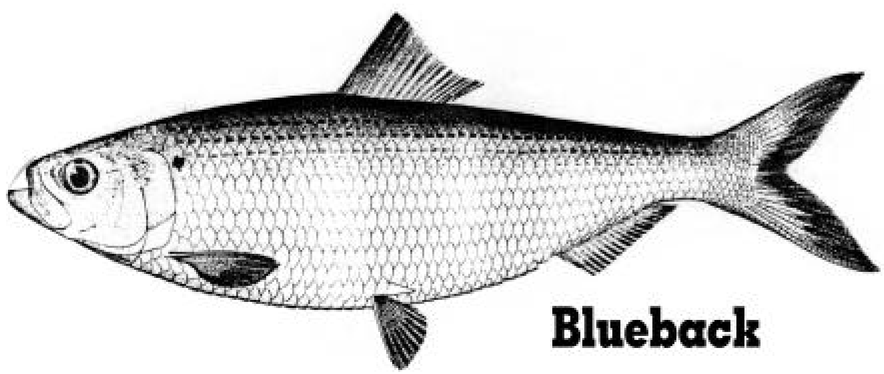
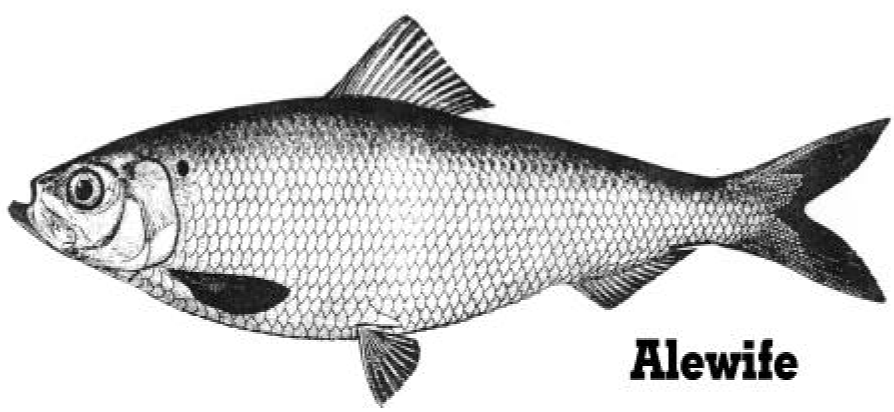
North Carolina
Fishery Management Plan

Albemarle Sound Area
River Herring



Blueback



Alewife

North Carolina
MARINE
FISHERIES
Dept. of Environment and Natural Resources

February 2000

North Carolina Fishery Management Plan:
Albemarle Sound Area River Herring

By
River Herring Plan Development Team

North Carolina Division of Marine Fisheries
Department of Environment and Natural Resources
Morehead City, NC 28557

February 2000

1. Acknowledgments

The 1999 Albemarle Sound River Herring Fishery Management Plan (FMP) was developed under the direction of the North Carolina Marine Fisheries Commission (MFC) with the advice of the MFC River Herring Advisory Committee (RHAC). The plan was prepared by the North Carolina Department of Environment and Natural Resources' Division of Marine Fisheries (DMF), Wildlife Resources Commission (WRC), Division of Water Quality (DWQ), and the US Fish and Wildlife Service (USFWS). Deserving special recognition are the members of the River Herring Advisory Committee, the MFC and WRC, staff of DMF, WRC, DWQ and USFWS, and numerous individuals who contributed their time and knowledge to this effort.

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3. Executive Summary

The management unit for the Albemarle Sound Area River Herring Fishery Management Plan (FMP) includes the two species of river herring (blueback herring, *Alosa aestivalis*, and alewife, *A. pseudoharengus*) and their fisheries throughout the Albemarle Sound area of northeastern North Carolina and the Atlantic Ocean from Cape Hatteras to the North Carolina/Virginia border northward.

Stock Status

When the exploitation rate on a fish stock exceeds sustainable or target levels, then overfishing is occurring. The June 1999 Division of Marine Fisheries stock assessment indicates the Albemarle Sound area river herring stock is overfished. This determination is based on an overall evaluation of the stock and review of several available stock-status indicators.

Spawning stock biomass is greatly reduced from historical levels exceeding 4 million pounds. There are too few repeat spawners in the stock. Recruitment to the stock has been poor for several years, as indicated by both juvenile abundance index (JAI) (below the long-term average for more than 10 years) and the estimated number of recruits (fewer than 5 million since 1989). Blueback herring spawning repetition has been below 5% since 1987. Fishing mortality has exceeded sustainable levels for 25 of the last 27 years.

Fishery Status

The river herring fishery can be divided into two segments: commercial and recreational, with both occurring in Coastal, Joint and Inland Waters. These fisheries are entirely dependent on sexually mature fish, age 3 and older. Fisheries in Coastal Waters are under the regulatory jurisdiction of the Marine Fisheries Commission (MFC), while river herring fisheries in designated Inland Waters are under the Wildlife Resources Commission (WRC).

Commercial Fishery

The North Carolina river herring fishery began in the mid-1700s, and has always been concentrated in the Albemarle Sound area. Since the late 1800s, the areas fished and gears used to harvest river herring have remained essentially unchanged. The extent of the river herring fisheries in both amounts of gear and harvest, however, has declined significantly. The fisheries in the Albemarle Sound area are now pursued as multi-species fisheries, which are not totally dependent on river herring. Annual landings prior to the early 1970s regularly exceeded 10 million pounds.

Landings in the commercial fisheries have been depressed since the late 1980s (not considering the limits imposed since 1995). The depressed nature of the fishery has greatly reduced the economic value of the harvest, and almost eliminated what was once an extensive processing sector which provided hundreds of seasonal jobs for local residents.

In 1995, a fishing season was implemented by MFC rule which prohibited taking blueback herring and alewife by any method from April 15 through January 1. This rule was adopted to allow more fish to escape fishing mortality and spawn. The rule remained in effect in 1995 and 1997. In 1996 and 1998, the rule was suspended only for the Chowan River pound net fishery, at which time the fishery operated on a total allowable catch, 250,000 lb and 400,000 lb, respectively. The MFC amended the rule in a temporary action for the 1999 harvest granting the Fisheries Director proclamation authority, to take various actions and impose an annual quota of 450,000 lb for the entire management area.

During 1995-1998, North Carolina accounted for 29-52% of the total river herring landings from the U.S. Atlantic coast, compared to 13.6-84.5% from 1950 to 1994. The Chowan River pound net fishery contributed 60.3%-76.5% of the states annual river herring harvest during 1995-1999.

Recreational Fishery

The recreational river herring harvest is unknown.

Socioeconomic Considerations

Commercial value of river herring in North Carolina peaked in 1985 at $846,000. The value then fell sharply to approximately $67,000 in 1993 due to lower landings, but a rise in the average price per pound helped to temper somewhat the effect on revenues to fishermen. The gross income earned from river herring fishing has declined significantly in recent years. There has been a severe decline in river herring processing activities over the years, due to reduced harvest and demand for the products. A recovered fishery of several million pounds, either as a food source or as bait, would produce more revenue to the fishermen. Economic data specific to the recreational river herring fishing are not available.

Principal Issues

Stock Condition

River herring stocks are currently overfished and cannot replace themselves at existing levels of mortality (recruitment overfishing). Fishing mortality can be reduced through management actions implemented to improve the status of the stocks. The nature of the fisheries during a recovery period and thereafter would depend on the severity of management restrictions utilized to reduce fishing mortality and promote stock recovery, market conditions, economic conditions of the affected fishermen, and many other factors.

Habitat and Water Quality

Considerable habitats important to river herring have been degraded or lost in the Albemarle Sound area. There are still problems with non-point source runoff and some discharges in the area, but the overall water quality of the area has improved since the late 1970s fish kills and algae blooms were common. Habitat and water quality protection, conservation, and restoration are essential to accomplish the goals and objectives of the FMP. Local spawning populations may have been eliminated in some streams, but restoration techniques can be applied once such streams are identified.

Assessment Data

Full assessment of the river herring resources from the entire Albemarle Sound area are needed and will require a major expansion of research and monitoring activities. Fishery-dependent and fishery-independent sampling must be initiated throughout the area.

Socioeconomic Data

Every management decision has socioeconomic effects. The DMF should begin regular sampling of licensees for data with which to develop socioeconomic baselines from which to estimate impacts of decisions.

Education

The river herring fishery, even though it was North Carolina's largest food fish fishery for many decades, is poorly known beyond the immediate Albemarle Sound area. The general public should be educated concerning both the history and potential future benefits which can come from a recovered fishery.

Management Goals

To manage the Albemarle Sound area river herring fishery in a manner that is biologically, economically, and socially sound while protecting the resource, the habitat, and its users. The management plan for river herring will be adaptive and involve regular reviews and responses to new information about the current state of the resource, the habitat and its users.

To achieve an interim spawning stock biomass (SSB) level for the Albemarle/Roanoke system river herring that coincides with a 4 million pound SSB level for the Chowan River stock. (This level of SSB is considered the Minimum Stock Size Threshold (MSST)).

To achieve for the long-term a spawning stock biomass (SSB) level for the Albemarle/Roanoke system river herring that coincides with an 8 million pound SSB level for the Chowan River stock. (This level of SSB is considered the Biomass capable of producing MSY (Bmsy)).

Optimum Yield

The river herring stock assessment indicates that maximum sustainable yield (MSY) for Chowan River blueback herring for a recovered stock is approximately 2 million pounds. Consequently, the target optimum yield (OY) for a healthy river herring population can not exceed 2 million pounds. Because the stock is overfished, the allowable harvest, or rebuilding OY, must provide for stock rebuilding. The rebuilding OY for river herring is not to exceed 300,000 pounds of commercial harvest. Based on stock projections incorporating the stock-recruitment relationship, this level of harvest may rebuild the stock to the threshold spawning stock biomass (minimum stock size threshold, MSST) of 4 million pounds in 14 years and to the MSY biomass in 24 years. This level of harvest should not be exceeded until the JAI reaches a three-year moving average of 20 or the spawning stock biomass exceeds the MSST of 4 million pounds.

Management Objectives

1. Identify and describe fishery and population attributes necessary to sustain long-term stock viability.
2. Restore river herring stocks in the Albemarle Sound area to viable status.
3. Protect, restore and enhance spawning and nursery area habitats.
4. Manage the fishery in a manner to sustain long-term stock viability, traditional harvest and forage uses, and prevent recruitment overfishing.

5. Initiate, enhance, and/or continue programs to collect and analyze biological, social, economic, fishery, and environmental data needed to effectively monitor and manage the river herring fishery.
6. Promote a program of education and public information to help the public understand the causes and nature of problems in the river herring stock, its habitats and fisheries, and the rationale for management efforts to solve these problems.

Management Actions

Stock Restoration

*Specific objectives will be achieved through the preferred Fisheries Management Alternative (see below).

Habitat and Water Quality

*Conduct spawning area surveys in one drainage basin annually, beginning in Spring 2001.

*Develop and implement a Coastal Habitat Protection Plan for river herring spawning and nursery areas.

*Develop and implement drainage area habitat restoration plans and alleviate identified impediments.

* Protect river herring spawning and nursery areas by specifically designating such areas through MFC rules.

*The Environmental Management Commission (EMC) should take appropriate steps to achieve established water quality objectives and protect designated river herring spawning and nursery areas.

*The Coastal Resources Commission (CRC) should take appropriate steps to achieve established habitat objectives and protect designated river herring spawning and nursery areas.

Fishery Management Alternatives

* The MFC approved management alternative is to allow an annual commercial quota (calendar year) for river herring in the Albemarle Sound Management Area of 300,000 pounds allocated as follows:

(1) 200,000 pounds to the pound net fishery for the Chowan River Herring Management Area;

(2) 67,000 pounds to the Albemarle Sound Herring Management Area gill net fishery; and

(3) 33,000 pounds to be allocated at the discretion of the Fisheries Director.

*It is unlawful to possess more than 25 blueback herring or alewife (river herring), in the aggregate, per person per day taken for recreational purposes.

*Effective January 1, 2001, it will be unlawful to use drift gill nets with a stretched mesh less than 3 inches from January 1 through May 15 in the ASRHMA.

*Once the MSST of SSB equals 4 million pounds (mlb) is reached, the DMF should recommend measures to achieve the target biomass capable of producing MSY (SSB= 8 mlb) that equals 8 million pounds and an ultimate harvest of OY.

*The WRC should implement a no-sale provision for river herring taken with Special Device Licenses and prohibit gill nets in Inland Water in the ASRHMA.

*The DMF and WRC should prepare and implement a plan to restore river herring spawning runs in designated areas.

Data Collection

*Expand and enhance fishery-dependent and fishery-independent sampling throughout the ASRHMA.

*Design and implement surveys to estimate the recreational fishing catch/effort and collect biological data.

*Fund research to evaluate impacts of water quality on larval and juvenile river herring.

*Design and conduct studies on multi-species effects on river herring, specifically abundance of top predators, such as striped bass.

*Other Fishery Management Alternatives: The following alternatives were considered by the MFC.

*Status quo: 450,000 lb commercial fishery quota allocated among existing fisheries and no recreational limits; This alternative results in continued overfishing of the stock, which violates the FRA.

*100,000 lb commercial bycatch fishery allocated among existing fisheries and 10 fish per person per day recreational limit; and

*Fixed exploitation rate- annual quota would be set based on annual fishing mortality target applied to current stock abundance that varies from year to year. Recreational limit of 25 fish per person per day.

*Total moratorium on river herring landings, with severe fishing restrictions to minimize wasteful bycatch.

4. Introduction

4.1 Management Authority

4.1.1 Introduction

Fishery management includes all activities associated with maintenance, improvement, and use of the fisheries resources, including research and monitoring, development, regulation, enhancement, and enforcement.

North Carolina's existing fisheries management system is extremely powerful and flexible, with rule-making authority vested in the Marine Fisheries Commission (MFC) and Wildlife Resources Commission (WRC) within their respective jurisdictions. The Division of Marine Fisheries (DMF) implements MFC rules and policies. The General Assembly retains for itself licensing and limited entry authorities. In the 1998 amendments to the Fisheries Reform Act of 1997, the General Assembly established a process for limiting entry for fisheries under the FMP process. Federal authority under the Magnuson-Stevens Act applies for fisheries in the Exclusive Economic Zone (the area from 3 to 200 miles offshore; it also applies to a limited extent in areas within state jurisdiction deemed Essential Fish Habitat (EFH)). It does not apply to river herring in state waters because the fisheries and distribution of the stock are primarily within the jurisdictional waters of the coastal states. The Atlantic coast states worked together through the Atlantic States Marine Fisheries Commission (ASMFC) to prepare and implement an interstate FMP, but the regulatory responsibility and authority remain with the states. Passage of the Atlantic Coastal Fisheries Cooperative Management Act in 1993 gave the ASMFC oversight for species with ASMFC plans, but plans are implemented by the states. Thus, the MFC/WRC (rules) and DMF/WRC (research, enforcement, etc.) utilize their authorities to manage the fisheries. The MFC and WRC have the ability to establish seasons, authorize or restrict fishing methods and gear, limit quantities taken or possessed, and restrict fishing areas. Thus, all necessary authority needed for management of the river herring fisheries are available through the existing state fishery management process. Appropriate use of this authority, with the cooperation of stakeholders, will be demonstrated by restoration of the resource and productive fisheries.

In 1986, the North Carolina Department of Natural Resources and Community Development, WRC and United States Fish and Wildlife Service entered into a cooperative agreement (Agreement No. 14-16-0004-87-904) for anadromous species restoration in historically significant coastal river basins. The cooperative program's desire is to restore self-sustaining stocks of anadromous fishes in coastal North Carolina waters through a combination of fishery management techniques including stocking, regulations, and assessment. This cooperative program continues today.

4.1.2 Legal authority for management

Many different state laws (General Statutes - G.S.) provide the necessary authority for fishery management in North Carolina. General authority for stewardship of the marine and estuarine resources by the North Carolina Department of Environment and Natural Resources (NCDENR) is provided in G.S. 113-131. The DMF is the arm of the Department which carries out this responsibility. The same statute also grants management authority to the WRC within its jurisdictional area. Enforcement authority for DMF enforcement officers (Marine Patrol) and WRC officers is provided by G.S. 113-136. Rule-making authority is granted to the MFC and WRC by G. S. 113-134. General Statute 113-181 authorizes DMF research and statistical programs. The MFC is charged to "manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources of the State of North Carolina" (G.S. 143B-289.51). The MFC can regulate fishing times, areas, fishing gear, seasons, size limits, and quantities of fish harvested and possessed (G.S. 113-182 and 143B-289.52). General Statute 143B-289.52 also allows the MFC to delegate authority to implement its regulations for fisheries "which may be affected by variable conditions" to the Director of DMF by issuing public notices called "proclamations." The General Assembly has retained for itself the authority to establish commercial fishing licenses, but has delegated to the MFC authority to establish permits and permit fees for various commercial fishing activities. Thus, North Carolina has a very powerful and flexible legal basis for coastal fisheries management.

The Fisheries Reform Act of 1997 (FRA) established a process for preparation of coastal fisheries management plans (FMPs) in North Carolina. The FRA states that "the goal of the plans will be to ensure the long-term viability of the State's commercially and recreationally significant species or fisheries. Each plan will be designed to reflect fishing practices so that one plan may apply to a specific fishery, while other plans may be based on gear or geographic areas.

Each plan will:

a. Contain necessary information pertaining to the fishery or fisheries, including management goals and objectives, status of the relevant fish stocks, stock assessments for multi-year species, fishery habitat and water quality considerations consistent with Coastal Habitat Protection Plans (CHPP) adopted pursuant to G.S. 143B-279.8, social and economic impact of the fishery to the State, and user conflicts.

b. Recommend management actions pertaining to the fishery or fisheries.

c. Include conservation and management measures that prevent overfishing, while achieving, on a continuing basis, the optimal yield from each fishery."

Optimal yield is defined in the FRA as "The amount of fish that:

a. Will provide the greatest overall benefit to the State, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems;

b. Is prescribed on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factors; and

c. In the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in the fishery." (FRA; G. S. 113-182.1)

4.2 General Problem Statement

4.2.1 Stock Problems

A fish stock exhibiting low abundance or biomass is considered overfished; if the exploitation rate on a stock exceeds sustainable or target levels, then overfishing is occurring. The June 1999 stock assessment (Carmichael 1999, Section 13, Appendix 1) indicates that the

Chowan River blueback herring stock is overfished. This determination is based on an overall evaluation of the stock and review of several available stock-status indicators.

There is an inadequate number of spawners and too few repeat spawners. Spawning stock biomass is greatly reduced from historical levels. Recruitment to the stock has been poor for several years, as indicated by both the juvenile abundance index (JAI) and the estimated number of recruits. Fishing mortality has exceeded sustainable levels for 25 of the last 27 years. Landings in the commercial fisheries have been depressed since the late 1980s (not considering the limits imposed since 1995). The depressed nature of the fishery has greatly reduced the economic value of the harvest, and almost eliminated what was once an extensive processing sector which provided hundreds of seasonal jobs for local residents.

4.2.2 Environmental Issues

Problems exist in the areas of physical habitat and water quality. Considerable habitats have been lost through wetland drainage, stream channelization and conversion to other uses. Streams are blocked by dams (including beaver dams), storm debris, and other physical barriers. Migration and spawning may be affected by replacement of small road bridges with culverts; research on this topic is underway. Pulp mill effluent and other oxygen-consuming wastes are discharged into a number of streams. Practices to control non-point discharges are inadequate. Nuisance algal blooms, fish kills, and fish diseases have occurred for many years. There are questions concerning the status of the forage base for, and predators of, river herring.

4.2.3 Insufficient Assessment Data

Data concerning the stock are lacking in many areas. Few fishery-independent data are collected. More complete data on adults during the spawning run are needed regardless of the length of the fishing season. Accurate fishing effort data are needed for all commercial fishing gears. No catch, effort, or biological data exist for the recreational fishery.

4.2.4 Inadequate Environmental Data

All fish stocks are basically dependent on environmental conditions for their survival. The key environmental conditions which control river herring behavior, survival, fitness and spawning success are unknown beyond a few measures, such as water temperature. There is no system in place to gather such environmental data.

4.2.5 Lack of Socioeconomic Data

Some initial socioeconomic data for commercial fishermen were gathered for this FMP. Otherwise, no data exist with which to estimate fishery impacts on the larger economy. No data at all exist for the recreational fishery. Regular collections of such data are necessary to formulate, and evaluate the impacts of, management decisions.

The river herring fishery is one of the oldest commercial fisheries in North Carolina (see Section 6.1), with significant cultural value. Because the fishery is based entirely on migrating fish, it is highly seasonal, and no fishermen are dependent on river herring for their entire fishing income. Traditionally, river herring fishermen have fished part-time, often working in agriculture the rest of the year. The major harvest gear, the pound net, is quite expensive to set and maintain. All pound net sets are officially registered with DMF, as required by rule. The only other gears with significant landings are various types of gill nets. As the stock has declined, pound net fishermen have found it economically difficult to remain in the fishery. Most of these same fishermen have cooperated with the MFC and DMF in data collection and development of management strategies over the last few years, but the stock has continued to decline. As the FMP is implemented, consideration should be given to maintenance of access to the fishery by the traditional methods, including those fishermen who have used those methods.

4.3 Definition of Management Unit

The management unit for this FMP includes the two species of river herring (blueback herring, *Alosa aestivalis,* and alewife, *A. pseudoharengus*) and their fisheries throughout the Albemarle Sound area of coastal North Carolina and the Atlantic Ocean from Cape Hatteras northward.

The management areas are defined as follows:

Albemarle Sound River Herring Management Area (ASRHMA)-Albemarle Sound and all its Coastal, Joint and Inland water tributaries; Currituck Sound; Roanoke and Croatan sounds and all their Coastal, Joint and Inland water tributaries, including Oregon Inlet, north of a line from Roanoke Marshes Point 35° 48' 12"N-75° 43' 06"W, running 122° (M) across the north point of Eagles Nest Bay 35° 44' 12"N-75° 31' 09"W (Figure 1).

Chowan River Herring Management Area (CRHMA)-Northwest of a line from Black Walnut Point 36° 00' 00"N-76° 41' 00"W; running 40°(M) to Reedy Point 36° 02' 12"N-76° 39' 20", to the North Carolina/Virginia state line; including the Meherrin River (Figure 2).

River herring are distributed throughout the coastal waters of North Carolina, ascending many streams to their headwaters or until blocked by dams or other obstructions. As shown in Table 1, they have been harvested historically from virtually all coastal streams. Over the last 20-30 years; however, the fisheries have been overwhelmingly concentrated in the Albemarle Sound area. In addition, historical landings data (Section 13, Appendix 2) indicate that the river herring fisheries have always been concentrated in that area, with minor fisheries in other coastal streams. The DMF has conducted spawning and nursery area surveys and some age composition work for most of the coastal streams outside the Albemarle Sound area, but this work ended 10-18 years ago, varying with area, as federal aid funds were decreased (Table 2). Current data, other than landings data, simply do not exist for river herring outside the Albemarle Sound area. Finally, significant fishery management issues are well-documented for the Albemarle Sound area, but not for other areas. For the reasons provided above, this FMP will be limited at this time to the river herring fisheries of the Albemarle Sound area as described above.

