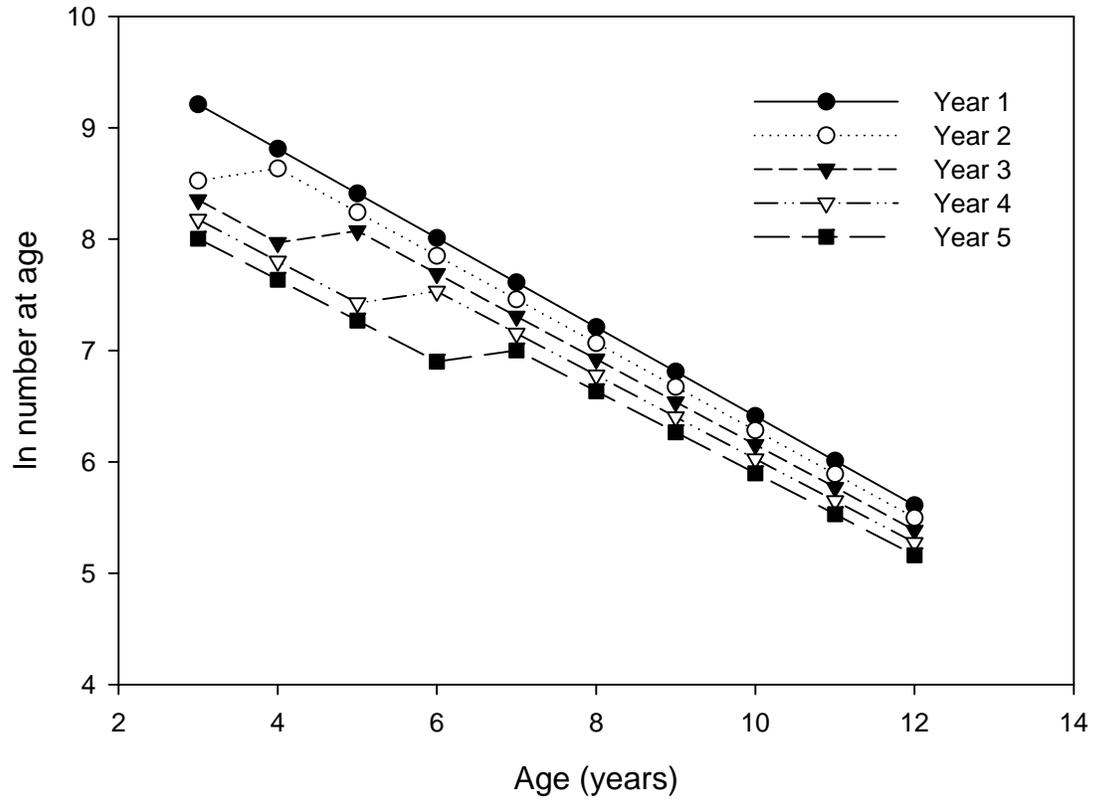
Figure 6. Effect of a permanent decrease in recruitment from one constant level to another starting in year two.
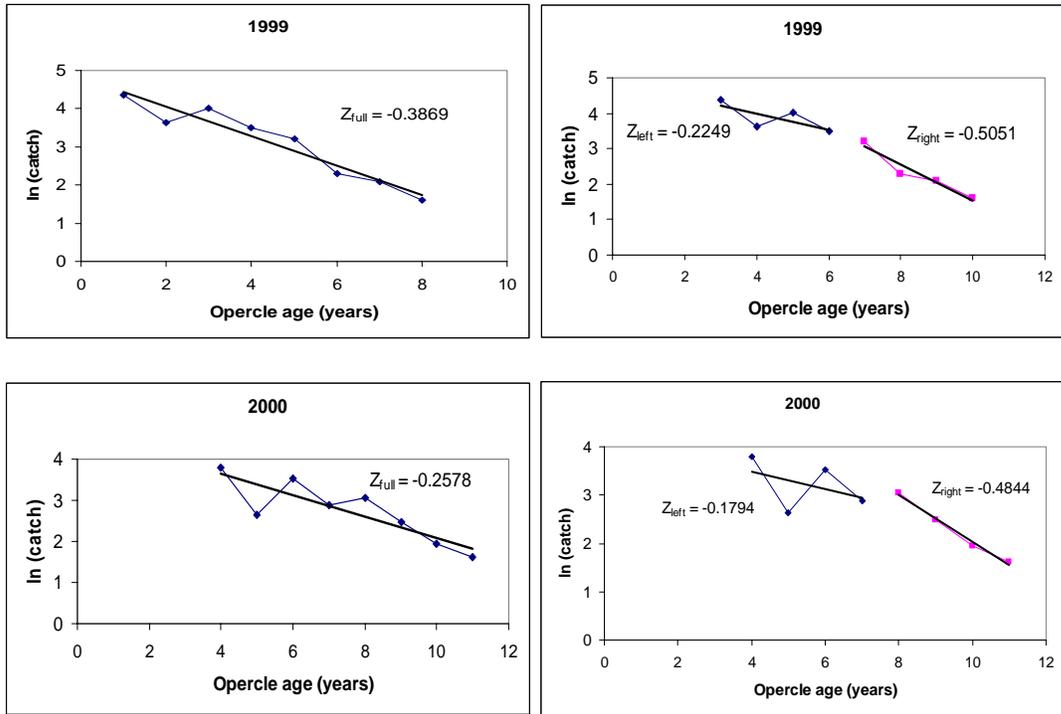
Figure 7. Cross-sectional catch curves (left) and non-equilibrium cross-sectional catch curves (right) for 1997 and for 1999 through 2004. Operculum age was derived from tautog obtained primarily from commercial landings with some opportunistic data obtained from recreational catch. Ages with less than 5 fish per age were not used in the regression and only the descending limb is shown.