4.4 Existing Plans, Statutes, and Rules

4.4.1 Plans

An Atlantic States Marine Fisheries Commission (ASMFC) plan for shads and river herring was initially approved in 1985 (ASMFC 1985), but no restrictions were included. Amendment No. 1 to the Interstate Fishery Management Plan for Shad and River Herring

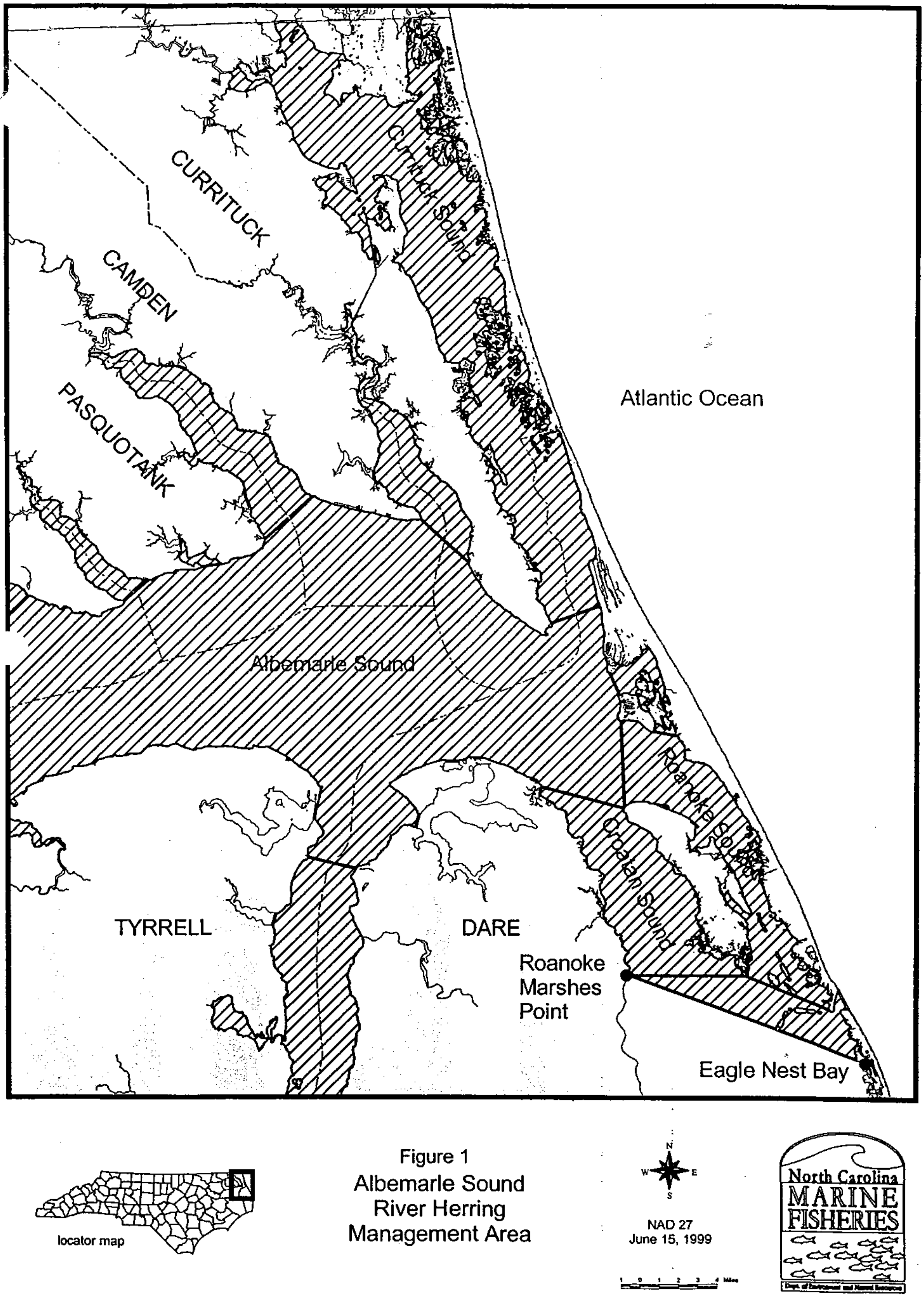


Figure 1
Albemarle Sound
River Herring
Management Area

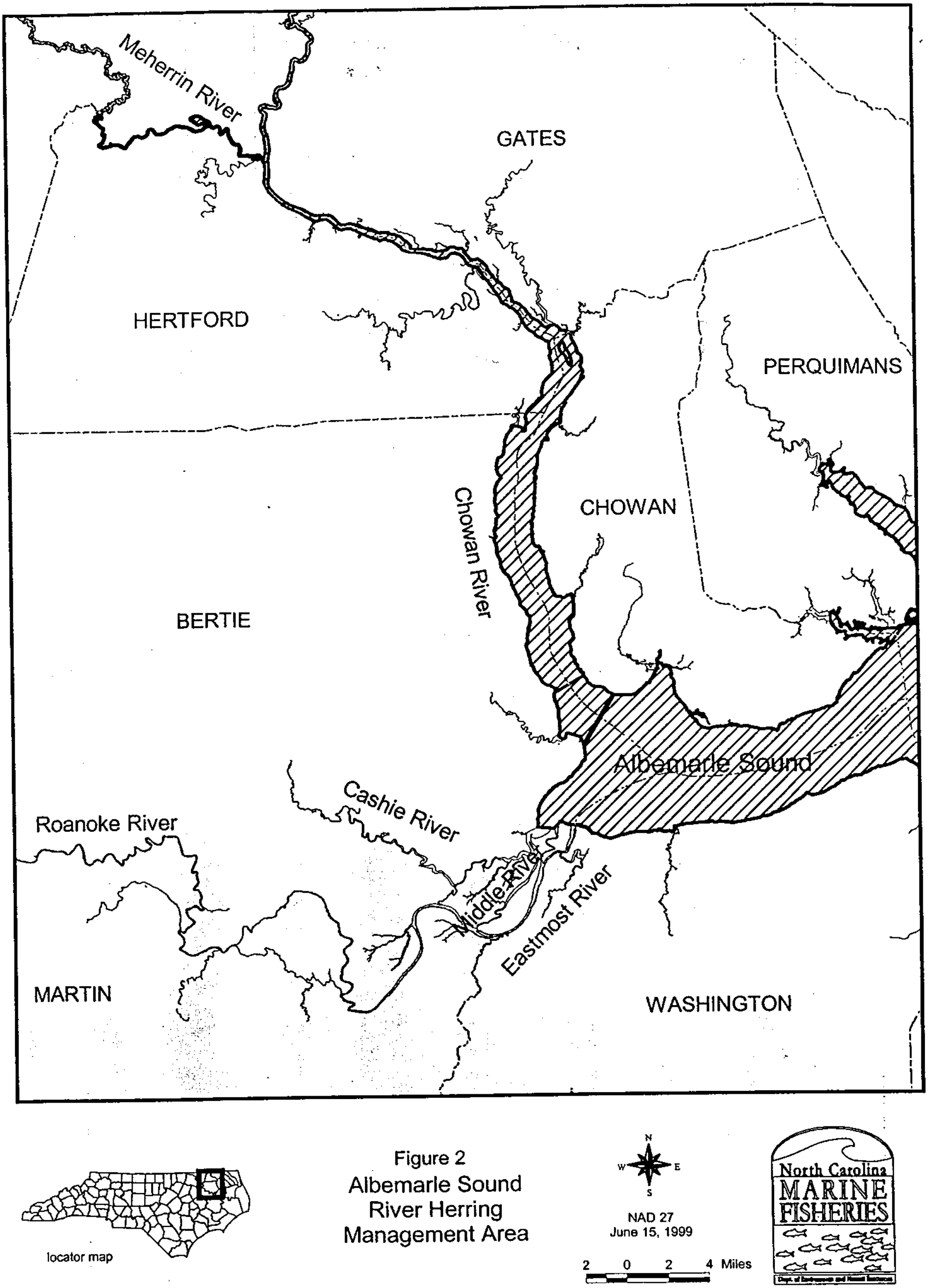


Figure 2
Albemarle Sound
River Herring
Management Area

Table 1. River herring landings and value by waterbody in North Carolina, 1962-1999.

	Albemarle Sound		Croatan Sound		Currituck Sound		Chowan River	
Year	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)
1962	3,262,600	32,626	20,000	200	25,000	250	10,786,000	107,860
1963	2,366,100	23,661	25,000	250	40,400	404	12,288,400	122,884
1964	1,920,500	19,205	35,000	350	22,300	223	4,948,900	50,760
1965	1,827,700	19,976	15,000	150	10,000	100	10,944,200	112,080
1966	1,274,200	13,916			1,000	20	10,911,300	116,597
1967	322,100	5,427	5,000	50	11,700	121	18,016,100	309,992
1968	1,067,200	16,824	3,300	35	10,000	150	12,950,100	194,881
1969	769,000	13,415	19,300	193	12,000	180	17,536,100	266,614
1970	217,600	3,263			1,000	20	10,701,300	173,541
1971	553,500	9,088					10,426,000	166,339
1972	297,551	6,480	2,670	53			10,594,117	182,052
1973	472,153	13,327	4,590	137			7,350,578	196,212
1974	150,490	5,748			7,554	288	5,736,905	224,074
1975	597,440	28,659					5,031,756	168,847
1976	356,123	21,304			4,150	415	5,734,776	286,830
1977	828,679	38,247					7,418,218	360,962
1978	491,372	24,688			3,950	208	5,615,113	239,227
1979	466,389	32,741	3,000	120	2,900	128	4,303,663	260,229
1980	680,476	51,882	18,815	1,505	4,850	420	5,382,954	379,206
1981	1,050,871	87,524	18,653	933	2,585	225	3,314,447	202,814
1982	1,558,873	144,751	75,646	7,564	22,787	2,597	7,459,968	515,545
1983	1,190,909	118,887	110,576	10,732	39,255	3,614	4,405,915	313,747
1984	1,791,289	193,857	15,616	2,170	9,100	1,258	4,561,503	382,919
1985	2,296,010	177,908	31,759	2,110	4,137	414	8,871,391	635,190
1986	689,297	94,764	49,942	3,998			5,767,874	517,945
1987	705,585	85,153	65,500	7,860			2,334,719	265,640
1988	1,490,413	178,848	3,700	444			2,259,888	271,186
1989	554,878	69,157					908,145	110,795
1990	365,881	56,047	2,000	300			710,849	106,635
1991	352,458	28,361	10,572	1,015			1,202,535	87,799
1992	217,918	22,161	2,616	183			1,135,340	113,655
1993	111,749	10,308			117	15	801,115	56,806
1994	180,271	33,348	729	73	1,357	136	390,852	44,017
1995**	97,137	34,277	1,723	344	640	160	280,681	73,482
1996**	104,166	34,284	4,708	2,140	114	28	404,884	81,930
1997**	109,876	46,886	9,436	5,344	159	60	201,928	67,748
1998**	115,436	46,389	16,831	13,692	157	62	377,311	137,874
1999**	85,128		21,101		*	*	332,466	

Continued

Table 1. (Continued)

Year	Roanoke River Pounds	Roanoke River Value ($)	Tribs. To Albemarle S. Pounds	Tribs. To Albemarle S. Value ($)	Pamlico Sound Pounds	Pamlico Sound Value ($)	Pamlico River Pounds	Pamlico River Value ($)	Neuse River Pounds	Neuse River Value ($)
1962	122,000	1,220	6,600	66	16,200	162	61,100	611	2,000	20
1963	300,000	3,000	23,100	231	16,900	169	27,700	277	4,000	40
1964	565,000	5,650	26,800	268			33,500	335	8,200	82
1965			12,000	120	3,200	33	13,400	139		
1966	256,300	2,566	41,400	498	18,700	391	15,500	262	500	5
1967	38,000	746	27,700	475	33,900	467	30,300	425		
1968	1,306,300	19,771	34,000	593	75,600	933	4,500	55	200	9
1969	1,286,100	19,293	10,200	181	2,000	20	1,500	56		
1970	469,400	14,270	65,100	1,118			200	11		
1971	1,670,500	26,062	61,700	1,396	1,000	25	100	2	400	10
1972	335,488	7,393	7,317	167						
1973	92,056	3,571	5,132	216	149	7			1,240	49
1974	256,110	13,588	53,838	2,682			3,995	340	650	33
1975	230,433	14,485	89,850	3,374			250	15		
1976	300,100	27,775	6,211	426						
1977	252,700	21,232	20,746	895	490	29	2,980	238		
1978	383,199	15,328	76,418	5,454	30,697	1,465	5,200	260		
1979	209,950	12,258	45,392	2,695	2,894	216	64,444	3,397	1,130	56
1980	71,773	6,911	20,323	1,615	5,263	527	32,609	2,110		
1981	155,860	13,118	17,432	1,416	39,774	3,627	10,049	1,482	*	*
1982	240,540	25,725	49,956	4,629	4,565	429	12,556	1,864	3012	451
1983	92,200	14,415	20,093	1,812	5,471	639	3,813	528		
1984	65,672	8,495	49,815	5,315	403	60	11,137	1,280		
1985	204,750	20,826	128,678	8,222	4,190	499	7,308	731		
1986	244,994	26,519	14,860	1,937	3,780	424	3,306	496		
1987	7,450	894	60,154	7,218			2,288	297		
1988	56,425	6,771	20,250	2,430	339,425	40,731	1,593	195		
1989	10,342	1,331	16,266	2,377	*	*	934	105		
1990	5,973	896	60,037	9,065	1,505	166	307	43		
1991	2,127	284	7,686	813						
1992	255,772	25,578	343	51						
1993			3,206	360	26	3	*	*		
1994	569	699	29,015	18,429	1,000	245	14	1	1,668	167
1995**	2,858	715	47,723	20,112	3,923	1,022	*	*	64	15
1996**	2,176	1,679	12,562	12,077	625	154	*	*	103	59
1997**	2,216	1,267	4,766	5,080	518	304			185	278
1998**	662	945	10,338	6,491	601	395	56	19	539	186
1999**	*	*	4,470		*	*	*	*	*	*

Continued

Table 1. (Continued)

Year	Cape Fear River Pounds	Cape Fear River Value ($)	Atlantic Ocean Pounds	Atlantic Ocean Value ($)	Other areas Pounds	Other areas Value ($)	State total Pounds	State total Value ($)
1962	100	1			800	8	14,302,400	143,024
1963	4,500	45			3,500	35	15,099,600	150,996
1964	700	7					7,560,900	76,880
1965	300	3					12,825,800	132,601
1966	400	6					12,519,300	134,261
1967	300	4			900	5	18,486,000	317,716
1968	200	8			73,500	1,410	15,524,900	234,669
1969					125,500	3,765	19,761,700	303,717
1970	1,100	23			65,700	1,510	11,521,400	193,756
1971	1,200	50			7,500	150	12,721,900	203,122
1972							11,237,143	196,145
1973							7,925,898	213,519
1974							6,209,542	246,753
1975			2,338	121			5,952,067	215,501
1976							6,401,360	336,750
1977							8,523,813	421,603
1978	704	50			500	25	6,607,153	286,705
1979			19,388	1,939			5,119,150	313,779
1980			*	*	1,460	151	6,218,523	444,327
1981			143,232	5,252	823	459	4,753,723	316,850
1982			7,679	726	2,121	318	9,437,703	704,599
1983					100	15	5,868,332	464,389
1984			9,497	843	2,077	231	6,516,109	596,428
1985			*	*	55	6	11,548,278	845,906
1986			40,270	1,210			6,814,323	647,293
1987			19,279	1,000			3,194,975	368,062
1988			19,517	1,561			4,191,211	502,166
1989					512	77	1,491,077	183,842
1990			11,073	1,107			1,157,625	174,259
1991							1,575,378	118,272
1992			110,794	10,773	395	52	1,723,178	172,453
1993					1	0	916,235	67,494
1994			305,934				911,410	127,706
1995**			19,174	18	62	16	453,985	130,159
1996**			*	*	165	38	529,503	132,389
1997**			5,568	1,966	158	56	334,810	128,989
1998**							521,431	202,437
1999**			*	*	386		443,551	

* Denotes confidential data, included in total landings.

** Season enacted by rule, various management measures taken on Chowan River pound net fishery.

Table 2. River herring research and monitoring work by the North Carolina Division of Marine Fisheries in the rivers and sounds of eastern North Carolina.

		Type of work				
System	**Years**	**Spawning areas**	**Juvenile abundance**	**Adult age**	**Migration**	**Stock assessment**
Albemarle Sound area	1971-present	1972-80 1982-83 1987-88 1993	1972-present	1972-present	1974-76	1996,1998, 1999
Tar-Pamlico	1974-81	1975-76 1980	1974-81	1974-81	1975-76	
Neuse	1976-81	1977-79	1976-81	1976-81	1977-79	
White Oak	1973-75	1974-75	1974-75	1974-75		
New	1973-75	1974-75	1974-75	1974-75		
Cape Fear	1975-81	1976-81	1975-81	1976-81		

(ASMFC 1998) was approved in 1998. It provides for restrictions on the American shad (*A. sapidissima*) fisheries in the ocean, but makes no specific regulatory recommendations concerning river herring. However, the plan includes greater biological monitoring and reporting requirements for river herring. Further, the ASMFC plan recommends that existing management regimes be maintained or strengthened. Plans of the regional fishery management councils under the federal Magnuson-Stevens Act do not directly affect the river herring fisheries. However, river herring may be taken as bycatch in the mid-Atlantic and New England area fisheries for Atlantic mackerel and Atlantic herring. There are Magnuson-Stevens Act FMPs for these fisheries, so there are indirect federal management effects on North Carolina's river herring fisheries. In addition, the South Atlantic Fishery Management Council's Habitat Plan for the South Atlantic Region (SAFMC 1998) specifically considers habitat needs for anadromous fishes, including both species of river herrings.

4.4.2 Statutes

All management authority for North Carolina's river herring fishery is vested in the State of North Carolina. Since the stock depends greatly on habitats found in both Coastal and Inland Waters, the North Carolina Marine Fisheries Commission and the North Carolina Wildlife Resources Commission will implement management actions in their respective jurisdictions.

General authorities noted in Section 4.1.2 provide the MFC and WRC with regulatory powers to manage the fisheries. There are some statutes (G.S. 113-268 (a), (b), and (c)) which prohibit unauthorized use of another person's fishing gear. The two commissions promulgate specific rules to implement management objectives.

4.4.3 Rules

4.4.3.1 Marine Fisheries Commission Rules

- Rule North Carolina Administrative Code (NCAC) 3M .0513 was amended in a temporary rule action as follows (effective 1 March 1999): The Fisheries Director by proclamation, based on environmental and local stock conditions, can specify size, season, area, quantity, means and methods of harvest and require submission of statistical and biological data. An annual (calendar year) commercial quota of 450,000 lb for river herring is established in the ASRHMA. The CRHMA pound net fishery was allocated 300,000 lb; 100,000 lb to the ASRHMA gill net fishery; and 50,000 lb may be allocated at the discretion of the Fisheries Director. The definitions of the management areas are contained in Section 4.3.

- NCAC 3J .0101. Unlawful to use or set fixed or stationary nets
  (1) Where they constitute a hazard to navigation
  (2) So as to block more than two-thirds of a waterway
  (3) In the middle third of any marked navigation channel
  (4) In the channel third of any of the rivers tributary to Albemarle Sound

- NCAC 3J .0102. Unlawful to use nets or net stakes
  (1) Within 150 yards of bridges across Roanoke and Alligator rivers
  (2) Within 300 yards of highway bridges across Albemarle, Croatan, Currituck, or Roanoke sounds or Chowan River

- NCAC 3J .0103. Gill nets (a) The Director may, by proclamation, restrict gill net areas, seasons, mesh size, means and methods, and number and length.
  (b) Specific gill net marking requirements
  (c) Gill nets must be 200 yards from a pound net in use

- NCAC 3J .0107 Pound nets
  (a) Identification requirements
  (b) Must have permit to set pound net; permit process

- NCAC 3J. 0203 Chowan River
  (1) Anchoring of lead lines of nets
  (2) Restricted areas for pound nets
  (3) Pound nets must be at least 200 yards apart

4.4.3.2 Wildlife Resources Commission Rules

Under WRC rules, river herring are considered as "nongame fish". Nongame fish may be taken by "special devices" (nets, traps, etc) as provided in rule (section NCAC 15A 10C), as well as by hook and line.

- 10C .0401

  (a) General provisions

  (b) Some species, including river herring, taken by special devices may be sold

- 10C .0402

  (a) Authorizes taking nongame fish for bait using dip nets, small seines, cast nets, and minnow traps

- 10C .0404 (b)

  (1) and (2) Restrictions on setting fixed gill nets

  (3) Requires attending gill nets in certain counties, including the entire Albemarle Sound area

- 10C .0407 provides specific seasons and restrictions by county and for some waters within some counties

5. General Life History

5.1 Introduction

The alewife and the blueback herring, collectively known as river herring, are anadromous members of the family Clupeidae (herrings and shads). "Anadromous" means they migrate from the ocean, enter coastal bays and sounds through inlets, and ascend freshwater rivers and streams to spawn. Surviving adults return to the ocean after spawning. The young fish use rivers and estuaries as nursery grounds as they migrate downstream after hatching. After the juveniles leave the rivers and estuaries in the fall or early winter, they complete their development in the Atlantic Ocean, over the continental shelf off New England (Loesch 1987;

Jenkins and Burkhead 1993). The two species occur geographically together from New Brunswick and Nova Scotia in Canada south to the northern coastal area of South Carolina. Blueback herring occur further south, to northern Florida. There are important life history differences between the two species (Loesch 1987). Alewives select slower-flowing areas for spawning. Blueback herring have been reported to select faster-flowing sites in areas where both species occur; however such areas generally do not exist in the FMP management area. In areas where both species occur, alewives generally spawn earlier. While fish are believed to return to the streams of their birth for spawning, both species readily colonize new streams or ponds and will reoccupy systems from which they have been extirpated (Loesch 1987). Both juveniles and adults respond negatively to light, in both riverine and offshore habitats, with alewives remaining deeper in the water column in both habitats (Klauda et al. 1991). Both species are important prey at all life stages for many other species of commercial and recreational importance. Both species have also been widely stocked in inland freshwater lakes and reservoirs where they live and reproduce entirely in freshwater and serve as prey for freshwater game fish.

The percentage of alewife and blueback herring present in major Albemarle Sound tributaries has varied, based on sampling of the commercial catch (Johnson et al. 1981). The percentage of alewife ranged from 4 % in 1977 to 49 % in 1979, with alewife dominating the early catches in each year. From 1989 through 1992, the percentage of alewife ranged from 14.2 to 31.2% (Winslow and Rawls 1992). The same pattern of early dominance by alewife, with subsequent later dominance by blueback herring, is evident in weekly species composition samples taken during the 1980-92 spawning runs on the Chowan and Scuppernong rivers (Winslow et al. 1983; Winslow and Rawls 1992). The fraction of alewife in the commercial catch for those years ranged from 27 to 37%.

5.1.1 Alewife

The alewife has a grey to grey-green back and silvery sides. They range in size as adults from about 9 in (230 mm) to over 13 in (330 mm). Adult alewives were sampled offshore during National Marine Fisheries Service (NMFS) Atlantic Coast trawl surveys (Fay et al. 1983; Loesch 1987). The majority of catches occurred at depths less than 328 ft (100 m). Alewives were more abundant than blueback herring when all samples were combined. Alewives were most abundant at depths between 184 and 361 ft (56 and 110 m), deeper than blueback herring. Neves (1981) felt that the greenish dorsal coloration of the alewife is associated with the deeper vertical distribution of the species relative to blueback herring, given that a greenish coloration would provide better camouflage at those depths, since green wavelengths penetrate deeper than blue. Catches of the species in the ocean were confined to areas north of 40° north latitude in summer and fall. Winter catches were made between 40° and 43° north latitude. Spring catches were distributed over the entire Continental Shelf.

Alewives which spawn in Albemarle Sound tributaries migrate from the northwest Atlantic Ocean, through Oregon Inlet and perhaps Hatteras Inlet, in late winter and early spring. Spawning surveys conducted by the DMF since the mid 1970s (Street et al. 1975; Johnson et al. 1977; Johnson et al. 1981; Winslow et al. 1983; Winslow et al. 1985; Winslow and Rawls 1992) during March through May have documented spawning in many tributary streams of Albemarle Sound's major tributaries. Known historical anadromous fish spawning sites are depicted on the maps presented in Section 13, Appendix 3 and are listed in Section 9.1, which describes critical and essential habitats for the species. Although the alewife has been reported as ranging from Newfoundland south to South Carolina (Loesch 1987), surveys reported by Rulifson et al. (1982) in 1980 and repeated 12 years later (Rulifson 1994) indicated that the species now occurs in south Atlantic coastal rivers only in North Carolina. In North Carolina, populations were reported in the North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator rivers (all tributaries of Albemarle Sound); Lake Mattamuskeet and canals to the lake, Tar-Pamlico, Pungo, Neuse, and Trent rivers (tributaries to Pamlico Sound); New River; White Oak River; and Cape Fear, North East Cape Fear and Brunswick rivers. Status of these populations is presented in Table 4 of Rulifson (1994). All populations were listed as either "declining" or "status unknown" as of 1992.

Anadromous alewives may begin spawning as early as age three, with the majority reaching sexual maturity at age 4 or 5. Fecundity in females ranged from 60,000 to 100,000 eggs (Fay et al. 1983). Spawning populations are generally younger in the south. Females sampled from Albemarle Sound tributaries were primarily (94-97%) ages 4 through 6, with fish present up to ages 7 or 8 (Johnson et al. 1981). The historical average repeat spawning from 1972 through 1981 was 9.4% for alewife (see Section 5.3).

Spawning occurs in the spring, earlier in the south and later in the north. Alewives generally spawn 3-4 weeks before blueback herring in areas where the two species co-occur. Alewives in North Carolina spawn at water temperatures of 55-61° F (12.9-16° C) (Tyus 1974; Winslow 1989; Winslow et al. 1983). Alewives use a wide variety of spawning sites, such as stream edges and flooded backwaters. Eggs of alewife hatch in approximately 50 to 360 hours, depending upon temperature (Fay et al. 1983). The alewife yolk-sac stage lasts from 2 to 5 days. Larval alewives range in size from 0.2 to 0.8 in (4.3 to 19.9 mm). Transformation to the juvenile stage occurs at about 0.8 in (20 mm). Like juvenile blueback herring, juvenile alewives may initially exhibit upstream movement, later moving downstream as fall approaches. Emigration from Albemarle Sound occurs between September and November of the first year of life, and may be stimulated by heavy rainfall, high water, and/or sharp declines in water temperatures. Habitat requirements for critical early life history stages of the alewife as determined by Klauda et al. (1991) are presented in Table 3.

Alewives primarily consume zooplankton, although fish eggs, crustacean eggs, insects and insect eggs and shrimp, squid and small fishes may be eaten in some areas or by larger individuals (Jenkins and Burkhead 1993).

Alewife are important prey for other species jointly managed by federal and state governments and the ASMFC, including bluefish, American eel, striped bass and weakfish. Freshwater species managed by the state also consume alewife (largemouth bass, pumpkinseed, redfin pickerel, shiners, walleye, white bass, white perch and yellow perch; Loesch 1987).

5.1.2 Blueback Herring

Blueback herring have a blue to blue-green back and silver sides with a prominent dark spot on the shoulder. In contrast to the alewife, bluebacks have a black peritoneum lining the body cavity. They range in size from around 9 in (230 mm) at age three to around 12.3 in (313 mm) at age eight or nine. Catch data from NMFS ocean trawl surveys (Neves 1981) indicate that bluebacks spend most of their time offshore in water depths of less than 328 ft (100 m). North of

Table 3. Habitat requirements for the critical early life history stages of alewife, *Alosa pseudoharengus* (after Klauda et al. 1991).

Life Stage	Zone	Temperature °C	Salinity %	Dissolved Oxygen mgL^{-1}	pH	Hardness mgL^{-1} $CaCO_3$	Alkalinity mgL^{-1} $CaCO_3$	Suspended Solids mgL^{-1}	Current Velocity cm^{s-1}
Egg	substrate and water column	11-28 (suitable) 16-21 (optimum)	NIF* (suitable) 0-2 (optimum)	>5.0 (suitable) NIF (optimum)	5.0-8.5 (suitable) NIF (optimum)	NIF	NIF	<1000 (suitable) NIF (optimum)	NIF
Prolarva	water column	8-31 (suitable) 15-24 (optimum)	NIF (suitable) 0-3 (optimum)	>5.0 (suitable) NIF (optimum)	5.5-8.5 (suitable) NIF (optimum)	NIF	NIF	NIF	NIF
Postlarva	water column	14-28 (suitable) 20-26 (optimum)	NIF (suitable) 0-5 (optimum)	>5.0 (suitable) NIF (optimum)	NIF	NIF	NIF	NIF	NIF
Early juvenile	water column and near substrate	10-28 (suitable) 17-24 (optimum)	NIF (suitable) 0-5 (optimum)	>3.6 (suitable) NIF (optimum)	NIF	NIF	NIF	NIF	NIF

*NIF means no information found.

Cape Hatteras, blueback herring were most abundant at depths between 89 and 180 ft (27 and 55 m). Catches of bluebacks in summer and fall were confined to the areas north of 40° north latitude. Winter catches were made between 40° and 43° north latitude. Spring catches were distributed over the entire Continental Shelf portion of the study area (Fay et al. 1983).

Bluebacks have a broader range in the south Atlantic than alewife, occurring as far south as coastal rivers in Florida. Rulifson's recent (1994) survey indicated that the species occurs in the following North Carolina river systems: North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator rivers (all tributaries of Albemarle Sound); Tar-Pamlico, Pungo, Neuse, and Trent rivers (tributaries to Pamlico Sound); New River; White Oak River; and Cape Fear, North East Cape Fear and Brunswick rivers. Sites in Albemarle Sound tributaries which have been documented as spawning habitat are depicted on the maps in Section 13, Appendix 3.

Blueback herring have been reported to spawn in the lower portions of the tributary rivers of estuaries along the east coast from Nova Scotia to the St. Johns River in Florida (Fay et al. 1983). They have been reported to travel much farther upstream in North Carolina than alewife. Loesch (1987) reported that there is no evidence that bluebacks do not travel just as far, if not farther, than alewife.

Bluebacks vary more than alewives in age of first spawning, although, their maturation rates are similar (Fay et al. 1983). Spawning populations in Albemarle Sound tributaries were dominated by ages 4-6 during the late 1970s and early 1980s (Johnson et al. 1981, Winslow et al. 1983). Fecundity of blueback herring females ranged from 45,800 eggs in a 9.4 in (238 mm) individual to 349,700 from a 12.2 in (310 mm) fish (Fay et al. 1983). In North Carolina, blueback herring begin spawning at warmer temperatures than alewives, with recorded spawning temperatures of 58-63° F (14.4-17° C) (Winslow 1989; Winslow et al. 1983). Bluebacks spawn in flooded backswamps, oxbows and along stream edges. Both species cease spawning when water temperatures rise above 81° F (27° C). Both species spawn in groups and scatter their eggs. Blueback herring eggs hatch in approximately 55 to 94 hours, depending upon the temperature. Yolk-sac larvae average 0.2 in (5.1 mm) at absorption and remain in that stage for 2-3 days. Larval blueback herring range from 0.2 to 0.6 in (4-15.9 mm) in length. Transformation to the juvenile stage is completed at about 0.8 in (20 mm) in length. Juveniles may exhibit an initial upstream movement during the summer, followed by downstream movement beginning in October. Juveniles exhibit diel movement, moving toward the bottom during the day and toward the surface at night. Emigration from estuarine nursery areas in North Carolina occurs between September and November of their first year. Little information is available on the juveniles of the species once emigration to sea has occurred. Habitat requirements for critical early life stages of blueback herring as documented by Klauda et al. (1991) are presented in Table 4.

Blueback herring, like alewives, are primarily zooplankton feeders. Young-of-the year bluebacks consumed various species of copepods and cladocerans (Jenkins and Burkhead 1993). In the ocean, the species' diet consists of copepods, other plankton, pelagic shrimps, small fishes and fish fry. The food of adults is similar to that of juveniles and includes insects during the spawning migration (Jenkins and Burkhead 1993). The blueback herring is a small species, and as such, is also an important forage species for other species. It is preyed upon by the same species which prey on alewife and other clupeid species, and constitutes an important link in estuarine and marine food webs between zooplankton and top predators.

5.2. Historical Abundance

In North Carolina, there are no long-term data available on river herring abundance. Historical abundance of river herring in Albemarle Sound, based on landings and effort data, was investigated by Hightower et al. (1996). Fisheries in Albemarle Sound once harvested large numbers of river herring, but landings in recent years are substantially lower. Average landings during the 90-year period of 1880-1970 were 11.9 million pounds (5.4 million kg). Landings in 1998, in contrast, were only 4.2 % of the historical average (519,289 lb; 235,548 kg; see Section 6). This comparison does not take into account the change in effort since the season was implemented in 1995. Hightower et al. (1996) noted that the estimate of maximum sustainable yield derived from their modeling of the period 1845-1993 was 12.6 million lb (5.7 million kg), similar to the long-term average reported landings. They stated that the only remaining question was whether habitat has been lost or degraded to such a degree that historical levels of harvest are no longer possible.

5.3 Present Stock Status

The DMF anadromous fish sampling program began in the Albemarle Sound area in 1972. Work began in the Tar-Pamlico, Neuse and Cape Fear systems during the mid-1970s.

Table 4. Habitat requirements for the critical early life history stages of blueback herring, *A. aestivalis* (after Klauda et al. 1991).

Life Stage	Zone	Temperature °C	Salinity %	Dissolved Oxygen mgL^{-1}	pH	Hardness mgL^{-1} $CaCO_3$	Alkalinity mgL^{-1} $CaCO_3$	Suspended Solids mgL^{-1}	Current Velocity cm^{s-1}
Egg	substrate and water column	14-26 (suitable) 20-24 (optimum)	0-22 (suitable) 0-2 (optimum)	NIF* (suitable) NIF (optimum)	5.7-8.5 (suitable) 6.0-8.0 (optimum)	NIF	NIF	<1000 (suitable) NIF (optimum)	NIF
Prolarva	water column	14-26 (suitable) NIF (optimum)	0-22 (suitable) NIF (optimum)	>5.0 (suitable) NIF (optimum)	6.2-8.5 (suitable) 6.5-8.0 (optimum)	NIF	NIF	<500 (suitable) NIF (optimum)	NIF
Postlarva	water column	14-28 (suitable) NIF (optimum)	0-22 (suitable) NIF (optimum)	>5.0 (suitable) NIF (optimum)	NIF	NIF	NIF	NIF	NIF
Early juvenile	water column and near substrate	10-30 (suitable) 20-28 (optimum)	0-28 (suitable) 0-5 (optimum)	>4.0 (suitable) NIF (optimum)	NIF	NIF	NIF	NIF	NIF

*NIF means no information found.

Sampling throughout the coastal area has been scaled back over the years due to a reduction in federal funds supplied by the Anadromous Fish Conservation Act (P.L. 89-304). River herring research and monitoring work conducted by DMF are shown in Table 2, by system and year. Specific sampling methods are described in Street et. al (1975), Johnson et. al (1977; 1981), Winslow et. al (1983; 1985) Winslow (1989; 1995; 1998), and Winslow and Rawls (1992). "The Status of Blueback Herring in the Chowan River, 1972-1998" (Carmichael 1999) stock assessment analysis is presented in Section 13, Appendix 1.

5.3.1 Fishing Mortality

Mortality rates were estimated by catch curve and catch at age analyses. Total mortality based on the catch curve analyses averaged around Z=1.5 for the 1972-1998 period. By subtracting the assumed natural mortality rate of M=0.5, fishing mortality is estimated at approximately F=1.0. Estimated fishing mortality from the catch at age model for 1972-1994 is 1.01, which is equivalent to an annual exploitation rate attributable to fishing of 52%. To account for the possibility that regulatory changes have had some impact on exploitation rates, F was estimated annually for 1995-1998. Average fishing mortality has dropped since 1995 to 0.59, largely due to the estimated value in 1997 of 0.27. Fishing mortality increased in 1998 to 0.58.

5.3.2 Recruitment

Recruitment at age 3 averaged 28.7 million fish a year between 1972 and 1985; but since 1986, it has averaged 5.1 million fish (Figure 3). Strong year classes in the late 1960s sustained the stock through the mid-1970s, when the poor 1975-1977 cohorts contributed to the decline in the late 1970s. Exceptional recruitment of the 1978-1981 cohorts, which averaged 37.6 million fish, allowed the stock to rebuild in the early 1980s, but from 1983 to 1986 several poor year classes coupled with high fishing mortality led to a precipitous decline in overall stock abundance that continued through 1998. Recruitment has been extremely low since 1989, averaging 3.5 million fish a year. Moreover, several moderate year classes observed since the early 1980s supported short-term catches, but they were subsequently removed through excessive exploitation.

Figure 3. Estimated recruitment, of Chowan River blueback herring, in numbers of age-3 fish, 1972-1998.

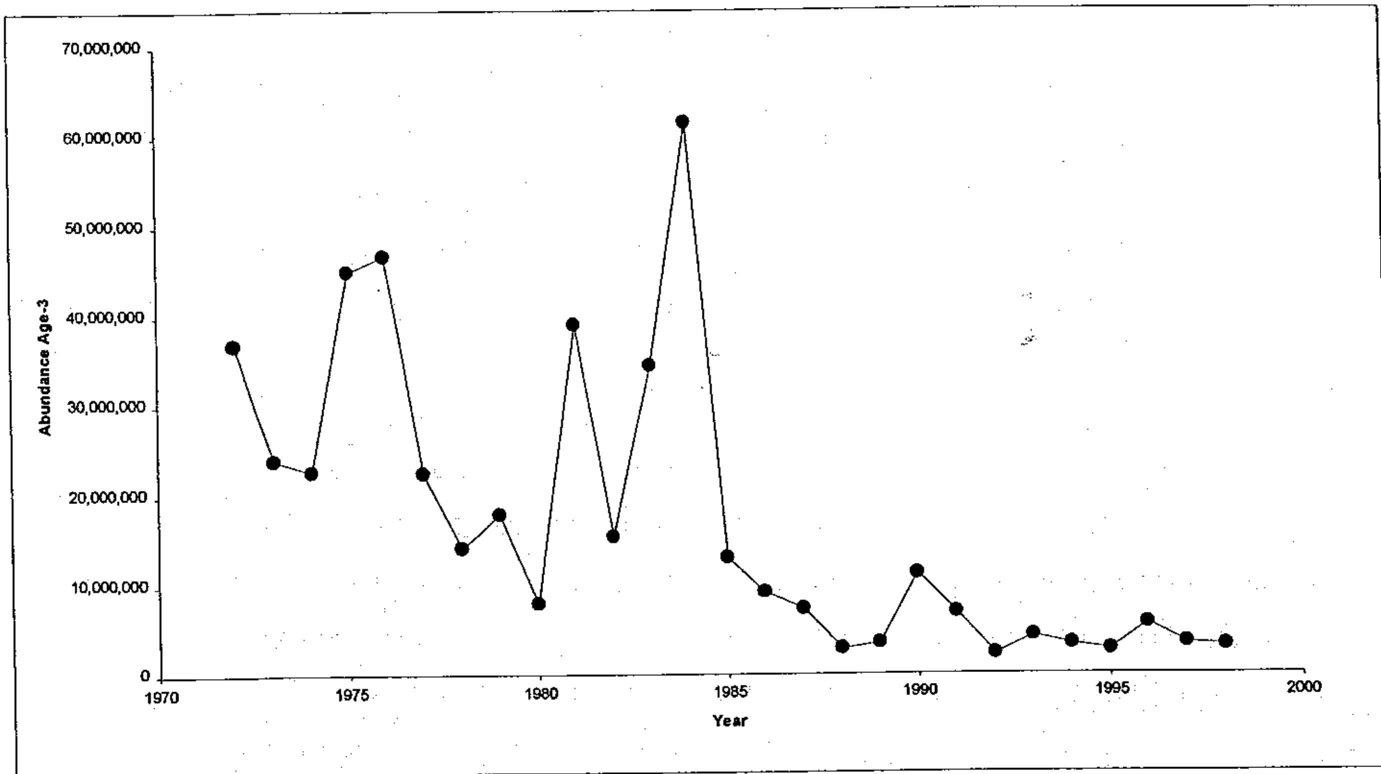
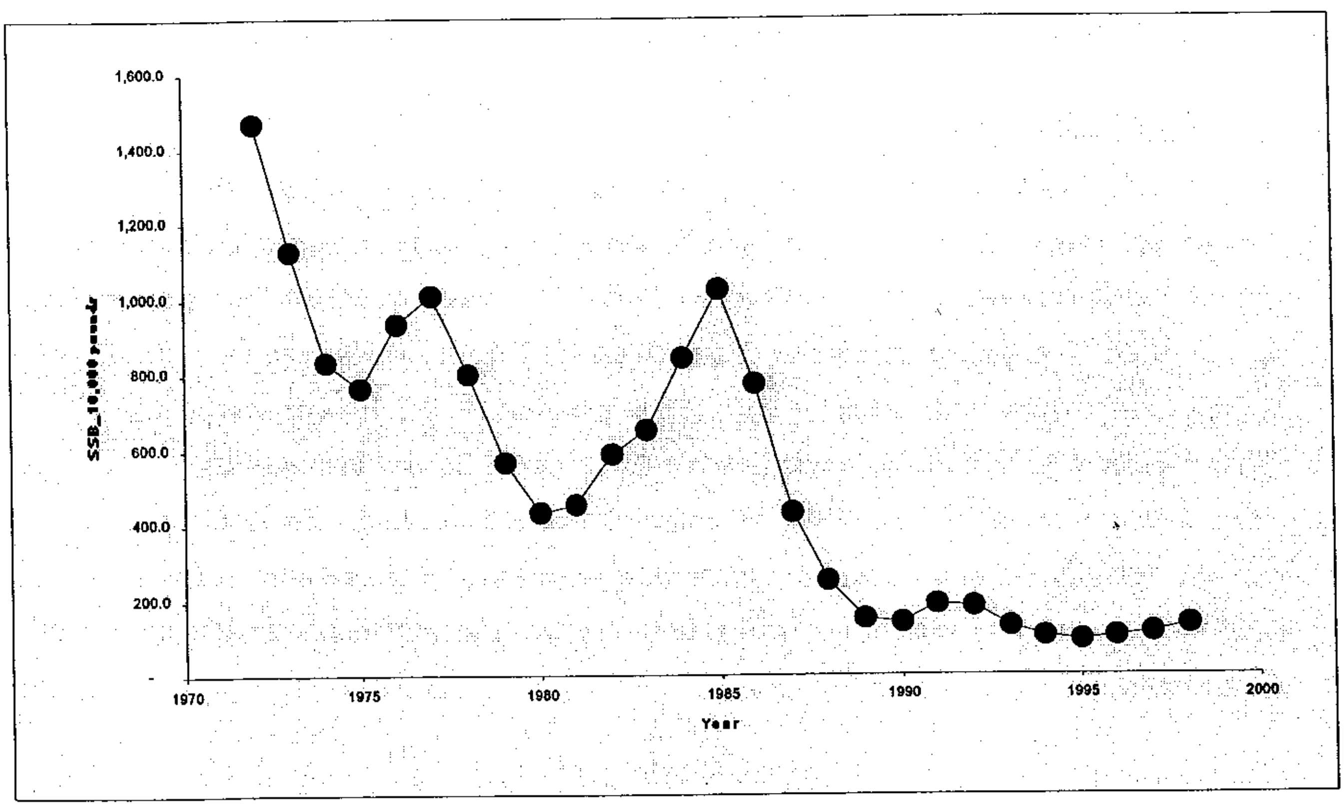


Figure 4. Estimated spawning stock biomass of Chowan River blueback herrring (in pounds x 10,000) 1972-1998.



5.3.3 Spawning Stock Biomass

Spawning stock biomass (SSB) declined significantly over the analysis period, dropping from a 1972-1985 average of 8.2 million pounds (mlb) to an average of only 2.1 mlb for 1986-1998 (Figure 4; Table 5). A slight increase in 1991 and 1992 can be attributed to the 1987 and 1988 year classes reaching maturity, but continued poor recruitment further reduced SSB to a record low in 1995 of 0.9 mlb. SSB has increased slowly each year since 1995, reaching 1.3 mlb in 1998. The recent increase is largely due to the 1993 year class, the best in the last seven years. However, given that the 1994 and 1995 cohorts are among the lowest observed, it is unlikely that this slight increase in 1998 will be maintained as these poor cohorts move through the population.

5.3.4 Juvenile Indices

The DMF began nursery area sampling for juvenile blueback herring and alewife in the Albemarle Sound area in 1972. This survey was designed to index annual relative abundance of juvenile blueback herring and alewife. Thirty-four stations were established in the western Albemarle Sound area and sampled with trawls and seines. The Carolina wing trawl was adopted as the standard trawl in place of the Cobb trawls in June 1974 (Johnson et al. 1977), and the seines were continued. The 34 stations (23 trawls and 11 seines) were sampled monthly during June-October. During September, an additional 43 stations (28 trawls and 15 seines) were sampled throughout the Albemarle Sound area to determine distribution and nursery areas of anadromous species.

The seine stations were pulled with a 60 ft bag seine with a 1/4 in mesh bag. One seine haul was considered one unit-of-effort. The Carolina wing trawl had a headrope length of 26 ft, containing webbing which ranged from 4 in stretched mesh in the wings to an 1/8 in mesh tail bag. The trawl was pulled for 10 minutes, which was considered one unit-of-effort. Samples were sorted to species, and up to 30 individuals of each alosid species present were measured to the nearest millimeter fork length (mm, FL), and all others were counted.

Based on catch consistency the seine proved to be the best sampling gear for blueback herring, and the wing trawl was best for alewife. Due to a further reduction in federal aid funds, trawl sampling was dropped at the end of June 1984.

Sampling with seines at the 11 core stations has continued during June-October each

Table 5. Spawning stock biomass and age-3 recruitment by cohort based on catch-at-age analysis for Chowan River blueback herring, 1969-1998.

Year	SSB (Pounds)	Recruits by cohort (est. at age-3)
1969		37.775
1970		24.020
1971		22.860
1972	14,658,461	45.502
1973	11,236,314	47.762
1974	8,337,979	22.041
1975	7,623,870	14.572
1976	9,343,361	17.704
1977	10,089,414	8.240
1978	8,015,481	39.088
1979	5,642,241	15.638
1980	4,334,143	34.926
1981	4,520,098	62.451
1982	5,869,962	12.757
1983	6,483,093	9.935
1984	8,439,608	7.336
1985	10,217,910	2.705
1986	7,718,047	3.438
1987	4,294,360	11.43
1988	2,515,429	6.908
1989	1,489,283	2.242
1990	1,360,700	4.273
1991	1,857,395	3.231
1992	1,813,063	2.584
1993	1,290,451	4.985
1994	1,028,607	3.055
1995	914,848	3.016
1996	1,014,317	
1997	1,114,928	
1998	1,345,225	

year (Figure 5). During September, an additional 13 seine stations are sampled throughout the Albemarle Sound area (Figure 5) to determine distribution and migration.

The juvenile abundance indices (JAI) for blueback herring and alewife have fluctuated over the years in the Albemarle Sound area (Figure 6 and 7). The highest CPUE recorded for blueback herring was in 1973 (362.9 fish/seine); the lowest was in 1994 (0 fish/seine), part of a very low CPUE trend during 1986-1999 (Figure 6). The twenty-eight year average CPUE for blueback herring is 70.4. The average CPUE for alewife during the same period is 2.5 fish/seine. In 1980 a CPUE of 12.4 fish/seine was recorded for alewife; other years were much below that level (Figure 7).

Annual sampling to determine the relative abundance of young of year striped bass has been conducted at seven sampling locations (Hassler stations, Figure 8), in the western Albemarle Sound area since 1955. Dr. W.W. Hassler (North Carolina State University) conducted the sampling program from 1955 through 1987, through various funding sources (Hassler et. al 1981; 1982, Hassler and Taylor 1986). The DMF has conducted the sampling since 1988 (Henry et. al 1992; Taylor and Hardy 1993, 1994; Trowell and Winslow 1997, 1998).

An 18 ft semi-balloon trawl, constructed of 1.5 in stretched mesh webbing in the body and 0.5 in stretched mesh in the cod end is utilized. Sampling takes place during mid-July through October annually. Each trawl sample is pulled for 15 minutes, which is considered one unit-of-effort. Samples are sorted to species, counted and measured to the nearest millimeter fork length (mm, FL).

The CPUE from the Hassler stations for blueback herring is shown in Figure 9. The 1996 (107.8) and 1997 (90.5) CPUEs were the highest since 1962, but the 1994, 1995, 1998 and 1999 CPUEs were less than 0.2. Figure 10 shows the CPUEs for alewife from the Hassler stations. The alewife CPUE in 1996 was 3.0, the first time it had been above one since 1984. However, in 1997, 1998 and 1999 the CPUE dropped to 0.66, 0 and 0.05 respectively.

5.3.5 Pound Net Catch-Effort

Fishing effort (ie. number of pound nets) in the Chowan River and Albemarle Sound area pound net fishery has declined since the early 1970s. In the Albemarle Sound area during 1971-1975, the number of pound nets ranged from 645 to 727 nets (Street and Davis 1976). Chowan River pound net fishing effort has declined each year since 1987 (Figure 11). The average

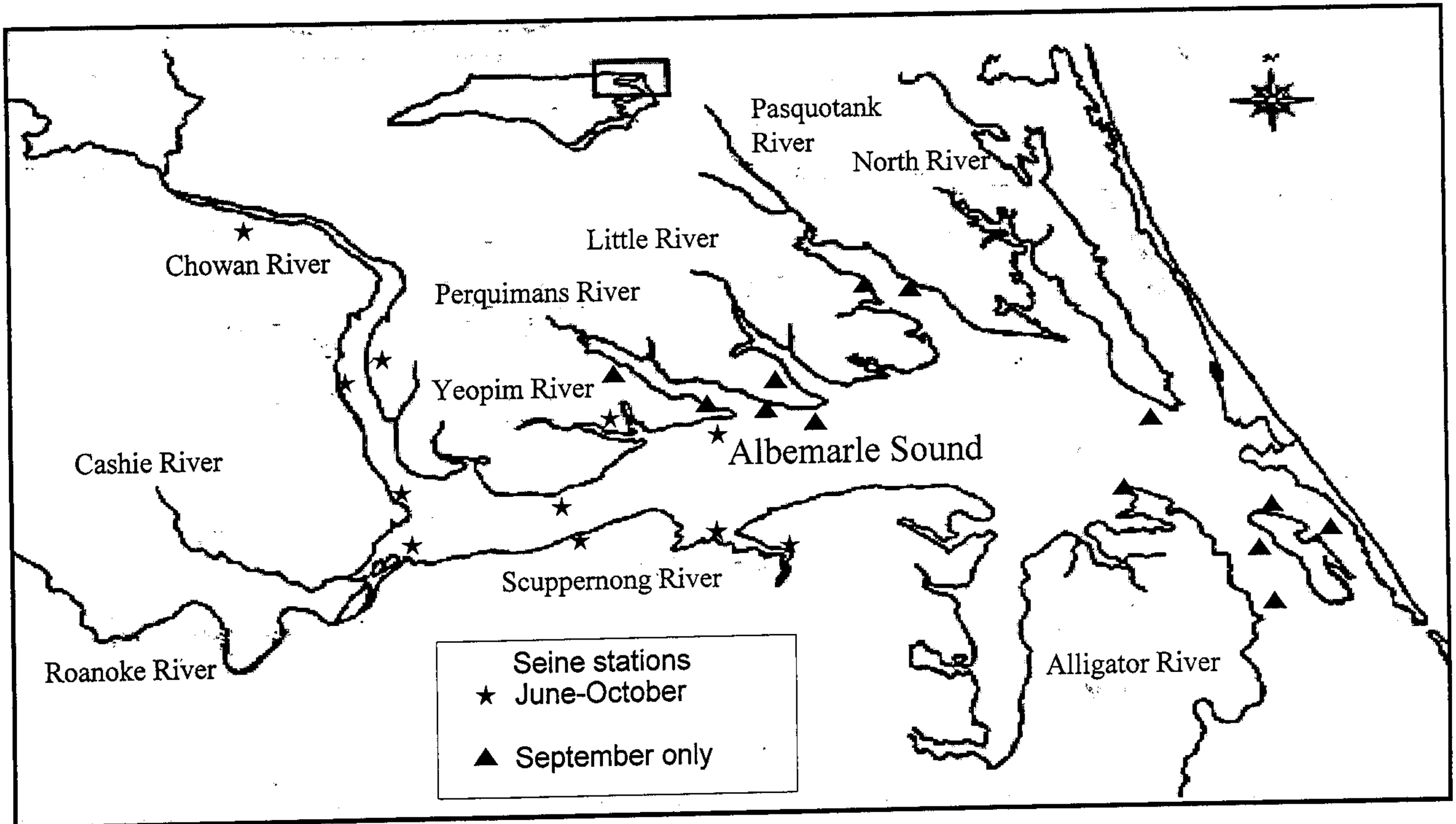


Figure 5. River herring nursery area sampling sites in the Albemarle Sound area, NC, 1972-1998.

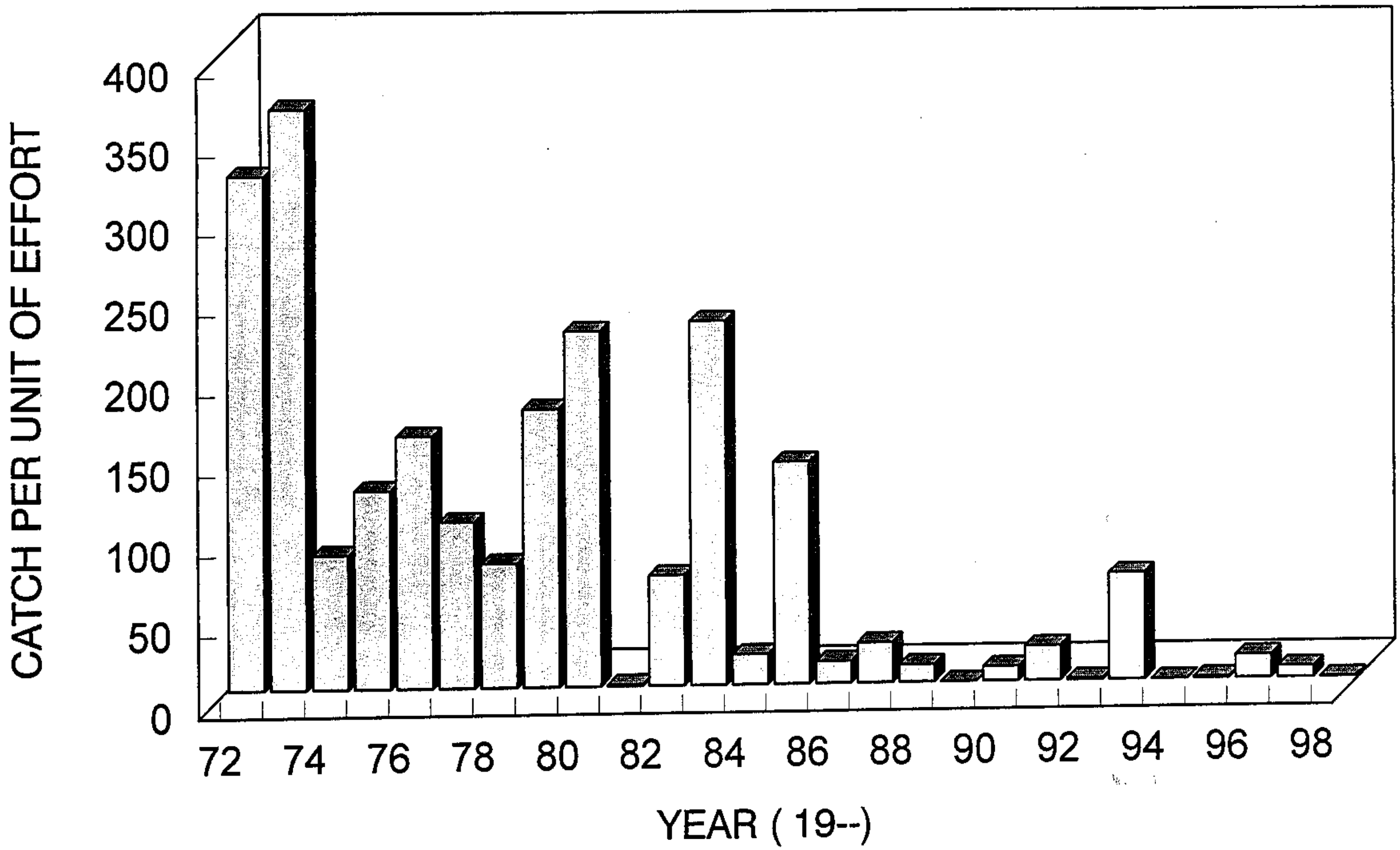


Figure 6. Juvenile abundance index by seine for blueback herring 1972-1998 year classes, from the Albemarle Sound area, NC.

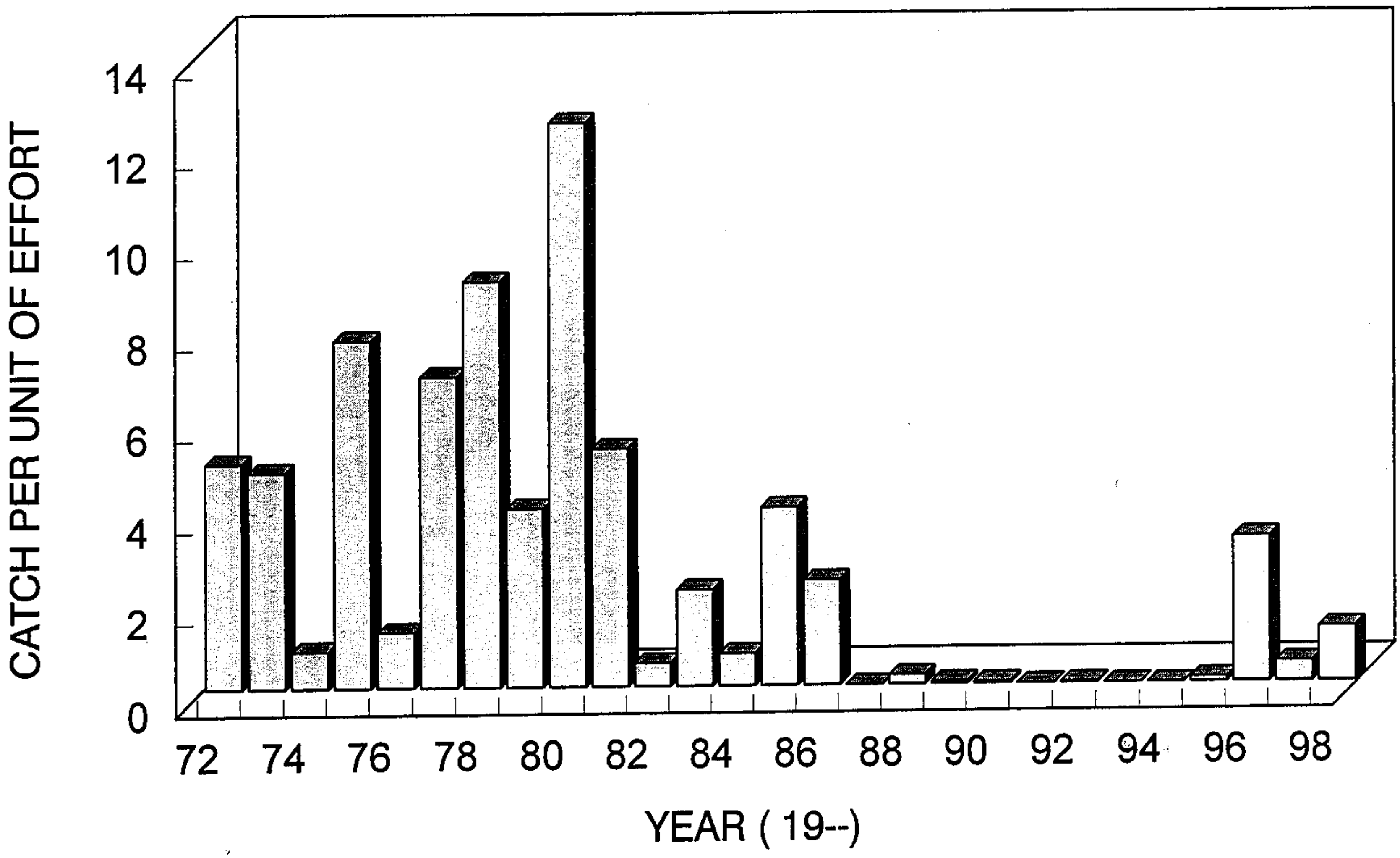


Figure 7. Juvenile abundance index by seine for alewife 1972-1998 year classes, from the Albemarle Sound area, NC.

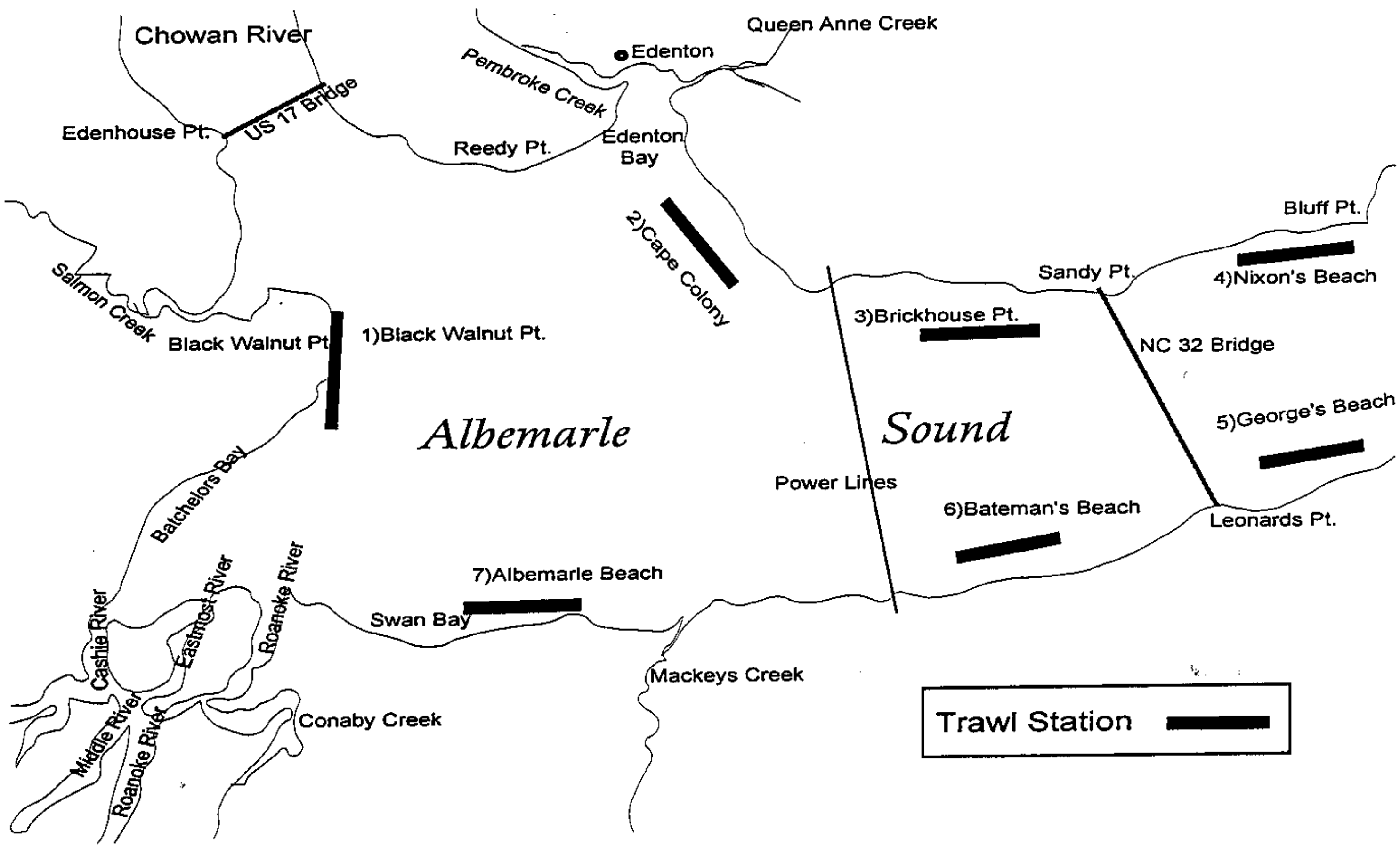


Figure 8. Trawl station locations (Hassler station) sampled in the western Albemarle Sound area, NC, 1955-1998. (Dr. W.W. Hassler conducted sampling during 1955-1987; DMF during 1988-1998)

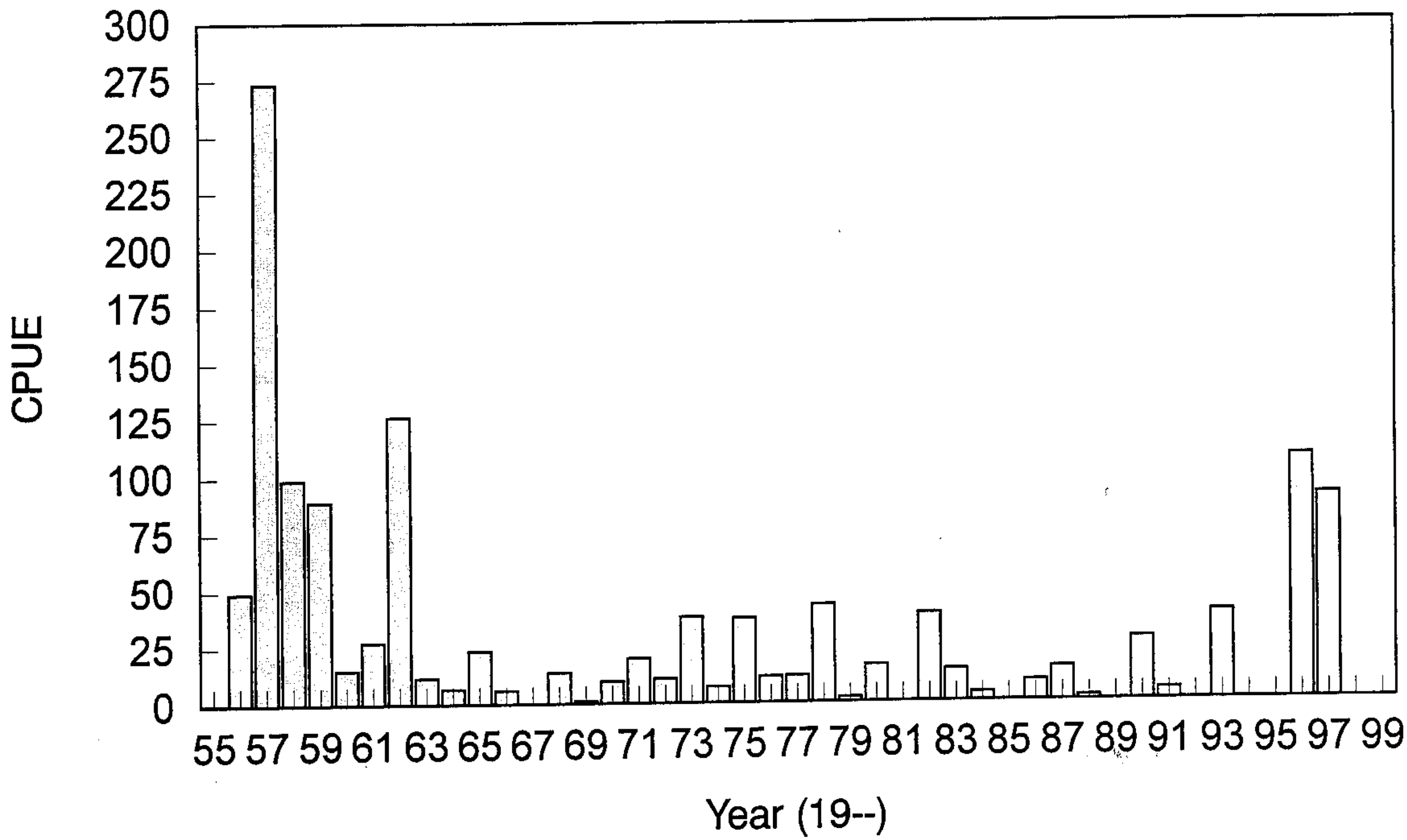


Figure 9 . Catch-per-unit-of-effort of juvenile blueback herring from Hassler trawl stations, western Albemarle Sound, NC, 1955-1998.

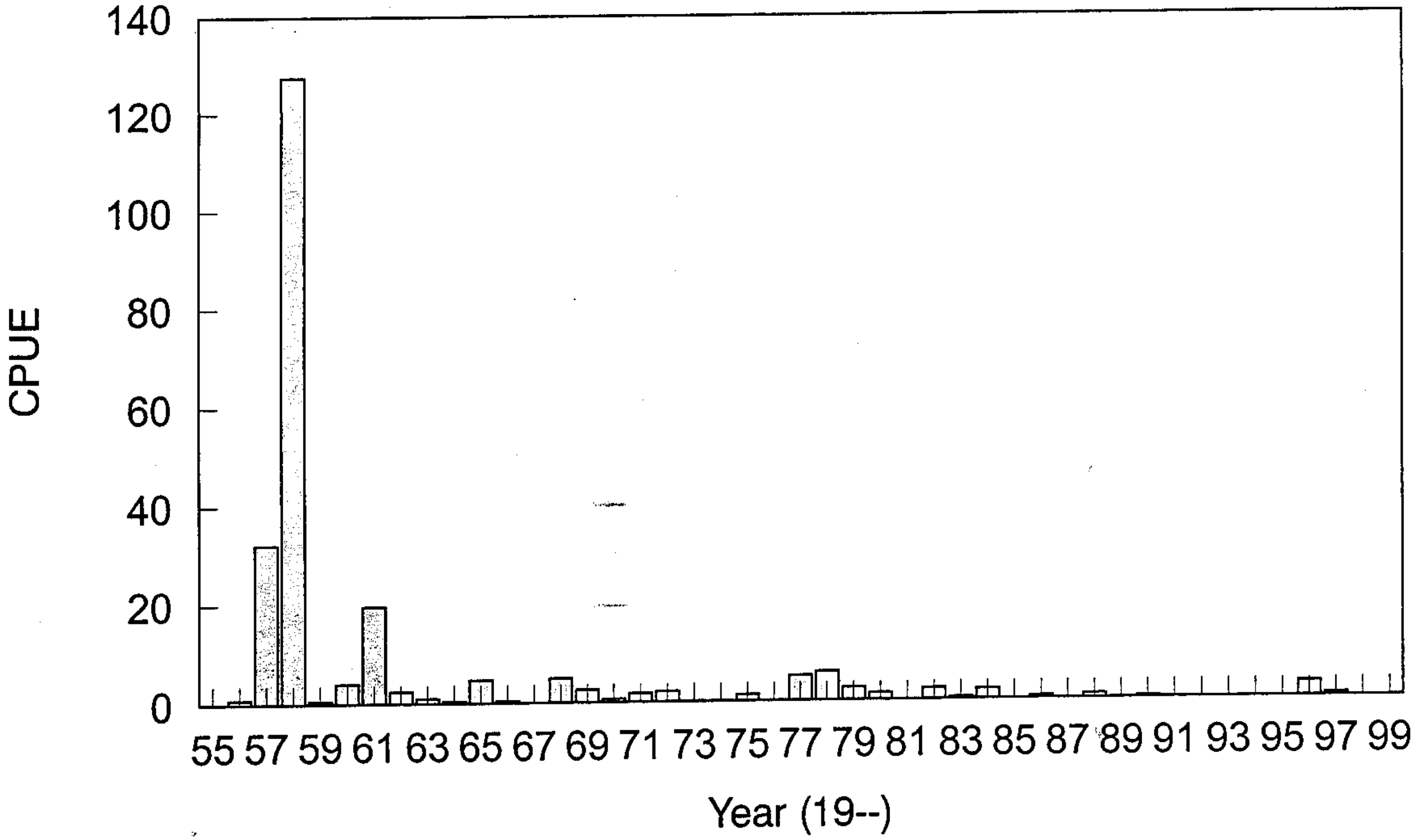


Figure 10. Catch-per-unit-of-effort of juvenile alewife from Hassler trawl stations, western Albemarle Sound, NC, 1955-1999.

number of pound nets set each week in 1977 was 539, compared to 451 in 1987. Prior to seasonal restrictions implemented in 1995, effort had decreased to 147 nets in 1994. Aerial flights were made weekly during spring 1995, 1996, 1997, and 1998 to determine the number of nets set. During 1999, aerial flights were also made. Based on the flights, the average number of nets set ranged from 50 (1995) to 92 (1997).

Several members of the Marine Fisheries Commission's River Herring Advisory Committee (RHAC) advise that since the season has been implemented and prior to 1998, some nets (8-10) may have been set only to satisfy the Pound Net Permit requirements (DEHNR 1997, 15 NCAC 3J .0107). These nets were not actively fished and probably were not a factor in the harvest or economic value. However, this anecdotal evidence cannot be refuted or substantiated due to the historic inability to determine whether or not the nets were actively fished. Therefore, determination of Pound Net Weeks (PNW) and subsequent CPUE may not be precise. (PNW is the number of pound net sets times the number of weeks fished).

Figure 12 shows the CPUE from the Albemarle Sound area pound net fishery, during 1971-1975. The CPUE was 18,614 lb per net in 1971, declining to 8,040 lb in 1975. No data are available for 1976. The CPUE has been determined for the Chowan River pound net fishery continuously since 1977 (Figure 13). In 1977, the CPUE was 14,895 lb per net, declining to 5,189 lb in 1987, and only 2,632 lb per net in 1994, the all time low prior to seasonal restrictions (Figure 13). In 1994, DMF began a new harvest data collection system through the trip ticket program which may affect comparisons with former years. Currently, there are no data on CPUE for gill nets, although DMF trip ticket data show that gill nets have accounted for 22.2-38.1% of the annual river herring harvest.

5.3.6 Age Composition/Mean Size at Age

The age structure of fish taken in the commercial river herring harvest (pound nets) in the Albemarle Sound area has been characterized since 1972. The Chowan River pound net fishery has been sampled annually, while pound net fisheries in the Alligator and Scuppernong rivers were sampled until 1993, when funding levels were reduced. From the 1970s to the early 1990s, sampling was conducted at up to six fishhouses on a weekly basis. Since 1993, only the Chowan area has been sampled. Throughout the years, unculled pound net samples of at least 30 individuals each of blueback herring and alewife were obtained at least weekly during the spring.

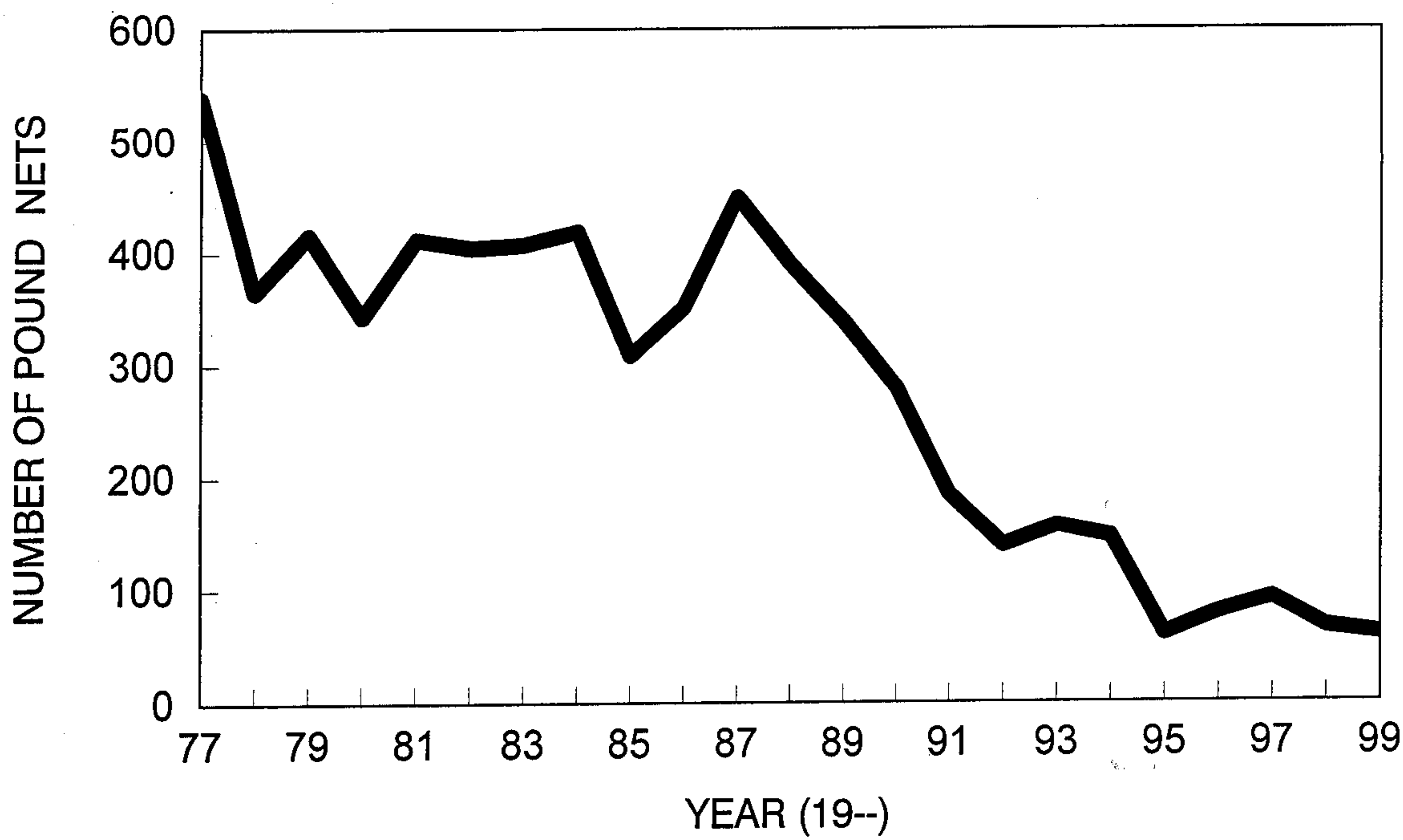


Figure 11. Mean number of river herring pound nets set in the Chowan River, NC, 1977-1999.

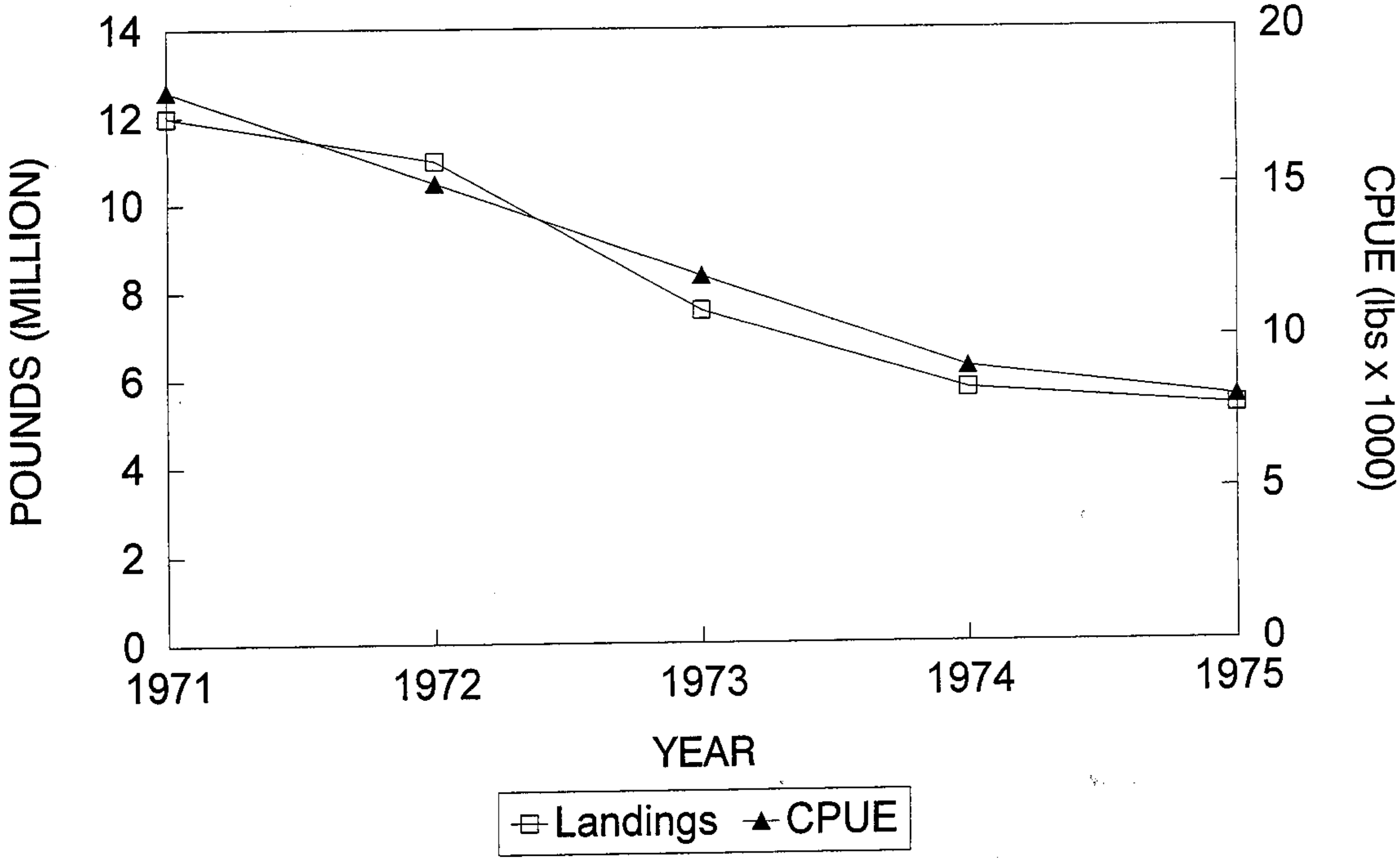


Figure 12. Albemarle Sound area river herring pound net landings and catch-per-unit-of-effort, 1971-1975.

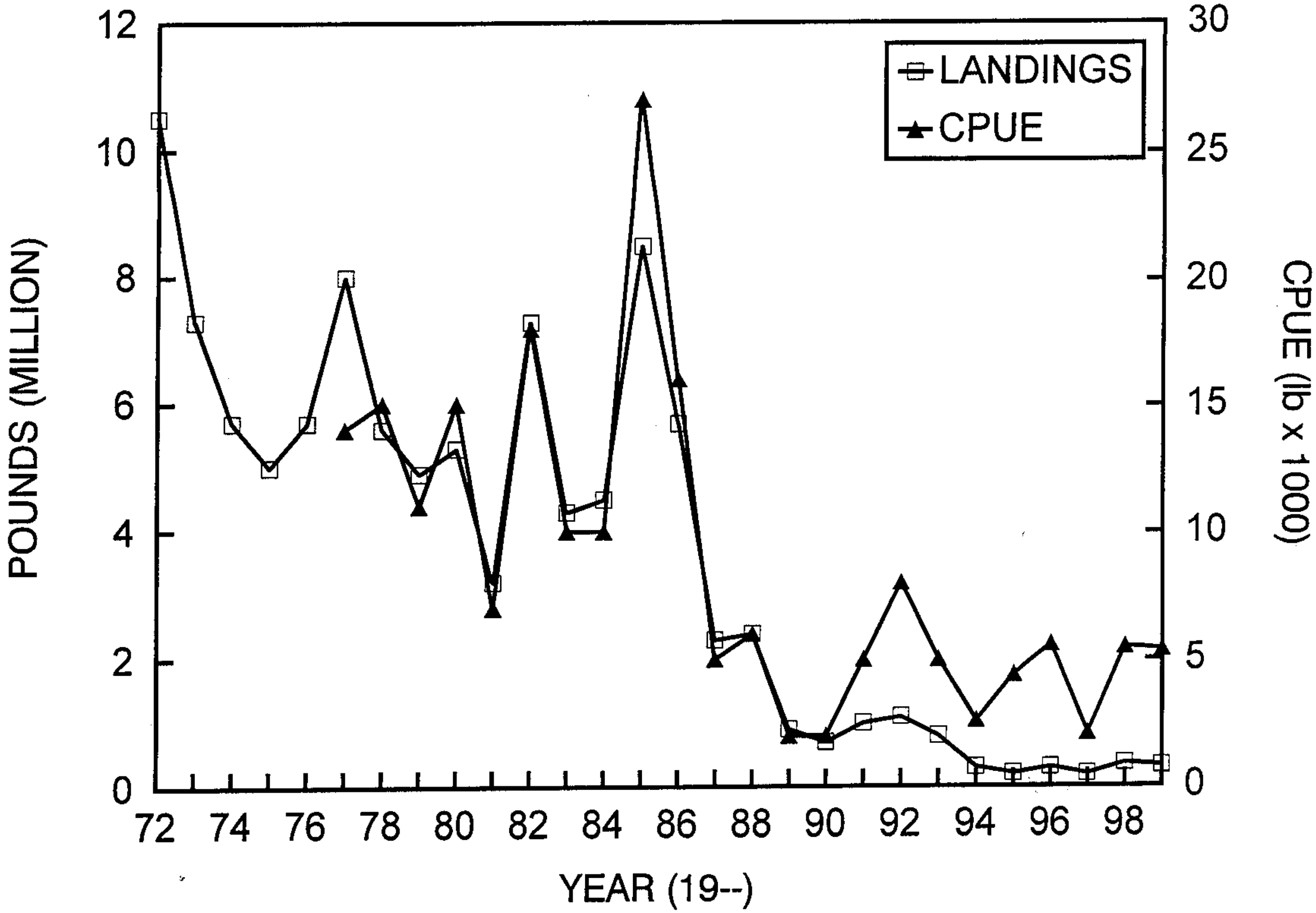


Figure 13. River herring pound net landings and catch-per-unit-of-effort, Chowan River, 1972-1999.

The DMF has always targeted for unculled pound net catches, but obtaining unculled catches has not always been possible in recent years. If unculled samples were not available, culled samples were taken at the fishhouse. Size, age and sex composition of the harvest was determined from these samples. During 1998 and 1999, samples were obtained from three cooperating Chowan River pound net fishermen. Samples of up to 30 fish from each fishermen were obtained, up to three times per week during the season, and after the season, as well, into the second week of May.

The commercial harvest of both species has been dominated by 3-5 year-old fish since sampling began in 1972. The percentage of blueback herring repeat spawners in the harvest averaged 14.8% during 1972-1982. From 1983 through 1998, the percentage of repeat spawners declined significantly, ranging from 0.6% to 6.1% (Table 6). During the 1990s, blueback herring spawning repetition has remained low, ranging from 1.2% (1994) to 4.7% (1993) (Table 6). The percentage of alewife repeat spawners has also decreased since the 1970s (Table 7), with a mean of 9.4% from 1972 through 1981. Since 1988, no or very small samples of alewife have been obtained annually from the Chowan River pound net fishery, due to their scarcity in the harvest. Concern arises with the decrease of repeat spawners, due to the loss of spawning potential in the stock. The older fish that have spawned more than once are much more fecund.

Data from pound nets for both species and sexes (1972-1998), show a general decline of 1-2 inches in the mean length at age . However, in 1995 and 1996, an increase in the mean size of blueback herring was observed in most ages, but length dropped again in 1997 and 1998 (Figure 14). Alewife mean size at age is presented in Figure 15. No alewife samples have been obtained from the Chowan River pound net fishery since 1996. Kornegay (1978) indicated an overlap of size of river herring, ages 4 to 6, which is the expected natural variation in size. The meaning for this decrease in size is unknown, but may be an indicator of stock problems.

6. Status of Fisheries

6.1 Introduction

The river herring fishery can be divided into two sections: the commercial fishery and the recreational fishery, with both occurring in Coastal, Joint and Inland Waters. These fisheries are entirely dependent on sexually mature fish, age 3 and older. Although some of the gears used are

Table 6. Percentage of blueback herring repeat spawners (spawned two or more times) and maximum number of spawning marks from the Chowan River pound net fishery, 1972-1998.

Year	Percent male	Percent female	Percent sexes combined	Maximum number of spawning marks
1972	19.5	24.1	21.1	4
1973	17.8	19.8	18.3	4
1974	13.5	22.0	16.4	3
1975	3.5	4.3	3.9	2
1976	2.5	10.6	5.3	3
1977	4.6	10.7	7.3	3
1978	5.6	9.1	7.1	3
1979	19.0	22.3	20.1	4
1980	17.5	31.6	24.6	4
1981	13.1	19.5	16.2	4
1982	15.0	12.5	13.9	4
1983	2.0	0.9	1.6	3
1984	0.4	2.1	1.3	2
1985	2.4	4.8	3.3	2
1986	2.8	10.0	6.1	2
1987	3.9	2.5	3.3	2
1988	1.2	3.6	2.0	2
1989	0.9	0.0	0.6	2
1990	2.7	2.2	2.5	2
1991	0.0	10.0	4.2	3
1992	5.3	0.9	3.7	2
1993	3.5	7.1	4.7	2
1994	0.0	3.2	1.2	2
1995	0.0	4.1	1.6	2
1996	3.4	2.0	2.8	2
1997	2.8	2.6	2.7	2
1998	2.3	3.0	2.7	2

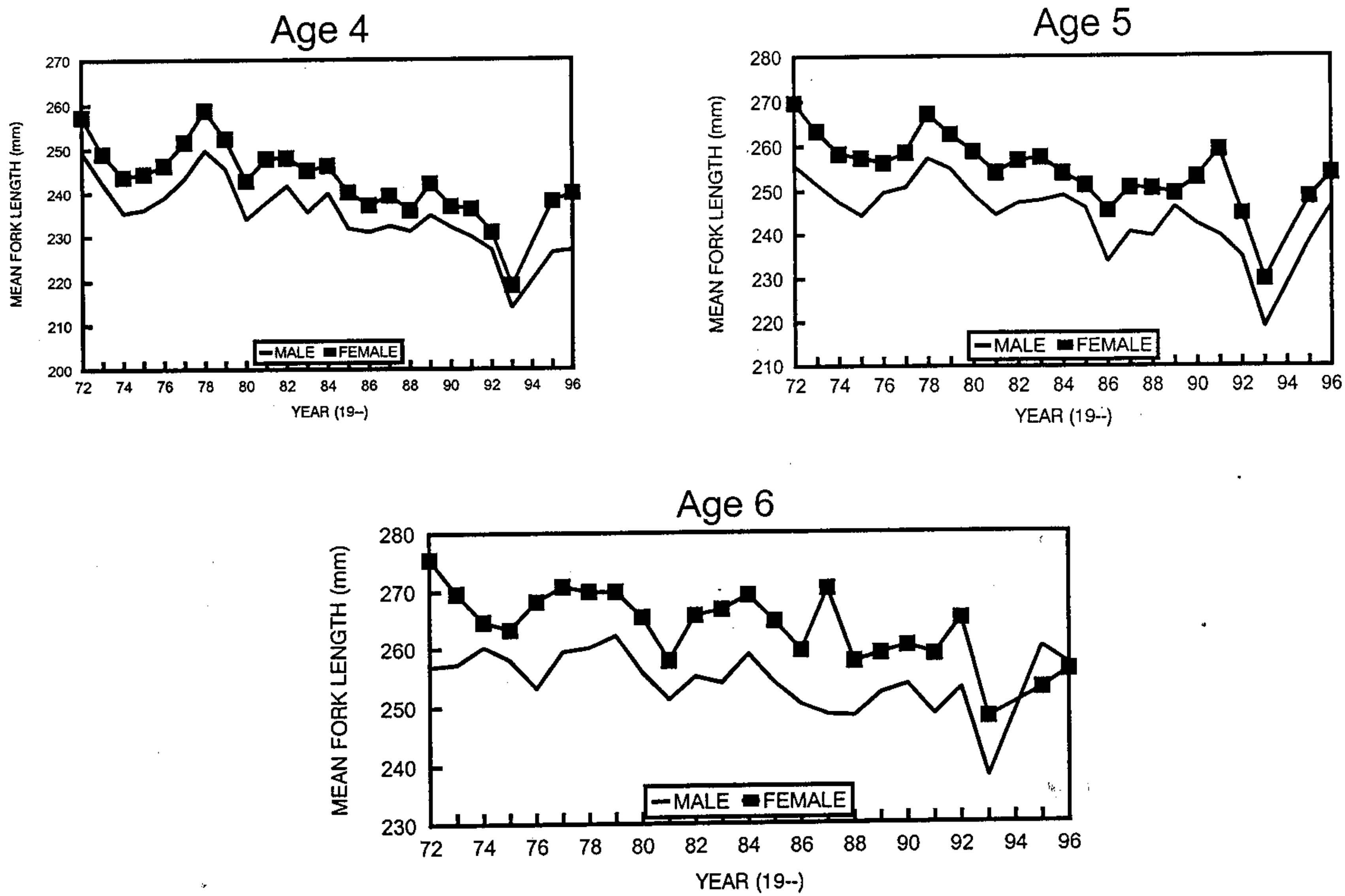


Figure 15. Mean length at age of alewife from the Chowan River pound net fishery, 1972-1996.

employed by both fisheries, they are treated separately because the fisheries are regulated by two separate commissions. Fisheries in Coastal Waters are under the jurisdiction of the MFC, while herring fisheries in designated Inland Waters are under the WRC. The different jurisdictional areas are described in North Carolina Fisheries Rules for Coastal Waters, 1997-1998 (NCDEHNR 1997).

6.2 Commercial Fishery

6.2.1 Historical

River herring have been subjected to intensive exploitation since colonial times along the Atlantic coast. The Albemarle Sound area has always been the center of the North Carolina fishery. In North Carolina, river herring were among the first fish to be exploited commercially because their oily flesh allowed them to be salt-preserved, without ice or refrigeration.

Fishing served largely subsistence, rather than commercial, purposes in colonial times. During the late colonial and antebellum periods, planters in the Edenton area developed major fisheries for spawning American shad and river herring in the Chowan River and Albemarle Sound. Only during the postbellum period - with improved transportation and the availability of ice - were markets created for fresh fish and shellfish, allowing independent watermen to emerge (Taylor 1992).

The first significant commercial fishing operation was documented in 1765, at Wingfield Plantation owned by Alexander Brownrigg, on the Chowan River. This was a haul seine fishery for herring and shad. Brownrigg's success inspired other planters on the Chowan River to develop fisheries to supplement their production of agricultural commodities (Taylor 1992).

Edenton's fisheries were seasonal and operated only during the spring, when herring and shad ascended the Chowan and other coastal rivers to spawn. Still, fishing had become an important enterprise by the time of the American Revolution. Between 1771 and 1776, 851 vessels cleared the Edenton customhouse carrying 24,432 barrels of fish. Most of the fish were bound for the British West Indies, although small quantities were shipped to the Middle Atlantic colonies, the Azores, and Canary Islands, southern Europe and the New England colonies (Barber 1931). Much of the Chowan's fish catch was also sold or bartered locally (Taylor 1992).

The growth of Edenton's fisheries, as well as the nation's, continued during the antebellum period and was linked to the expansion of slavery. Between 1790 and 1860, North Carolina's slave population tripled, increasing from roughly 100,000 to 330,000 individuals. Planters needed an inexpensive food supply for their laborers, and fish provided an excellent source of protein. Over time, some planters left the sheltered waters of the Chowan to establish herring and shad fisheries on Albemarle Sound (Taylor 1992).

In 1807, Joseph Skinner, owner of Manor House established the first very large-scale fishery on Albemarle Sound. Skinner's enterprise prospered, and by 1846, fifteen large haul-seine fisheries operated on Albemarle Sound from the mouth of Little River to Edenton Bay, a distance of about 30 miles (Taylor 1992). Those fisheries functioned essentially as adjuncts of plantation agriculture; they were seasonal, required large capital for investment, and yielded large profits (Skinner 1846).

The fishing season began in mid-March with the first runs of herring and ended in May. Free blacks or employees of the fishery actually did the fishing. Slaves were too valuable to risk injury in the fishery. Each fishery employed approximately forty to eighty men and women, who worked under the plantation owner or his "shore manager". Workers fished from open beaches, the adjacent waters having been cleared of obstructions that could snag or tear a net. Behind the beach lay packing and salting sheds, where the catch was processed, and crude shelters for the laborers. Fishing was carried on around the clock, seven days a week prior to the Civil War, and fishermen usually made four to five hauls of the net in a twenty-four hour period (Taylor 1992). After the Civil War, there was a day off from Saturday midnight to Sunday midnight (North Carolina Department of Conservation and Development 1963).

The seines used in the fisheries were enormous, generally measuring from 2,200 to 2,700 yards in length and 18 ft in depth. The nets were set from two large rowboats, each manned by a captain and ten oarsmen. The boats, each with half of the seine piled on its deck, traveled in tandem a mile or more offshore to a pole, parted company, and payed out the seine in a line roughly parallel to the shore. Then the boats returned to opposite ends of the beach, and the men attached the net's hauling lines to huge windlasses powered by as many as eight horses or mules. Smaller windlasses, located at intervals down the beach, were attached to "toggle lines" that ran out to the seine and maintained its shape in a diminishing half circle as it was drawn ashore. The catch was processed by the cutters, salters and packers (Taylor 1992).

The fisheries on Albemarle Sound made very large catches. Records maintained from

1835 to 1874 at the Willow Branch Fishery, located at the mouth of Chowan River, show annual catches of herring usually numbered from 1 million to 3 million fish. These fisheries produced several commodities. They sold their catch as fresh herring, cut herring (split but not salted), or pickled herring (salt and packed in barrels). Fresh and cut herring were sold "on the beach", mostly to neighboring farmers. Individuals usually bought from 2,000 to 4,000 fish, which they salted and packed. In 1845, those fish cost $4.00 to $10.00. Most fresh fish were sold locally. However, the bulk of the catch was pickled and shipped to wholesale grocers and brokers in Virginia and Baltimore, Md. (Taylor 1992).

Despite its seasonal nature, fishing became an important business on Albemarle Sound and the Chowan River during the antebellum period. The 15 large haul seine operations in existence in 1846 employed about 1,000 people. In the late 1850s, to set up and operate a haul seine through its first season would cost $12,000 to $15,000. Thus, the opportunity to realize large profits in the fishing business was limited to a select few in the planter and merchant class (Taylor 1992).

The Civil War brought this prosperity to a close. In 1863 North Carolina authorities prohibited haul seining because they feared that fishermen would either sell their catches to the "Federals" or have them confiscated (Taylor 1992).

The herring haul seiners resumed fishing on Albemarle Sound and the Chowan River after the Civil War, and their operations grew even larger. In 1869, Captain Peter Warren of Chowan County introduced steam-powered winches for landing seines, and ten years later he became the first to employ a small steamboat for setting the huge nets. Others followed, and the steam-powered haul seines made extremely large catches. In 1880, the average catch for steam-powered seines on the sounds was 1,750,000 herring. Horse-powered seines on the sound usually caught 1,500,000 fish, and the small river seines netted about 1 million fish (Taylor 1992).

At the beginning of the season, some of the catch from the sound seines was iced and shipped to northern cities. New markets developed with the completion of the Albemarle and Chesapeake Canal in 1869. Nearly all of the catch from the river seines, however, was sold fresh to farmers in northeastern North Carolina and Virginia.

The huge haul seines, though very efficient, ultimately became victims of their own size. In 1869, two Ohio brothers, Captain John and William Hetterick, arrived in Edenton and began fishing with pound nets in Albemarle Sound (Earll 1887). The pound net was a simple device, a long line of stakes draped with netting extended out into the channel, diverting migrating fish into a small, heart -shaped funnel and then into the "pound", or trap, nearshore (Figure 16). One or two men in a small boat, wielding large dip nets, removed the fish from the pound. The use of the pound net revolutionized fishing in North Carolina, especially in Albemarle Sound (Taylor 1992).

Pound nets had several advantages over haul seines: they cost just a few hundred dollars, were tended by only two or three men, and could be set up anywhere, even on a wooded shore. The haul seiners immediately attempted to have pound nets outlawed. The number of pound nets increased from 117 in 1880 to 950 in 1890 (North Carolina Board of Agriculture 1896). In 1887, pound nets harvested 7 million lb, haul seines 10.5 million lb and gill nets 71,780 lb (Chestnut and Davis 1975). By 1896 there were at least 1,125 pound nets on Albemarle Sound, and only a handful of haul-seine fisheries remained. Pound nets choked Croatan Sound by the early 1900s, and fish entering Oregon and New inlets ran a veritable gauntlet before reaching Albemarle Sound and their spawning grounds in the Chowan and Roanoke rivers. The fishermen of Albemarle Sound protested as their catches dwindled, and in 1905 legislators passed the Vann Law, which required that an open channel through the sound be maintained for the passage of migrating fish (Taylor 1992).

The prolific growth of pound nets resulted in a rapid decrease in haul seines. Fifteen haul seine operations were located on Albemarle Sound in 1846 (Taylor 1992), twelve operated in 1880 (Boyce 1917), four were functional in 1896 (Stevenson 1899), and only the Greenfield fishery remained in 1902; it closed by 1907 (Taylor 1992).

Pound nets during the late 1800s were set along the shores with 1 to 25 pounds or hearts in each string. Chestnut and Davis (1975) reported that 2,767 pound nets were set in North Carolina in 1927. Since the 1960s, the majority of the river herring pound nets have been set in the rivers, and the leads seldom exceeded 200 yards in length (Walburg and Nichols 1967). Chowan River has been the center of the river herring pound net fishery. In 1977, 615 pound nets were set in the Chowan River. From the late 1970s to the late 1980s the number of river herring pound nets ranged from 421-615 nets annually in the Chowan River. The amount of pound nets in the Chowan declined from 348 in 1989 to 175 nets in 1994.

Gill nets, anchor and drift, have historically been utilized in the river herring fishery, and

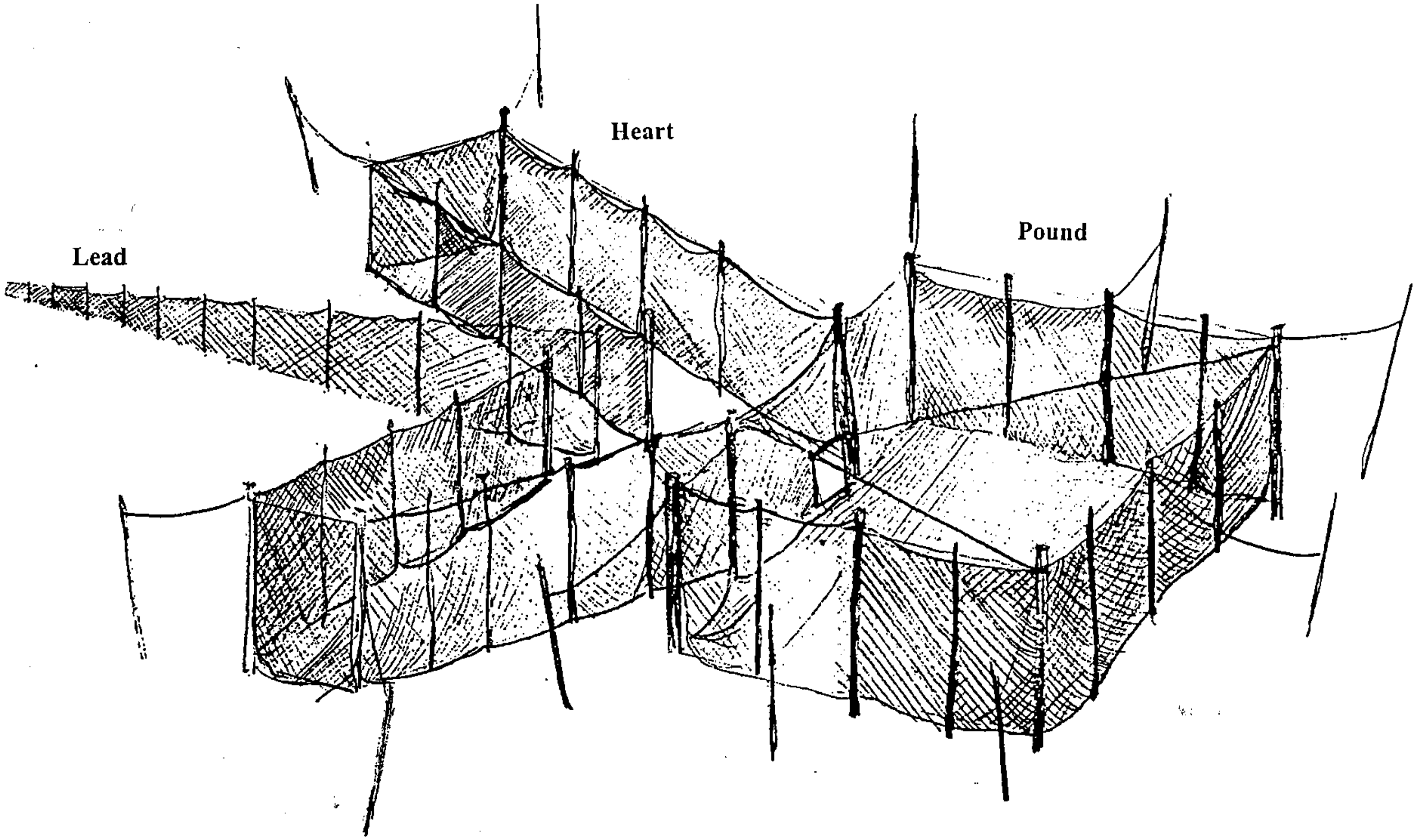


Figure 16. Diagram of a pound net.

their use continues. The amount of gill net effort in the fishery prior to 1994 is unknown. During the 1970s, the gill net harvest of river herring accounted for approximately 15% of the total Albemarle Sound area harvest. However, from 1987 to 1994, the proportion of gill net landings increased to 24-40% of the total river herring harvest from the Albemarle Sound area. This increase may have been due to a directed fishery for roe fish. Figure 17 shows the pound net and gill net landings from the Albemarle Sound area during 1978-1999. In 1986, approximately 6 million lb were harvested in pound nets and 900,000 lb from gill nets. During 1988, pound nets landed 2.3 mlb and gill nets 1.5 mlb. A total of 425,000 lb was harvested from pound nets and 175,000 lb from gill nets in 1994 (Figure 17). Several other minor types of commercial gear have been used in the herring fishery: fyke nets, fish wheels, and dip nets. These gears have contributed very little to the total harvest in the Albemarle area.

The Albemarle Sound area accounted for 66-100% of the state's river herring harvest from 1889 to 1994. Between 1962 and 1994, the Chowan River pound net fishery contributed 43-97% of the state's total river herring landings. Chestnut and Davis (1975) presented a synopsis of river herring landings by gear for the state (1887-1971), annual landings and value for some years, and landings by county (Section 13, Appendix 2). Annual landings by gear are shown in Table 8 for 1972-1999 and in Table 1 by waterbody for 1962-1999. The landings trend since 1985 continued down; the 1994 landings were the lowest recorded (911,410 lb) up to that time.

Taylor (1951) reported that the river herring fishery had declined during the last 40-50 years. During 1890 to 1900, annual river herring production was between 15 and 20 million lb, about 33% of the United States harvest. Between 1900 and the late 1940s, annual harvest fluctuated considerably, from a low of approximately 6 million lb in 1937, to a high of nearly 15 million lb in 1934. Such variations were probably the result of variable abundance, rather than economic factors. From 1950 to 1994, North Carolina accounted for 13.6-84.5% of the river herring landings of the Atlantic coast states.

From 1915 through 1965, various regulations were promulgated for the Albemarle Sound river herring fishery. The regulations included area closures, mesh and yardage restrictions and closed seasons (Section 13, Appendix 4).

Since the late 1800s, the areas fished and gears used to harvest river herring have remained essentially unchanged. The extent of the river herring fisheries in both the amount of

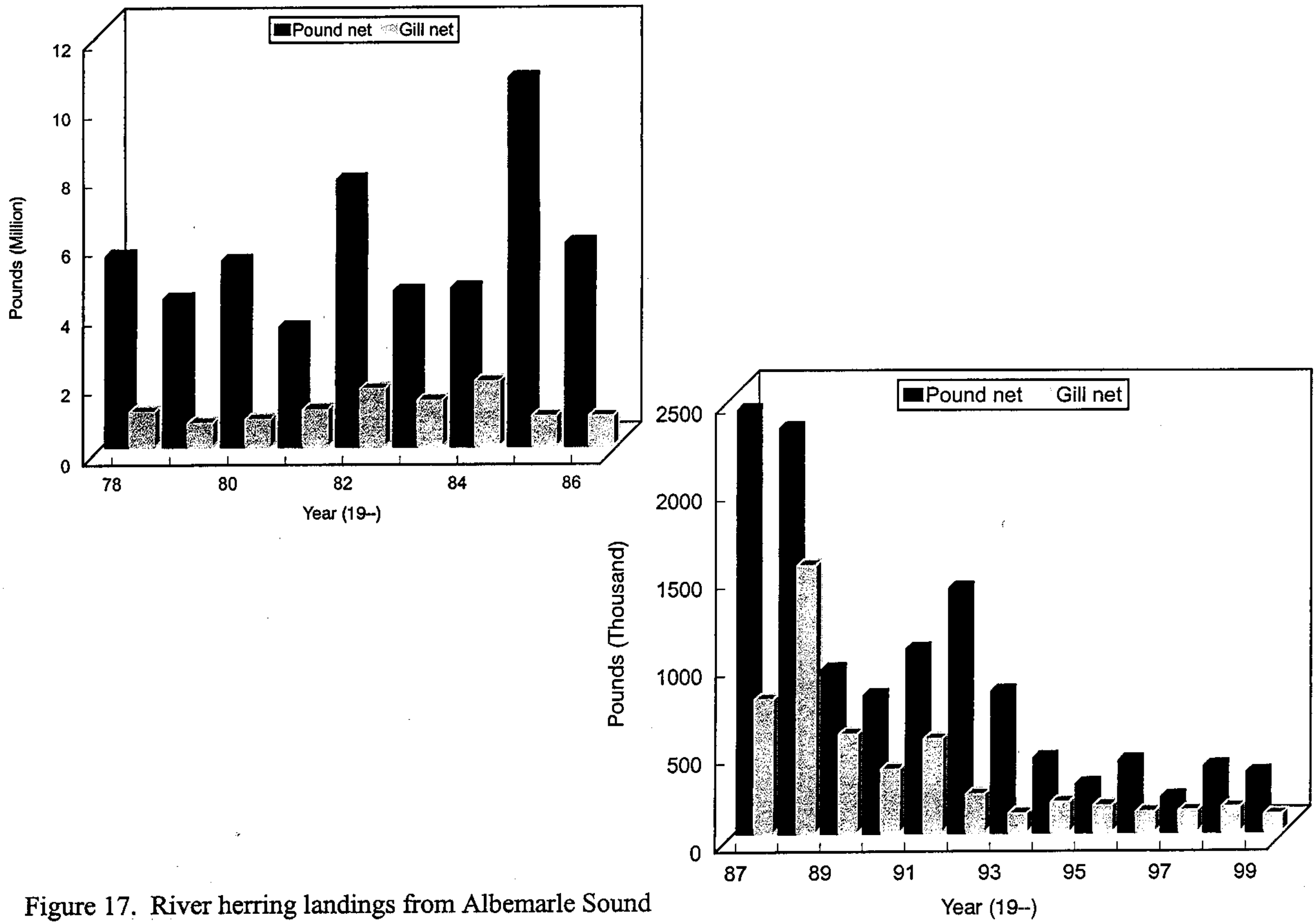


Figure 17. River herring landings from Albemarle Sound area pound nets and gill nets, 1978-1999.

Table 8. River herring landings and percentage by gear from North Carolina, 1972-1999.

	Pound net		Anchor gill net		Drift gill net		Haul seines		Trawl		Other gears		
Year	Pounds	Percent total landings	Pounds	Percent total landings	Pounds	Percent total landings	Pounds	Percent total landings	Pounds	Percent total landings	Pounds	Percent total landings	Total pounds
1972	10,868,387	96.7	1,863	0.02	46,248	0.4	320,645	2.9					11,237,143
1973	7,741,724	97.7	1,389	0.02	17,740	0.2	165,045	2.1					7,925,898
1974	5,866,038	94.5	31,277	0.5	49,000	0.8	263,227	4.2					6,209,542
1975	5,480,095	92.1	116,828	2	227,674	3.8	127,470	2.1					5,952,067
1976	6,106,419	95.4	122,553	2	111,900	1.7	60,488	0.9					6,401,360
1977	8,112,192	95.2	97,570	1.1	181,700	2.1	132,351	1.6					8,523,813
1978	5,487,100	83	876,009	13.3	128,719	1.9	96,875	1.5			18,450	0.3	6,607,153
1979	4,256,323	83.1	574,227	11.2	173,950	3.4	95,198	1.9	19,452	0.4			5,119,150
1980	5,354,430	86.2	757,576	12.2	56,898	0.9	46,513	0.7	1,506	0.02	1,600	0.02	6,218,523
1981	3,452,189	72.6	1,053,593	22.2	63,820	1.3	35,389	0.7	141,232	0.3	7,500	0.2	4,753,723
1982	7,720,694	81.8	1,649,488	17.5	37,000	0.4	20,721	0.2	7,679	0.08	2,121	0.02	9,437,703
1983	4,491,831	76.5	1,313,731	22.4	29,000	0.5	30,970	0.6			2,800	0.04	5,868,332
1984	4,591,016	70.5	1,866,635	28.6	36,632	0.5	6,452	0.1	9,497	0.2	5,877	0.1	6,516,109
1985	10,658,014	92.3	815,364	7.1	73,500	0.6	1400	0.01					11,548,278
1986	5,895,596	96.5	822,377	12.1	56,100	0.8			40,250	0.6			6,814,323
1987	2,411,710	75.5	764,602	23.9			*		18,563	0.6	100	0.003	3,194,975
1988	2,307,436	55	1,864,258	44.5					19,517	0.5			4,191,211
1989	928,759	62.3	562,308	37.7					*		10	0.01	1,491,077
1990	782,356	67.6	364,196	31.5					11,073	0.9			1,157,625
1991	1,042,110	66.1	533,268	33.9									1,575,378
1992	1,392,104	80.8	225,794	13.1					105,280	6.1			1,723,178
1993	804,380	87.8	111,628	12.2			*				227	0.02	916,235
1994	423,644	46.5	173,568	19	4,130	0.5	*		305,705	33.5	4,361	0.5	911,408
1995	274,191	60.4	156,137	34.4	3,126	0.7	*		19,100	4.2	1,430	0.3	453,984
1996	406,411	76.7	119,305	22.5	1,278	0.3	*				2,509	0.5	529,503
1997	201,793	60.3	123,333	36.7	2,781	0.9	*		5,550	1.7	1,351	0.4	334,808
1998	374,700	71.8	143,267	27.5	2,284	0.4			*		1,681	0.3	521,202
1999	336,934	76	102,121	23	2,165	0.5	187	0.1			2,144	0.4	443,551

* Denotes confidential landings; these are incorporated into "other gears".

gear and harvest, however, has declined significantly. The fisheries in the Albemarle Sound area are now pursued as multi-species fisheries, which are not totally dependent on river herring.

6.2.2 Current North Carolina Fishery

In 1995, a fishing season was implemented by MFC rule (DEHNR 1997, 15 NCAC 3M.0513), which prohibited taking blueback herring, alewife, American shad and hickory shad by any method from April 15 through January 1. This rule was adopted to allow more fish to escape fishing mortality and spawn. The rule remained in effect in 1995 and 1997. In 1996, the rule was suspended only for the Chowan River pound net fishery, extending the season for ten days. Once the season was extended, the fishery operated on a 250,000 lb total allowable catch (TAC). During 1998, the rule was again suspended, and the season extended for 15 days, only for the Chowan River pound net fishery which operated on a 400,000 lb TAC for the entire season.

The MFC amended the river herring rule (15NCAC 3M.0513) in a temporary action for the 1999 harvest. The temporary rule gives the Fisheries Director proclamation authority, based on variability in environmental and local stock conditions, to take various actions and imposes an annual quota for river herring in the Albemarle Sound River Herring Management Area of 450,000 lb (see Section 4.4.3.1).

During 1995-1998, North Carolina accounted for 29-52% of the total river herring landings from the Atlantic coast. Landings from the Albemarle Sound area accounted for 97.9-99.8% of the state's total river herring landings during 1995-1999. The Chowan River pound net fishery contributed 60.3%-76.5% of North Carolina's annual river herring harvest during 1995-1999. Since 1988, regulations enacted for striped bass conservation (gill net mesh size restrictions, yardage restrictions, area closures) have impacted river herring harvest in the Albemarle sound area. Even with these regulations the river herring gill net fishery in recent years has accounted for greater proportions of the overall harvest each year. During 1995-1999, anchor gill nets accounted for 21.2-38.1% of the annual river herring harvest (Table 8).

During 1995-1999, the number of pound nets set in Chowan River ranged from 73 to 102. In 1999, only 14 Chowan River pound net fishermen participated in the fishery. The Chowan River pound net fishery harvested 268,534 lb, 398,476 lb, 195,221 lb, 368,666 lb and 324,995 lb during 1995-1999, respectively.

The total number of vessels and trips in the Albemarle Sound area during January through May has increased annually since 1994 (Table 9). The number of small mesh gill net trips has increased since 1994, from 23,144 to a high of 30,412 in 1996, while the number of pound net trips has decreased from 6,979 in 1994 to 3,367 in 1998. The number of vessels harvesting river herring during 1994-1998 has ranged from 457 (1995) to 553 (1996). The total number of trips harvesting river herring has decreased since 1994, ranging from 2,503-3,354. Since the river herring season has been implemented, the number of river herring pound net trips has decreased. In 1994, pound net trips taking river herring totaled 893, compared to 411 in 1998. However, the number of trips with small mesh gill nets has remained fairly constant or increased (Table 9).

River herring have historically, and continue to be, utilized for human consumption. The filets are generally processed and salted, while the roe is utilized, either fresh or canned. During 1995-1998, the percentage of the river herring harvest utilized for bait ranged from 10.7 to 38.8%.

6.2.3 Ocean Fishery

Substantial oceanic landings of river herring were reported by foreign fishing fleets operating in United States coastal waters between 1967 and 1972. In 1969, the peak year, total reported landings of river herring in the foreign fishery were 10,950 metric tons (24 mlb). Foreign fleets harvested primarily fish that were less than 7.5 inches long and mostly immature (Street and Davis 1976). This level of fishing pressure on sub-adult river herrings probably was a major factor in the declines along the Atlantic coast seen in the mid-1970s.

Since 1977, the foreign fishery for river herring within the U.S. Exclusive Economic Zone (200 mile limit) has been restricted by federal rules under the authority of the Magnuson-Stevens Act. No directed foreign fishing for river herring has been allowed since the passage of the Magnuson-Stevens Act. The annual allocation of river herring landings to the foreign fisheries between 1977 and 1980 was 1.1 million pounds. Since 1981, the total annual allocation has been limited to 100 metric tons (220,460 lb), less than 2% of the total US river herring harvests in a typical year prior to that period. However, because the foreign trawl fishery and the joint-venture fishery for Atlantic mackerel take mostly immature river herring as a bycatch, the potential for over harvesting effects on the stocks still exists. Even though foreign fishing

Table 9. Number of vessels, number of trips, pounds, and value for all species and river herring from the Albemarle Sound Management Area, January-May, 1994-1998. ("Endorsement" refers to a license which authorized sale of fish.)

		All finfish species				River herring			
Year	Gear	Number of endorsements	Number of trips	Pounds	Value ($)	Number of endorsements	Number of trips	Pounds	Value ($)
1994	Drift gill net	16	76	5,057	4,582	4	61	2,742	3,620
	Large mesh gill net	163	1,194	9,849	159,695	6	8	127	176
	Other gears	240	1,509	242,493	82,838	16	97	2,481	339
	Pound net	65	1,343	643,970	131,397	46	543	292,877	31,253
	Run-around gill net	9	16	7,115	1,978	*	*	*	*
	Small mesh gill net	381	4,919	901,808	439,500	175	1,730	133,668	42,505
	Total:	**874**	**9,057**	**1,930,290**	**819,990**	**248**	**2,440**	**431,927**	**77,943**
1995	Drift gill net	3	33	3,133	784	3	33	3,126	782
	Large mesh gill net	206	1,244	89,006	113,102	9	14	335	740
	Other gears	262	1,672	287,455	110,715	14	60	771	201
	Pound net	46	726	529,677	130,731	34	297	246,307	64,762
	Run-around gill net	4	19	1,378	962				
	Small mesh gill net	502	6,587	674,229	392,868	168	1,728	110,269	45,277
	Total:	**1,023**	**10,281**	**1,584,878**	**749,162**	**228**	**2,132**	**360,808**	**111,762**
1996	Drift gill net	5	13	1,322	1,548	4	12	1,268	1,515
	Large mesh gill net	148	931	60,455	81,552	*	*	*	*
	Other gears	322	1,598	253,300	144,915	19	69	1,874	2,370
	Pound net	53	831	739,636	140,267	39	361	403,557	77,952
	Run-around gill net	*	*	*	*				
	Small mesh gill net	466	6,160	970,152	474,628	216	2,102	112,364	47,256
	Total:	**996**	**9,536**	**2,025,253**	**843,048**	**279**	**2,545**	**519,071**	**129,095**
1997	Drift gill net	11	64	3,142	3,250	7	59	2,598	2,967
	Large mesh gill net	244	2,357	200,463	276,697	13	19	484	878
	Other gears	268	1,703	240,925	173,314	14	61	495	254
	Pound net	46	837	405,828	121,497	34	286	145,879	49,839
	Run-around gill net	5	8	3,087	1,513				
	Small mesh gill net	429	5,765	738,442	449,567	157	1,153	72,271	39,270
	Total:	**1,003**	**10,734**	**1,591,887**	**1,025,838**	**225**	**1,578**	**221,727**	**93,208**
1998	Drift gill net	4	17	2,743	1,223	4	17	2,284	1,119
	Large mesh gill net	187	1,857	169,013	215,996	8	11	784	1,331
	Other gears	247	1,556	245,584	137,865	16	65	1,381	480
	Pound net	34	684	530,994	174,984	25	356	327,859	116,684
	Run-around gill net	8	13	860	504	*	*	*	*
	Small mesh gill net	408	5,518	915,741	533,309	192	1,494	90,250	50,652
	Total:	**888**	**9,645**	**1,864,935**	**1,063,881**	**246**	**1,944**	**422,561**	**170,267**

pressure on river herring stocks in offshore waters has been reduced for twenty-two years, the population has not recovered anywhere along the Atlantic coast.

In 1997, the Maine Department of Marine Resources established an observer program in the sea herring fishery. Stevenson and Scully (1999) reported 50 trips were observed, divided between purse seiners and mid-water trawls, fishing in coastal Gulf of Maine waters, from August 1997 through July 1998. Twenty-three purse seine trips were observed, with 50 sets made. A total of 27 mid-water trawl trips were made, with 54 tows observed. A total of 7,319 lb of blueback herring was observed, compared to 2.5 million pounds of sea herring landed during this study, indicating a very low catch of river herring from this fishery. The mid-water trawlers make about 800 trips a year, so that a sample of 27 trips represents about 3.5% of all trips (Stevenson and Scully 1999).

The ASMFC shad and river herring fisheries management plan (1985) expressed the concern of resource managers with the bycatch of river herring in the oceanic Atlantic mackerel fishery. This fishery is composed of a joint venture fishery and a directed fishery by foreign vessels. Bycatch of river herring was variable from year to year and averaged 105,727 lb between 1980 and 1989 and appeared to be increasing (Harris and Rulifson 1989). Bycatch limits for river herrings in the offshore mackerel fishery are currently set at 220,264 lb. Data from NMFS indicates that river herring catches in the Atlantic mackerel fishery were at least 600 lb during 1996 and 11,570 lb during 1997 (Mid-Atlantic Fishery Management Council 1998).

Measures must be taken to ensure that river herring bycatch in the offshore mackerel fishery is minimized. The Mid-Atlantic Fishery Management Council recommended that the foreign fishery stay at least 20 miles offshore, that a maximum bycatch of river herring be maintained and enforced, and that intercept fisheries be discouraged (ASMFC 1985).

Commercial ocean harvest of river herring occurs as bycatch in other fisheries of various gear types: gill net, otter trawl, and menhaden purse seine. During 1980-1998, the majority of the river herring harvest (in river and ocean) was taken in North Carolina (67%), Maine (15%) and Virginia (13%). Beach haul seines and trawls accounted for the major portions of North Carolina's Atlantic Ocean landings during 1962-1998 (Table 8 and Table 1). Between 1975 and 1999, Atlantic Ocean river herring landings from North Carolina have ranged from 0 to 305,934 lb, with an average during the period of 27,788 lb.

6.3 Recreational Fishery

The recreational fishery for river herring is probably best defined as that fishery in which river herring are targeted and used for personal consumption, i.e., not sold. In those waters designated by the WRC and the MFC as Coastal and Joint Waters, fishery managers assume that most herring harvested will be sold. In designated Inland Waters, the assumption is made that most herring harvested will be used for personal consumption; however, a portion of these may also be sold, as allowed by WRC rules. Gill nets and several variations of dip nets (called "special fishing devices" when used in Inland Waters) are the primary gears used to harvest river herring. Because river herring do not readily take bait or artificial lures, the hook and line fishery for them in coastal North Carolina is likely inconsequential.

Historically, river herring have been taken for personal consumption in every major North Carolina coastal river system. An analysis of river herring harvest by Baker (1968) indicated the majority of herring harvested by special device licensees in 1967-68 occurred in the Chowan and Roanoke river basins. Herring were also harvested in other river basins, but American shad and hickory shad (*Alsoa mediocris)* were of more importance to fishermen in those areas. Coastwide, Baker (1968) estimated that special device licensees harvested 2.9 million pounds of river herring. The recreational component of this total, however, is unknown. Although these fish were taken by fishermen licensed by WRC at that time, changes in designations of Coastal/Joint/Inland Waters, changes in jurisdictional responsibilities between DMF and WRC, and the unknown proportion of these fish which were harvested with the intent of sale precludes an estimate of the historical level of river herring harvest for personal consumption.

Currently, the extent of river herring harvest for personal consumption in coastal North Carolina is unknown. According to Wildlife Enforcement Officers who patrol the Inland Waters of the Cape Fear, Neuse, and Tar-Pamlico river basins, very few (usually none) special device licensees specifically targeting river herring are encountered in these areas, principally due to the low numbers or absence of these species. Special device licensees targeting river herring are still encountered in small tributaries of the Roanoke and Chowan rivers during spring months, and an active recreational herring fishery persists in tributaries to Meherrin River. Recreational river herring fishermen are still found at small bridge crossings over tributaries to other Albemarle

Sound river systems such as the Pasquotank, Perquimans, Yeopim, and Scuppernong rivers. Low effort directed at river herring harvest in these areas is likely indicative of low river herring abundance.

From 1992 through 1998, sales of WRC special fishing device licenses increased in the Chowan River basin from 94 to 290 (Figure 18). This increase in sales has been most evident in Chowan, Gates, and Bertie counties since 1995. These increases in license sales occurred after implementation of the initial April 15 river herring season closure by MFC in 1995. As an example, special device license sales in Chowan County totaled less than 20 during the 1995/96 license year, but during the 1997/98 license year, well over 100 licenses were sold. If the licensees in these counties were targeting river herring in Inland Waters, this increase in license sales could reflect continued river herring harvest in Inland Waters after DMF's harvest closure in Joint and Coastal Waters. Close regulatory coordination between WRC and DMF will be necessary to ensure effective harvest restrictions where necessary.

A recreational drift net river herring fishery has existed on the Roanoke River for many years. This fishery has never been fully assessed by DMF or WRC. DMF initiated a pilot drift net creel survey in 1999 to characterize this fishery for development of future monitoring strategies and provide managers with weekly reports of recreational drift net activity (participation, catch rates, species composition, net sizes, etc.). Sampling was conducted in the lower river area including Williamston, Jamesville, and Plymouth. Interviews were conducted three days per week, for a total of 21 sampling days in 1999. Catches of river herring ranged from 20 to 300 fish per vessel with a mean of 106. Drift duration ranged from 1 to 5 hours with a mean of 2.2 hours. A total of 2,764 river herring were observed in the survey. Because there was no estimate of total effort, total catch cannot be estimated. Through the survey, the county of residence of the fishermen was determined. Martin, Edgecombe, Greene and Pitt counties accounted for the majority of the fishermen.

6.4 Social Significance

As noted previously, fishing for river herring each spring is a long-standing tradition in eastern North Carolina, socially as well as economically. Generations of local residents have pulled seines, set small gill nets, and drifted gill nets on the Chowan, Roanoke, Tar, Neuse and other rivers to catch river herring for fish fry events. These events often served to raise money

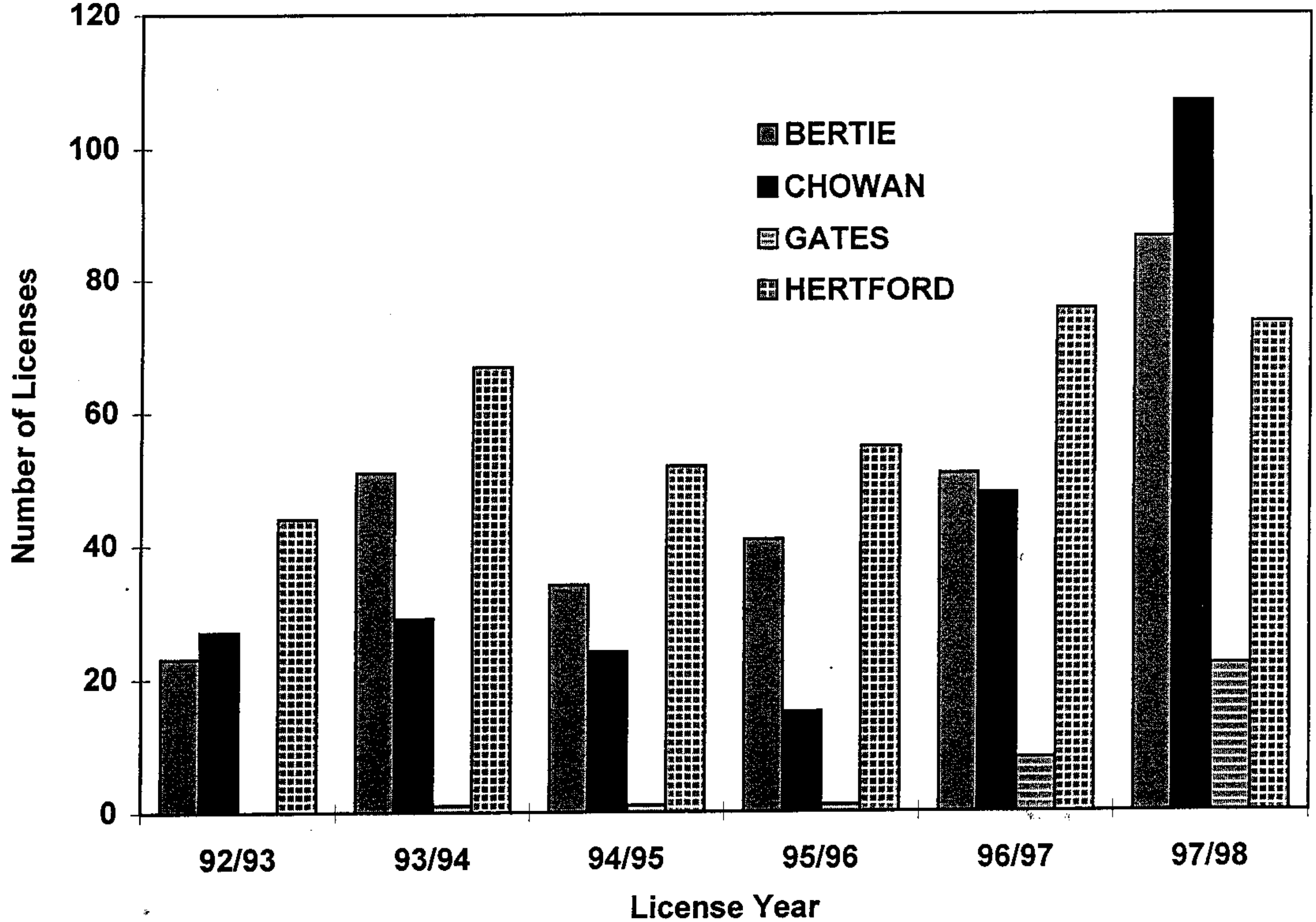


Figure 18. Sales of NCWRC special fishing device licenses (non-commercial) in counties bordering Chowan River.

for a church or civic organization. This tradition is in jeopardy because the stock has declined to such a low level. The social values of river herring should be considered as the stock recovers through implementation of this plan.

7. Economic Status

7.1 Commercial Fishery

7.1.1 Harvesting Sector

7.1.1.1 Ex-vessel Value

The commercial value of North Carolina's river herring landings increased from about $200,000 in the early 1970s to a peak of $846,000 in 1985 (Table 10). The value then fell sharply to about $67,000 in 1993 due to lower landings, but a rise in the average price per pound helped to temper somewhat the effect on revenues to fishermen.

A regular survey is conducted in which DMF periodically obtains price estimates from dealers for fish they have purchased from fishermen. The data from the survey are averaged to provide a value on an annual basis, because the river herring fishery is highly seasonal and prices fluctuate greatly within the season, based on supply and demand. Very high prices of as much as $1.50 per pound may be received early in the season for small landings from gill nets fished in the eastern part of the management area. Much lower prices of $0.09 to $0.25 per pound are received by pound net fishermen (according to some industry sources) in the Chowan River who catch the bulk of the river herring. Due to confidentiality of landings data (less than three dealers reporting), specifics for certain gears/value can not be provided. People in the industry indicate that approximately 75% to 85% of the pound net catch was processed as salted fish and canned roe each of the last three fishing seasons.

7.1.1.2 Fishing Income

DMF collected landings data from fish dealers in 1979-1982 for three pound net fishermen along the Chowan River. These data were utilized in the report by Everett (1983) relative to the impacts of pulp mill effluent on the river herring fishery. Based on the data collected, the value of river herring ranged from $23,750 to 35,560 per fisherman.

Table 10. Commercial value of river herring landings, North Carolina, 1972-1998.

Year	Current value	Real value ($)	Current price/lb ($)	Real price/lb ($)[1]
1972	196,145	518,902	0.02	0.05
1973	213,519	472,387	0.03	0.06
1974	246,753	509,820	0.04	0.08
1975	215,501	416,025	0.04	0.07
1976	336,750	522,093	0.05	0.08
1977	421,603	604,882	0.05	0.07
1978	286,705	386,916	0.04	0.06
1979	313,779	345,191	0.06	0.07
1980	444,327	506,067	0.07	0.08
1981	316,850	354,418	0.07	0.07
1982	704,599	704,599	0.07	0.07
1983	464,389	440,597	0.08	0.08
1984	596,428	529,217	0.09	0.08
1985	845,906	738,138	0.07	0.06
1986	647,293	518,249	0.09	0.08
1987	368,062	262,901	0.12	0.08
1988	502,166	337,704	0.12	0.08
1989	183,842	128,651	0.12	0.09
1990	174,259	118,382	0.15	0.10
1991	118,272	79,112	0.08	0.05
1992	172,453	110,476	0.10	0.06
1993	67,494	43,127	0.07	0.05
1994	127,706	79,124	0.14	0.09
1995	134,934	79,001	0.30	0.17
1996	132,389	79,800	0.25	0.15
1997	128,988	72,424	0.39	0.22
1998	201,281	111,823	0.39	0.21

[1] Base year 1982=100

Source: DMF Trip Ticket Program.

Gross income (revenues) derived from the river herring fishery was estimated using the Trip Ticket and Endorsement-to-Sell (ETS) license databases. Gross income earned from the river herring fishing has declined substantially in recent years. For example, the 1997 gross income per ETS license of $518 (range from less than $1 to $9,961) was less than the 1995 average of $585 (range from less than $1 to $16,363). Confidential personal financial records available from some Albemarle Sound area fishermen tend to substantiate this trend.

7.1.1.3 Ex-vessel Price

Table 11 shows the annual average prices received by fishermen by county for river herring landed from pound nets and gill nets in the Albemarle Sound area, as reported through DMF trip tickets during 1994-1998. There are considerable differences between the gears and among counties. Martin County gill net fishermen generally received the highest prices, while pound net fishermen from Chowan and Martin counties generally were paid the least per pound. Gill nets usually take river herring in small quantities early in the season before the fish become abundant. Because the supply is small relative to demand at that time, fishermen receive high prices, often on a per-fish basis, so a small catch can have a relatively high value. In contrast, fish are landed from pound nets in larger quantities, with fishermen usually receiving a lower price per pound.

7.1.1.4 Employment

Although the number of ETS licenses is not necessarily indicative of the number of individuals involved in the fishery, it does provide an indication of fishing activity. The number of ETS-holders reporting any river herring sales on trip tickets has remained relatively stable, ranging from 244 in 1994-1995 to 298 in 1995-1996. If sales of more than $100 of river herring are examined, the number of license holders selling river herring falls below 90 during each successive license year. River herring fishermen are predominantly owner-operators who may fish alone or with one or possibly more crew members. Most of these fishermen utilize vessels 18 ft in length or less.

7.1.2 Distribution and Processing Sector

7.1.2.1 Seafood Dealers

All seafood products, including river herring, landed in North Carolina are required to be sold through licensed dealers, some of whom are also fishermen. Although the number of dealers buying river herring fluctuated in the 42-60 range in recent years, the bulk of landings are handled by a few dealers in Chowan County and one in Bertie County.

Employment associated with river herring distribution by the seafood dealers depends on the volume of product handled; specific data are not available.

7.1.2.2 Processing Sector

There has been a severe decline in river herring processing activities in North Carolina

Table 11. Average price per pound for Albemarle Sound river herring landed from gill nets and pound nets for counties with both gears, 1994 - 1998

	County									
	Bertie		Chowan		Martin		Dare		Tyrrell	
Year	Gill	Pound	Gill	Pound	Gill	Pound	Gill	Pound	Gill	Pound
1994	$0.15	$0.10	$0.16	$0.10			$0.21		$0.28	$0.10
1995	$0.25	$0.25	$0.35	$0.26	$0.40	$0.25	$0.22	$0.25	$0.27	$0.24
1996	$0.22	$0.13	$0.31	$0.20	$1.55		$0.22	$0.21	$1.02	$0.46
1997	$0.35	$0.27	$0.41	$0.34	$1.40		$0.37		$1.05	$0.65
1998	$1.27	$0.34	$0.38	$0.35	$1.58		$0.72		$0.58	$0.34

over the years. The number of plants processing river herring increased from three to seven during 1970-1989 (Table 12). Processing activities fell during subsequent years in relation to a sharp decline in landings and due to the demand for the product.

The value of river herring processed products increased steadily from $341,000 in 1970 to a peak of almost $1.5 million in 1984 and has since decreased (Table 12). For example, within about a decade, processed product value declined more than 1700%, from about $1 million in 1985 to $55,000 in 1994.

The processing sector provides full-time and seasonal employment in some communities. Employment by the river herring processing declined greatly during 1970-1997 (Table 12). This decline is probably linked to decreased availability of raw product in recent years.

7.1.3 Economic Impact of Commercial Fishing

The economic impact of river herring harvesting activities is demonstrated by the value of its estimated purchases from other major economic sectors. Based on a total landed value of $129,000 in 1997, the industry paid 43% in wages, salaries, and profits, and 57% in non-wage expenditures. The largest components of non-wage expenditures were loan payments, fuel and oil, gear, supplies, repair and maintenance, and other expenses.

The estimated economic impact resulting from the harvesting activities was about $277,000 in 1997. This estimate shows the decline in the economic importance of the river herring fishery from the 1970s and early 1980s to the present.

7.2 Recreational Fishing

Economic data specific to recreational river herring fishing are not available at this time. The economic value of the recreational river herring fishery on a recovered stock may be significant.

7.3 Potential Economic Value

River herring landings and market value are both at historic low points. As the stock recovers, landings will increase. During the peak of the fishery in the 1970s, value was less than $0.05 per pound. Products included fresh whole fish, frozen bait, salt herring fillets, salt headless dressed fish, and roe (fish eggs), canned and fresh. The processing facilities have generally bait. Almost certainly the bait market will have to be exploited to utilize large catches from a recovered fishery. Fishermen will need advice, ingenuity, and experimentation to be financially successful in the low-end bait market.

8. Sociological Status

8.1. Commercial Fishery

8.1.1 Fisherman's Profile

A 1998 DMF survey of river herring fishermen from the Albemarle Sound area

Table 12. Sales and employment for river herring processors, North Carolina, 1970-1997.

Year	No. Plants	Seasonal employment	Yearly employment	Processed value
1970	5	134	130	$ 341,384
1971	5	137	137	825,858
1972	4	137	137	535,186
1973	5	98	98	687,066
1974	5	91	91	1,331,862
1975	5	126	113	1,299,315
1976	5	105	92	1,029,151
1977	6	112	104	601,511
1978	5	110	101	361,706
1979	4	93	75	419,177
1980	3	92	75	515,186
1981	3	69	44	481,133
1982	7	142	118	1,044,529
1983	5	99	71	1,427,178
1984	4	88	60	1,461,946
1985	6	118	98	1,027,221
1986	5	120	97	758,536
1987	5	120	95	257,207
1988	5	103	85	428,742
1989	5	86	73	145,336
1990	3	62	59	85,526
1991	3	60	56	103,496
1992	3	61	58	102,189
1993	3	62	60	121,600
1994	3	69	66	54,750
1995	2	76	76	*
1996	2	76	76	*
1997	2	72	72	*

* Confidential (less than 3 firms)

Source: National Marine Fisheries Service.

conducted for this FMP, indicates that the average age was 53 years, with a range of 44 to 59. Based on the survey, the average river herring fisherman has fished for approximately 20 years, and most have fished between 4 and 40 years. The educational level attained by those fishermen is high school graduation or more.

8.1.2 Economic Dependence on Fishing and Related Activities

Data from the trip tickets indicate that river herring fishermen also take other species. Consequently, river herring is not the main source of fishing income. As shown in Table 13, river herring accounts for less than 10% of the fishing income for more than 80% of the fishermen.

Most of the river herring fishermen do not fish full-time. The survey of river herring fishermen from the Albemarle Sound area showed that, on average, non-fishing activities accounted for 64% of their household income, 19% came from other fishing activities, and the remainder (17%) was derived from river herring fishing.

8.2. Recreational Fishing

Demographic data for recreational river herring fishermen are not available.

9. Critical and Essential Fish Habitats

9.1. Introduction

Maintaining habitat quality for managed fish species is of so much concern to the U.S. Congress, that they mandated the appropriate federal management agencies to define habitats vital to fish, with a view towards facilitating their increased protection. The North Carolina General Assembly also recognizes the importance of habitat quality, as illustrated through the creation of the Clean Water Management Trust Fund and other actions. The North Carolina Environmental Management Commission (EMC) has designated various waters of the state as Outstanding Resource Waters (ORW); the MFC has designated approximately 147,000 acres of coastal waters as Primary (PNA) and Secondary Nursery Areas (SNA); and Inland Primary Nursery Areas (IPNA) (about 10,000 acres) have been established by the WRC. These designations provide increased protection for these areas. State "critical habitat", as defined by the MFC, is located in North Carolina Fisheries Rules for Coastal Waters, 1997-1998 (Section 9.1.1.1) (DEHNR 1997). Essential Fish Habitat (EFH) for species managed through federal

Table 13. Distribution of percent of total fishing income of fishermen from the North Carolina river herring fishery, 1995-1998.

	Number of ETS by license year			
Percent of total fishing income from river herring	1994-1995	1995-1996	1996-1997	1997-1998
< 5%	188	241	188	198
5- 10%	21	23	19	16
10-15%	6	4	2	10
15-20%	5	4	11	2
20-30%	11	4	10	5
30-40%	4	3	7	5
40-50%	1	4	7	2
50-60%	3	1	1	2
60-70%	0	1	1	2
70-80%	0	4	1	5
80-90%	3	5	5	5
90-100%	2	4	3	3
Total	244	298	255	255

Source: DMF Trip Ticket Program.

Regional Fishery Management Councils and the NMFS is defined in the Magnuson-Stevens Fishery Conservation and Management Act (Public Law 94-265, as amended).

9.1.1 State Critical Habitat

The MFC defines critical habitat as "The fragile estuarine and marine areas that support juvenile and adult populations of economically important seafood species, as well as forage species important in the food chain. Critical habitats include nursery areas, beds of submerged aquatic vegetation, shellfish producing areas, anadromous fish spawning and anadromous nursery areas, in all coastal fishing waters as determined through marine and estuarine survey sampling. Critical habitats are vital for portions, or the entire life cycle, including the early growth and development of important seafood species" (NCAC 3I. .0101 (20) DEHNR 1997).

"Anadromous fish spawning areas are defined as those areas where evidence of spawning of anadromous fish has been documented by direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae" (NCAC 3I..0101 (20) © DEHNR 1997).

"Anadromous nursery areas are defined as those areas in the riverine and estuarine systems utilized by post-larval and late juvenile anadromous fish" (NCAC 3I.0101 (20) (D) DEHNR 1997).

9.1.2 Federal Essential Fish Habitat

Within the 1996 amendments to Magnuson-Stevens Fishery Conservation and Management Act (also known as the Sustainable Fisheries Act), Congress defined Essential Fish Habitat (EFH) for species managed by the NMFS and the federal Regional Fishery Management Councils as follows (USDOC 1996):

> "The term "essential fish habitat" means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity."[16 U.S.C. 1802, Section 3, 104-297]

The U.S. Secretary of Commerce was instructed to:

> "...within 6 months of the date of enactment of the Sustainable Fisheries Act, establish by regulation guidelines to assist the Councils in the description and identification of essential fish habitat in fishery management plans (including adverse impacts on such habitats) and in the consideration of actions to ensure the conservation and enhancement of such habitats." [16 U.S.C. 1855, Section 305, 104-297(b)(1)(A)]

Congress further mandated that the federal Fishery Management Councils:

> "...shall comment on and make recommendations to the Secretary [of Commerce] and any Federal or State agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource under its authority." [16 U.S.C. 1855, Section 305, 104-297(b)(3)(B)]

Given that the South Atlantic and Mid-Atlantic Management Councils have prepared no FMPs for anadromous fish species, there are currently no FMP's for them to amend to include designated EFH. However, it was determined that, for the purposes of the Sustainable Fisheries Act, anadromous fish species which spent any part of their life cycle in waters under the jurisdiction of a particular Council would be deemed "under its authority". Therefore, river herring which spawn in Albemarle Sound tributaries are considered under the jurisdiction of the New England, Mid-Atlantic and South Atlantic councils since they reside much of the year in Atlantic Ocean waters outside the three-mile state waters boundary, and traverse waters under the jurisdiction of each of these councils during the course of their annual migration between continental shelf habitat off New England and their Albemarle Sound tributary spawning grounds. Further, despite the lack of a fishery management plan to amend, the South Atlantic Fishery Management Council (SAFMC) chose to include information in its Final Habitat Plan for the South Atlantic Region (SAFMC 1998) describing EFH for river herring and other anadromous species, to provide a basis for Council implementation of its mandate for carrying out the commenting provisions of Section 305 of the Sustainable Fisheries Act. This provision gives North Carolina an additional mechanism, through its representatives on the Mid-Atlantic and South Atlantic councils, for requesting additional scrutiny of federal or state projects which, in its view, are likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource within the state which spends any time in waters under the jurisdiction of those councils. River herring meet that requirement.

9.2.1 Alewife Critical and Essential Habitat and Environmental Requirements

The SAFMC described habitats used by alewife which would be designated as EFH, if there was a Council plan to amend, as follows:

> Spawning habitats for alewives can vary from streams only a few meters (yards) wide to larger rivers. Although some authors have reported that alewives ascend further upstream than blueback herring, others believe that upstream distribution is a function of finding appropriate spawning habitats. Alewives use standing water, oxbow lakes and mid-stream areas as spawning sites, as well as coastal ponds with an open connection to the ocean [none in North Carolina]. Optimum hatching temperature was 18° C (64° F). Temperatures below 10° C (50° F) resulted in the absence of a functional jaw in alewives. Alewives apparently tolerate salinity changes well. Juveniles use coastal rivers and swamps, as well as estuaries, for nursery habitats prior to migrating to the Atlantic Ocean through inlets in the fall (SAFMC 1998: 275-276).

Based on historic and present sampling by DMF for the presence of spawning adults, eggs, larvae and juveniles, EFH for alewife in Albemarle Sound and its tributaries are depicted in Section 13, Appendix 3, and specifically include the following **(bold-indicates river herring, either or both species)**: Roanoke River, and its tributaries **Indian Creek, Conoho Creek, Conine Creek, Devils Gut, Bradley Creek,** an unnamed oxbow downstream of Halifax (see Map 1), Cashie River, Hoggard Mill Creek, Wading Place Creek, **Middle River and Conaby Creek** (see Maps 6 and 7); Chowan River and its tributaries **Meherrin River, Turkey Creek,** Potecasi Creek, **Nottoway River, Buckhorn Creek, Somerton Creek, Cole Creek, Wiccacon River, Ahoskie Creek, Chinkapin Creek, Bennetts Creek, Trotman Creek, Catherine Creek, Warwick Creek, Stumpy Creek, Dillard (Indian) Creek, Currituck (Keel) Creek, Sarem Creek,** Rockyhock Creek, Pollock Swamp, and Salmon Creek (see Maps 2, 3 and 7); Perquimans River and its tributaries Mill Creek, Goodwin Creek, Raccoon Creek (Walters Creek) and **Suttons Creek** (see Maps 4 and 8); Little River and its tributaries **Halls Creek, Deep Creek and Symonds Creek** (see Map 4); **Pasquotank River and its tributaries Sawyers Creek, Mill Dam Creek, Knobbs Creek, Areneuse Creek, Portohonk Creek and Newbegun Creek** (see Map 5); North Landing River and its tributaries Tull Creek and **Shingle Landing Creek** (see Map 5); upper portion of the North River (see Map 5); Albemarle Sound and its tributary Kendrick Creek (Mackeys Creek) (see Maps 7 and 9); Edenton Bay and tributaries, Pembroke Creek and Queen Anne Creek (see Map 7); Yeopim River and its tributaries Bethel Creek, Burnt Mill Creek, Middleton Creek and Yeopim Creek (see Map 8); Scuppernong River and its tributaries, Bee Tree Canal, Cherry Ridge including canals to and including Lake Phelps (see Map 9); and Alligator River and its tributaries Alligator Creek, Second Creek, the Frying Pan, Northwest Fork, Southwest Fork, **Whipping Creek Lake, Mill Tail Creek,** South Lake, and East Lake, and Swan Lake (see Map 10).

9.2.2 Blueback Herring Critical and Essential Habitat and Environmental Requirements

The SAFMC described habitats used by blueback herring which would be designated EFH, if there was a Council plan to amend, as follows:

> Blueback herring are reported to prefer spawning sites with fast currents and associated hard substrates; however, in South Atlantic coastal rivers, they frequently use flooded back swamps and spawn in and among the vegetation of aquatic bed habitats. Preferred temperatures of juveniles ranged from 20 to 22° C, but they were encountered in the field at temperatures ranging between 11.5 to 32° C (53-89° F). Bluebacks are apparently highly tolerant of salinity changes,

since direct transfers of adults from fresh water to salt water and the reciprocal produced no mortality. The species requires coastal rivers, associated palustrine forested and aquatic bed wetland habitats, and downstream estuaries as well as the offshore marine environment for completion of its life cycle (SAFMC 1998: 280).

Based on historic and present sampling by DMF for the presence of spawning adults, eggs, larvae and juveniles, the EFH for blueback herring in Albemarle Sound and its tributaries are depicted in Section 13, Appendix 3 and specifically include the following **(bold-indicates river herring, either or both species)**: Roanoke River and its tributaries Indian Creek, Conoho Creek, Conine Creek, Devils Gut, **Bradley Creek,** and an unnamed oxbow downstream of Halifax (see Map 1), Cashie River, **Mill Swamp Creek,** Wading Place Creek, Cow Creek, Gardners Creek, Middle River and Conaby Creek (see Maps 6 and 7); Chowan River and its tributaries Meherrin River, Kirby Creek, **Turkey Creek,** Potecasi Creek, **Nottoway River, Buckhorn Creek, Somerton Creek, Cole Creek**, Wiccacon River, Ahoskie Creek, Chinkapin Creek, Bennetts Creek, **Trotman Creek, Catherine Creek, Warwick Creek, Stumpy Creek, Dillard (Indian) Creek, Currituck (Keel) Creek, Sarem Creek,** Rockyhock Creek, Pollock Swamp, and Salmon Creek (see Maps 2, 3 and 7); Perquimans River and its tributaries Mill Creek, Goodwin Creek, Sutton Creek and Raccoon (Walters) Creek (see Maps 4 and 8); Little River and its tributaries Halls Creek, **Deep Creek and Symonds Creek** (see Map 4); Pasquotank River and its tributaries Sawyers Creek, Mill Dam Creek, **Areneuse Creek, Portohonk Creek,** Knobbs Creek and Newbegun Creek (see Map 5); North Landing River and its tributaries Tull Creek and Shingle Landing Creek (see Map 5); upper portion of the North River (see Map 5); Albemarle Sound and its tributary Kendrick Creek (Mackey Creek) (see Maps 7 and 9); Yeopim River and its tributaries Bethel Creek, Burnt Mill Creek, Middleton Creek and Yeopim Creek (see Map 8); Scuppernong River and its tributaries, including canals to and including Lake Phelps (Map 9); and Alligator River and its tributaries **Alligator Creek,** Second Creek, **The Frying Pan,** Northwest Fork, **Whipping Creek Lake, Mill Tail Creek,** South Lake, and East Lake (see Map 10).

9.3 Habitat Protection Status

The amount of river herring habitat (adult migration corridors, spawning habitat, and juvenile nursery habitat) which is presently afforded some protective status in Albemarle Sound and tributaries has not been quantified. Habitats may receive various levels of protection as a result of 1) placement in some form of permanent private (conservation easement) or public (national fish hatchery, national wildlife refuge, national park, state gameland, state park) ownership; 2) receiving special designation which highlights their value and may require a higher level of scrutiny of any proposed uses (Primary Nursery Areas, Outstanding Resource Waters, Essential Fish Habitat); or 3) requiring a federal or state permit for certain types of development (CAMA permit in coastal counties, Clean Water Act Section 404 permit in wetlands, Clean Water Act Section 401 Water Quality Certification in all waters, Clean Water Act Section 402 NPDES permit for all wastewater discharges).

Some habitats which are in public ownership and completely protected from future development provide spawning and nursery habitats for river herring. These habitats include spawning and nursery areas located in federal national wildlife refuges and within the boundary of Edenton National Fish Hatchery. River herring are documented to use portions of Roanoke River National Wildlife Refuge, Alligator River National Wildlife Refuge, and Mattamuskeet National Wildlife Refuge. They likely use portions of the other coastal national wildlife refuges in North Carolina, as well. Habitats located within the boundaries of both national and state parks also should remain protected from future impacts. A national park likely to host river herring is Cape Hatteras National Seashore.

The WRC has designated IPNAs in the Albemarle Sound area which serve as spawning and/or nursery habitats for river herring. These areas were established through extensive survey sampling conducted by personnel of DMF or WRC. These areas need to be maintained, as much as possible, in their natural state, and the populations within them must be permitted to develop in a normal manner with as little interference from man as possible. (NCAC T15A:10C.0501). The following Inland Waters have been designated: Broad Creek, Deep Creek and Lutz Creek-tributaries to North River; East Lake and Little Alligator River-tributaries to Alligator River;

Martin Point Creek (Jean Guite Creek), Tull Creek and Tull Bay- tributaries to Currituck Sound (NCAC T15A:10C.0503).

Specific state critical habitat areas have been noted in various DMF anadromous fish project reports: Street et al. (1975), Johnson et al. (1977; 1981), Winslow et al. (1983;1984), Winslow (1989), and Winslow and Rawls (1992). However, the MFC has not yet designated specific sites for protection under the categories defined in Section 9.1.1.1 of this FMP.

The degree to which remaining habitats not in public ownership or without special designations may be protected during federal or state permit review programs is totally dependent on the degree to which the regulatory agencies are willing to incorporate the recommendations of fishery management agencies, the commitment of permit applicants to effectively implement such recommendations, and the ability and will of management agencies to conduct follow-up studies and request regulatory agencies to enforce compliance when violations are documented.

Further protection for river herring spawning and nursery habitats may be achieved through establishment of programs which result in the restoration of function to habitats historically used by the species. One such program currently under development is the Edenton Bay Watershed Restoration Plan, a plan spearheaded by the North Carolina Office of the Environmental Defense Fund. Partners in the plan include Chowan County, the Town of Edenton, Albemarle RC & D Council, North Carolina Division of Soil and Water Conservation, North Carolina Division of Marine Fisheries, North Carolina State University, the University of North Carolina at Wilmington, and the U.S. Fish and Wildlife Service. The purpose of the plan is to initiate a multi-phase, multi-funded, integrated watershed restoration program focused on the restoration of water quality and watershed integrity necessary to restore the historic river herring fishery of Edenton Bay (Rader 1998).

The FRA of 1997 requires preparation of Coastal Habitat Protection Plans (CCHP) for various habitats important for coastal fisheries resources, including spawning and nursery areas and wetlands. Anadromous fish habitat will be subject to these plans as they are developed by DMF and WRC in cooperation with other agencies.

9.4 Water Quality

The water quality of coastal rivers in North Carolina has been monitored for many years, but few studies have attempted to document the effects of water quality on river herring. Rulifson (1994) listed poor water quality, including chemical pollution, turbidity, and low dissolved oxygen as a concern in relation to the decline in river herring stocks. The few studies that have investigated this relationship have focused on the Chowan River basin. The Chowan River has experienced serious water quality problems which resulted in nuisance algal blooms and fish kills throughout the 1970s and early 1980s (Stanley 1992). During this time period, there were only three major industrial discharges within the basin: United Piece Dye Works (UPDW) textile plant at Arrowhead Beach, Farmer's Chemical fertilizer plant at Tunis, and Union Camp Corporation paper mill at Franklin, Virginia (DWQ 1997a). Otherwise, the basin had little urban development and was dominated by forest and agriculture, which combined to make up 89% of the land cover (McMahon and Lloyd 1995).

Due in part to nutrient inputs from these discharges, as well as non-point sources, the Chowan River was the first coastal river in North Carolina to experience major eutrophication problems. This situation ultimately led to the designation of the Chowan River as Nutrient Sensitive Waters by the EMC in 1979, providing a legal basis for limiting nutrient inputs into the system (DWQ 1997a). As a result of this designation, a number of multi-disciplinary studies and water quality management programs were initiated within the basin. Water quality management plans including the Chowan/Albemarle Action Plan (DEM 1982a) and the Chowan River Water Quality Management Plan (DEM 1982b) were implemented, targeting nutrient reductions. In 1982, the goals of the Chowan River Water Quality Management Plan included a 30 to 40% reduction in phosphorus and a 15 to 25% reduction in nitrogen (DWQ 1997a). The fertilizer plant at Tunis has since closed, although seepage from waste ponds still located on the property is of concern. Both the paper mill and textile mill have implemented technological and process changes to improve the quality of their discharges. All of the municipal wastewater treatment facilities located in the basin have converted to land application operations in order to reduce the input of nutrients directly into surface waters. In addition, to combat non-point source inputs, agricultural best management practices (BMPs) are now used to reduce nutrient, sediment, and pesticide runoff from many of the farms in the basin.

Nitrogen inputs into the Chowan River from point sources have declined 92% from 1982, with only one discharger, UPDW, still discharging a significant amount of nitrogen. Most of this nitrogen is tightly bound in the inorganic dyes in a form which is not biologically available. The DWQ renewed the UPDW discharge permit in 1998, continuing to allow a nitrogen discharge of 20 mg/l until 2003, at which time the nitrogen limit will be lowered to 5.5 mg/l.

Between 50 and 75% of the nitrogen and 64-84% of the phosphorus flowing into the Chowan River in North Carolina comes from agricultural sources. In the lower river, an additional 30-37% of the nitrogen and 20-25% of the phosphorus comes from atmospheric deposition (DWQ 1997a). Estimates of nutrient sources and loads in Virginia, which comprise 76% of the Chowan watershed, were unavailable.

A concern which has materialized in the last decade is the role and impact of atmospheric nitrogen deposition in coastal estuaries in general and North Carolina in particular (Paerl 1995, Paerl et al. 1999). Increases in deposition of atmospheric nitrogen to sensitive estuarine and coastal waters appears to have contributed to accelerating algal production (eutrophication) and water quality declines (hypoxia, toxicity, and fish kills) (Paerl et al. 1999). Although atmospheric nitrogen is derived from a variety of sources, including urbanization as well as agricultural and industrial growth, recent increases in the North Carolina Coastal Plain are a direct result of the substantial increase in livestock operations and their associated nitrogen-rich (ammonia) wastes. Both the increase in, and changes in proportions of, nitrogen sources play roles in the structuring of estuarine and coastal algal communities, and may promote major biotic changes, including the proliferation of nuisance blooms (Paerl et al. 1999).

Nuisance algal blooms in the Chowan River peaked during 1981-1983, with eight blooms documented through the DWQ ambient monitoring program. In the 15 years since that time, there have been seven blooms recorded, only one since 1994. Blooms documented from citizen complaints track closely with the ambient blooms in the early-to-mid 1980s, then rise dramatically due to citizen interest and education (Figure 19). From 1991 to the present, there have been few blooms, with the exception of 1994. Chlorophyll *a* values (Figure 20) show a decline since the 1980s with only seven instances where chlorophyll *a* exceeded 20 µg/l (half the state standard) since 1991 (DWQ 1997a).

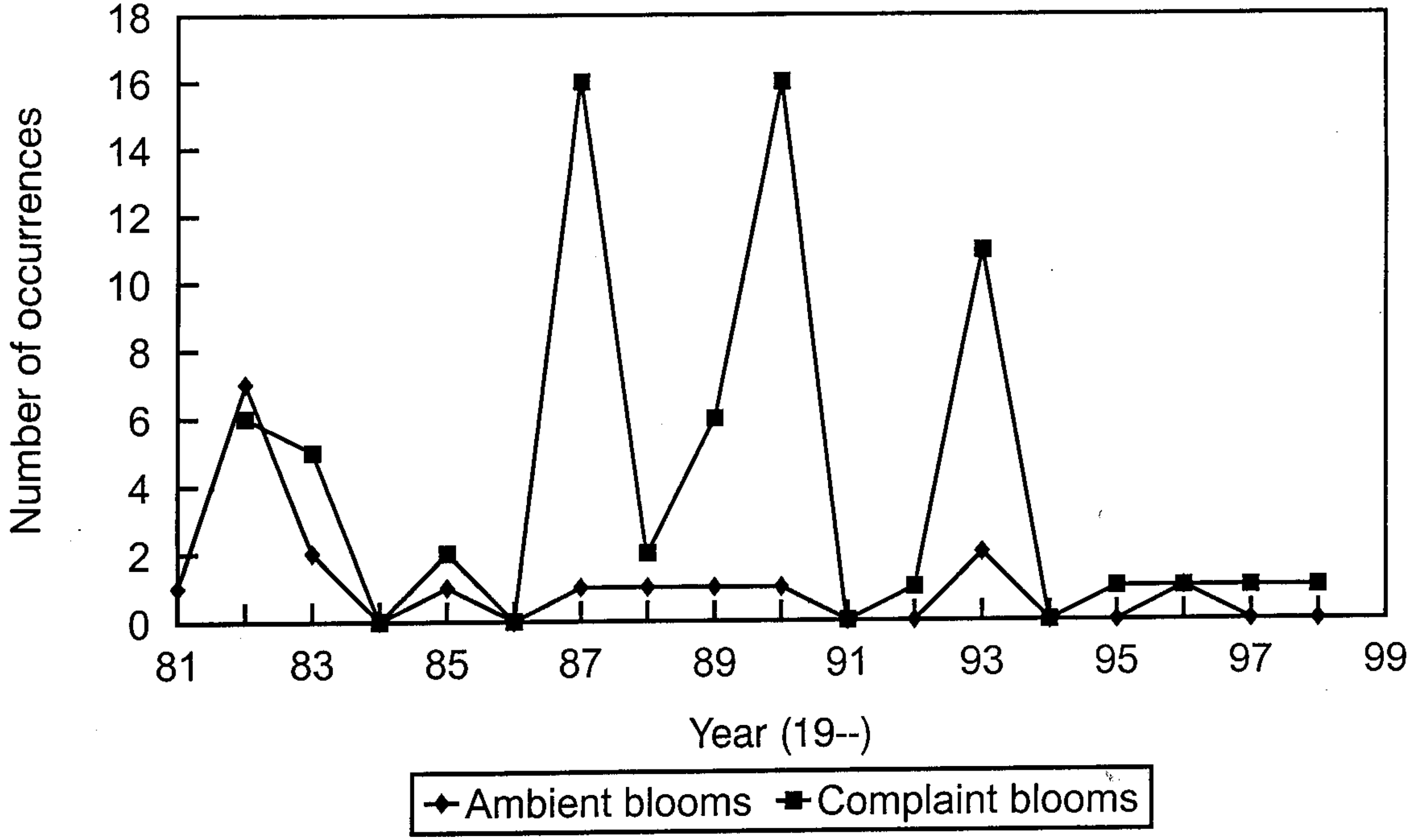


Figure 19. Occurrences of nuisance algae blooms in the Chowan River, 1981-1998.

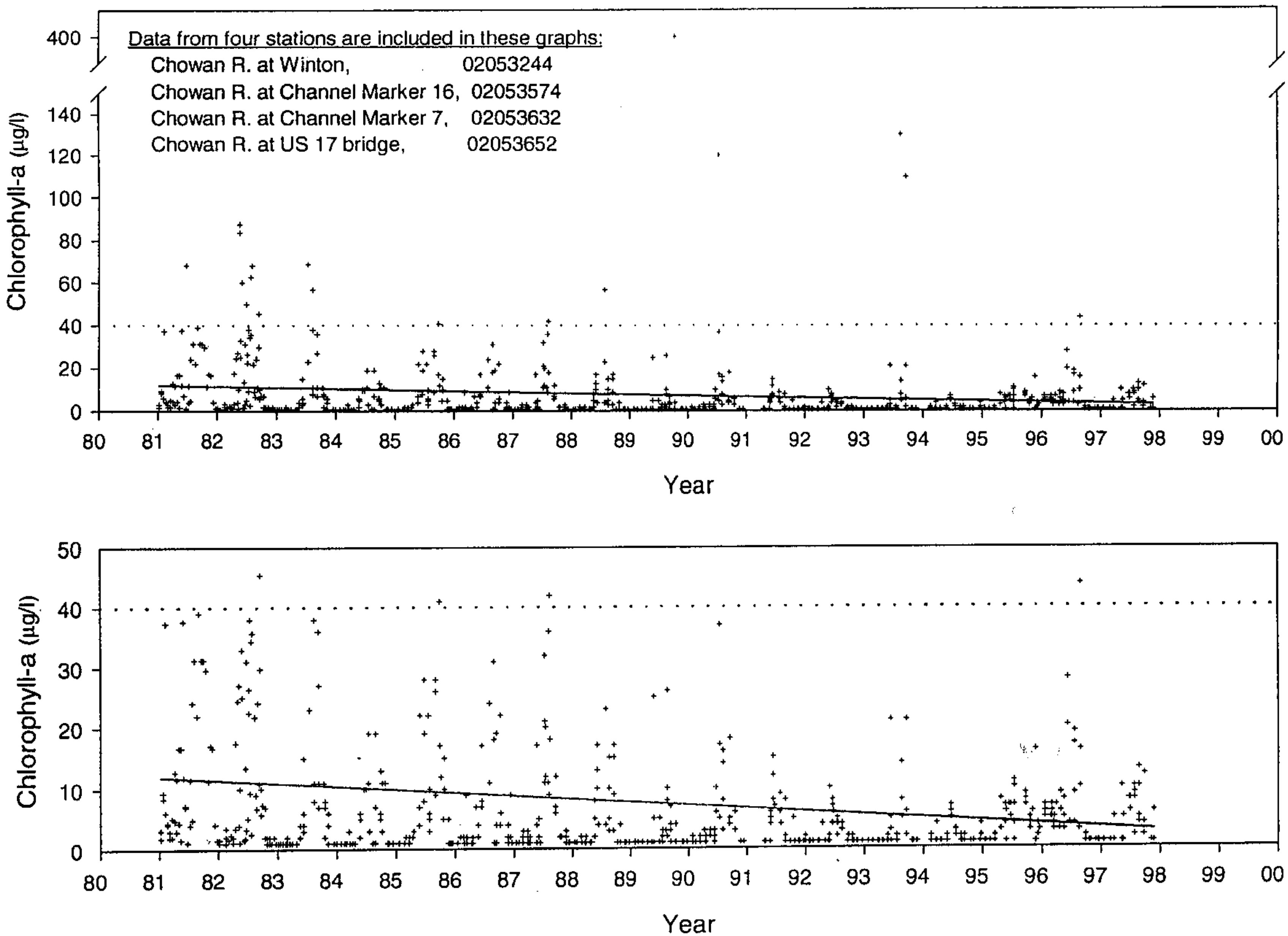


Figure 20. Chlorophyll-a concentrations for four water quality monitoring stations along the Chowan River
The bottom graph represents data between 0 and 50 µg/l. The rescaling of the y-axis is presented to more clearly show patterns among observations al lower concentrations. The dashed line represents the NC standard for chlorophyll-a (40 µg/l). The diagonal line is a linear regression line.

The National Oceanic and Atmospheric Administration (NOAA) conducted sediment sampling in North Carolina estuarine waters from 1994 through 1997 as part of their Estuarine Monitoring and Assessment Protocol (EMAP) (Balthius et al. 1998; Hackney et al. 1998; Hyland et al. 1996; Hyland et al. 1998). Of the 39 sites sampled by EMAP north of Oregon Inlet, 12 had more than two contaminants above a level where 10% of the international literature suggest biological degradation could occur. Nickel, chromium and DDT were the most frequent contaminants. While there was no geographical clustering of these sites, the sediments at all 12 sites containing multiple (3 or more) elevated contaminants were very muddy (silt/clay fraction >90%). All sites with less silt had lower chemical levels. Repeatability of contaminant levels was moderate; only 12 of 23 chemicals found to be elevated during one year, were elevated when sampled in another year. The implications of this information for river herring are unknown.

In 1990, DEHNR issued a consumption advisory for Chowan River fish due to elevated levels of dioxin in fish. As a result of improved discharges, dioxin levels in fish in the Chowan River have dropped to the point that the fish consumption advisory was lifted in 1998 for all fish but carp and catfish.

Dissolved oxygen (DO) levels drop below the 4 mg/l standard (swamp water standard) for significant periods of time in the lower Roanoke River and Albemarle Sound (Manooch and Rulifson 1989; Mulligan 1991; DEM 1992; Mulligan et al. 1993; Bales et al. 1993; Fromm and Lebo 1997; Lebo 1998). Hypoxic events occur most frequently in late spring, summer, and early fall (Mulligan 1991) and are most frequent in the portion of the river near Plymouth, in Cashie River downstream of Sans Souci, and in western Albemarle Sound. Reviews state that the biological oxygen demand (BOD) assimilative capacity in the lower Roanoke River (Jamesville to the Sound) has been exhausted (Briggs 1991; Mulligan 1991; Mulligan et al. 1993). Continuous DO monitoring data are available from United States Geological Survey (USGS) stations; those stations at Plymouth and Jamesville recently documented low DO events, as reported in the above referenced earlier studies. The USGS data at Plymouth indicate 21 consecutive days when daily average DO was below 5 mg/l (range between 1.0 and 4.9 mg/l) in late August and early September 1998. Ambient water quality monitoring by DWQ on a quarterly basis has not recorded the low DO levels, as indicated through the USGS continuous monitoring stations. Such infrequent sampling rarely measures acute events, such as low DO.

Concentrations of DO in the Roanoke River between Roanoke Rapids and Hamilton are higher, predominantly above the 5 mg/l standard. Concentrations are generally highest near the dam and decline downstream. Low flow water quality modeling (DEM 1996) and ambient data collection efforts document DO sags downstream of Weldon and downstream of Scotland Neck. Impacts to DO concentrations through the lower river have been attributed to a combination of reservoir operations, swamp water drainage, and over 30 permitted dischargers (totaling approximately 100 million gallons per day) of oxygen consuming municipal and industrial wastes (Rulifson et al. 1990; Mulligan et al. 1993; Fromm and Lebo 1997; Lebo 1998).

Despite these improvements, degraded water quality has been indicated repeatedly as a cause of the decline in the Chowan River herring fishery by fishermen as well as in the scientific literature (Winslow 1989; Stanley 1992; Rulifson 1994). As a result, several studies to evaluate the impact of water quality on various life stages of river herring have been completed. These studies were carried out prior to recent water quality improvements.

Two of these studies investigated the impact of pulp mill effluent on river herring. The Union Camp Corporation pulp mill stores its waste in settling ponds for much of the year, and in late fall to early winter, the waste is released into the Chowan River through a discharge canal located just north of the North Carolina-Virginia border. It had been hypothesized that this discharge caused river herring to alter their migratory route, and possibly avoid the Chowan River entirely. Kearson (1971) conducted a study to evaluate the impacts of the effluent on game fish, as designated by the WRC. Over a three-year period, 43,593 fishes were captured representing 15 game and 15 nongame species. A total of 8,436 fishes was tagged. Based on these collections and tag returns, it was determined that a mass avoidance of the pulp mill waste by game fish did not occur. Furthermore, the study indicated that concentrations of the effluent were not high enough to discourage river herring spawning.

Everett (1983) further assessed the impact of pulp mill effluent by comparing weekly river herring catches of three commercial fishermen within the Chowan River to weekly river concentrations of pulp mill effluent during the 1979-1982 seasons. During high flow years (1979, 1980, and 1982), the effluent made up a very low percentage (<5%) of river flow and did not appear to result in herring avoidance. However, during 1981, a low flow year, pulp mill waste comprised a large percentage (26%) of the flow, and based on catches, river herring did avoid the effluent. Everett (1983) further determined, based on historical flow data, that avoidance of pulp mill waste by river herring could not account for their decline. However, it was recommended that the effect of pulp mill waste on the food chain, in particular algal assemblages, and the subsequent impact on river herring be investigated.

To evaluate the impacts of water quality on river herring larvae, O'Rear (1983) conducted larval sampling in conjunction with water quality monitoring during the early 1980s at stations throughout the basin. In addition, larvae were collected, returned to the laboratory, and observed for several days. This study suggested that water quality within the basin did not have a direct effect on river herring larvae, but it did recommend further study of the larval food chain.

In 1982 and 1983, the zooplankton populations and the diet of juvenile blueback herring were studied in the Chowan River (Winslow et al. 1984). The study indicated that for a very productive system, zooplankton densities were low compared to James River, Virginia (the only comparable data available), suggesting that the forage base for juvenile river herring was poor. Therefore, it was hypothesized that juvenile blueback herring were selecting alternative, less suitable prey within the Chowan River resulting in poorer growth compared to herring populations in other river systems. However, the study was unable to link reduced densities of zooplankton to the excessive algal blooms and poor water quality. Zooplankton populations were limited in part by the flushing effects of high flows. In addition, a shift in the zooplankton community to strong-swimming copepods and small-bodied nauplii and rotifers suggested that filter-feeding predators, such as juvenile blueback herring, were controlling the zooplankton populations in the Chowan River (Winslow et al. 1984).

In 1996 and 1997, the effects of water quality on the hatching success of blueback herring eggs were investigated within the Chowan River and several of its tributaries (Waters and Hightower 1997). This study used 11 sites from the mouth of the river to its headwaters, including mainstem river sites and smaller streams. Factors such as temperature, pH, dissolved oxygen, nutrients, and contaminants (PCBs and pesticides) were considered. The results indicated that hatching success differed significantly among sites, but was generally good (exceeding 50%) within the basin. Excluding the Dillards Creek data, the hatching success was

75% or greater. Dissolved oxygen was the only water quality parameter with values outside the reported range for normal development of blueback herring eggs. Based on correlation and regression analyses, dissolved oxygen appeared to be the primary factor related to differences in hatch rate among sites. The lowest dissolved oxygen values and lowest hatch success occurred in a few small tributaries (Dillard, Deep Swamp, and Catherine creeks). These low-hatch tributaries are thought to comprise only a small proportion of the total spawning and nursery habitat in the Chowan River. Despite the need for a current study comparing water quality to larval growth and survival, this work, along with past research and general improvements in water quality, suggests that water quality currently has a relatively minor impact on river herring reproduction within the Chowan River.

Although a functional relationship between water quality and river herring abundance does not appear to exist in the Chowan River, the impacts of water quality on river herring reproduction in other coastal river systems have not been investigated. However, the North Carolina Division of Water Quality (DWQ) has identified water quality concerns for each coastal river in a series of basinwide water quality management plans (DWQ 1994, 1996a, 1996b, 1997a, 1997b, 1997c, 1998a, 1998b). For all river systems, these concerns include oxygen-consuming wastes, nutrient levels, toxic substances (heavy metals, chlorine, ammonia, etc.), pH, sedimentation, urban stormwater runoff, and fecal coliform bacteria levels. In addition, the plans identify concerns specific to each basin. For example, development along the North Carolina coast, particularly in the Albemarle Sound region, and the subsequent environmental impacts should be addressed. The effects of variable salinity regimes on submerged aquatic vegetation and fishery resources within Currituck Sound also requires further investigation. Currituck Sound salinity levels have increased due to freshwater diversion and usage as well as the construction of the Intracoastal Waterway which has resulted in the intrusion of saltwater. On the Roanoke and Tar rivers, the impact of reservoirs used for power generation and flood control need to be evaluated. In these systems, downstream flows are highly regulated, and their management can affect both water quality and habitat. The impacts from large-scale livestock operations need to be evaluated throughout the region and state. Research on the toxic dinoflagellate *Pfiesteria piscicida*, responsible for fish kills in the Tar-Pamlico and Neuse rivers, is underway. It should be noted that the presence of river herring has not been documented in any *Pfiesteria*-related kills. While these problems have been identified and must be addressed, their extent and impacts in relation to river herring spawning and nursery habitat within each basin have yet to be determined.

9.5 Other Habitat Concerns

The degradation and loss of critical freshwater spawning and nursery habitats are believed to have contributed to the decline in river herring stocks along the east coast of the United States, including North Carolina (Rulifson 1994). Rulifson (1994) indicated that within North Carolina, physical impacts such as channelization, dredge and fill activities, dams, industrial water intakes, industrial waste discharges, and road construction all had the potential to impact river herring reproduction. The extent of these impacts varies among river systems, and their link to river herring populations has not been fully investigated.

In North Carolina, spawning and nursery habitats of river herring have been delineated for most river systems. From the late 1960s to the early 1980s, several surveys were initiated for this purpose, including Baker (1968), Sholar (1975), Fischer (1980), Hawkins (1980a, 1980b), and Winslow et al. (1983). These studies demonstrated that river herring use a wide range of habitat types for spawning, such as small, densely vegetated streams; fresh and brackish marshes; hardwood swamps; and flooded low-lying areas adjacent to both mainstem rivers and tributaries. Baker (1968) indicated that herring used nearly all accessible rivers and streams in eastern North Carolina. However, much of these data are now dated, and the current status of spawning and nursery habitat is unknown for most areas. Furthermore, the overall quality of this habitat in general has never been well-documented, and the impacts of habitat degradation as a whole can not be measured. Nevertheless, because spawning and nursery areas are so diverse and widespread, any activities that alter aquatic habitat in eastern North Carolina have the potential to adversely impact river herring in some manner.

Dredging, draining, and filling activities have altered or destroyed habitat used by river herring during various life stages. In eastern North Carolina, these activities are most often associated with agriculture, residential development, and commercial forestry (Stanley 1992). Because very little historical data are available, losses to specific habitat types, such as wetlands and

SAV, and the subsequent impacts to river herring are hard to quantify. Nevertheless, a variety of studies have estimated losses to wetlands. Although these estimates include losses of wetland areas that are isolated and not accessible to river herring, they do indicate the overall magnitude of habitat loss, which is thought to be significant in some areas. Hefner et al. (1994) reported that in North Carolina, the net loss of wetlands from the mid-1970s to the mid-1980s was 1.2 million acres (485,640 ha), the highest net loss among states in the southeastern United States. A majority of these losses were swamps and bottom land hardwood forests. In the North Carolina portion of the Chowan River basin, Craig and Kuenzler (1983) documented a 30% reduction in oak-gum-cypress forested wetlands from 1964 to 1974. Over that same period, it was also noted that 31% of the total land within the North Carolina portion of the basin had been artificially drained for agriculture (Craig and Kuenzler 1983). Based on the wetlands tracking database maintained by the Wetlands/401 Unit of the Water Quality Section, DWQ, a total of 37 projects encompassing 44 acres (18 ha) of permitted wetland losses occurred in the Chowan River basin in 1996 and 1997 (DWQ 1998a) (Table 14). Many of these projects occurred in the lower Chowan River basin and impacted bottom land hardwood forests, brackish marshes, headwater forests, swamp forests, and wet flats. From 1994 to 1996, 48 acres (19 ha) of wetlands were permitted to be filled within the Albemarle Sound region, excluding the Chowan and Roanoke rivers (DWQ 1997b) (Table 15).

Rapid reductions in SAV have also occurred throughout many coastal estuaries. Although the use of SAV by river herring is not well-documented, juveniles pass through this habitat during their migration to the sea. As with wetland losses, reductions in SAV are hard to quantify due to the lack of historical data. However, in the Pamlico River, SAV abundance in 1985 was only one percent of that present in the 1970s (Stanley 1992). In Currituck Sound, similar reductions were documented from 1979 through 1984 (DWQ 1997b). In recent years, the return of SAV beds has been observed in both systems.

Stream channelization, most often associated with flood control projects, has also resulted in the loss of essential habitat. To evaluate this issue, Frankensteen (1976) compared a channelized creek (Grindle Creek) to a natural creek (Chicod Creek) within the Tar River basin. This work determined that high water velocities occurring in channelized sections of the stream prevented the entrance of both adult and juvenile herring into these areas. Channelization also removed in-creek vegetation and woody debris which served as a substrate for fertilized eggs. In

Table 14. Summary of the total Section 401 permitted impacts in the Chowan River Basin recorded by the Wetlands/401 Unit of the Water Quality Section, Division of Water Quality for 1996 and 1997 (DWQ 1998).

	Total permitted wetland impacts (acres)	Total number of projects
1996	22.42	18
1997	21.60	19

Table 15. Fill activities by wetland type in the Chowan River and Pasquotank River basins (Albemarle Sound and its tributaries excluding the Chowan and Roanoke rivers) basins from 1994 to 1996.

Wetland type	Acres of wetlands permitted to be filled in the Chowan River basin (DWQ1997a)	Acres of wetlands permitted to be filled in the Pasquotank River basin (DWQ1997b)
Bottom land hardwood forest	5.54	5.81
Salt marsh	0.00	16.51
Wet flat	11.91	39.36
Pocosin	0.00	0.37
Other	30.74	68.95
Total	**48.19**	**131.43**

addition, this loss of vegetation and debris reduced habitat for invertebrates resulting in a reduction in the diversity and quantity of prey for juvenile river herring. Disposal of spoil along the shoreline created spoil banks which prevented access for both adults and juveniles to sloughs, pools, adjacent vegetated areas, and backwater swamps. Problems associated with channelization have also been observed in other systems. Sholar (1975) stated that a channelized section of the New River did not provide suitable spawning habitat, contributing to reduced recruitment within the system. Hawkins (1980b) also noted that channelization had reduced habitat in Swift, Little Swift, and Bear creeks within the Neuse River basin. In the Albemarle Sound area, channelization projects have taken place on numerous tributaries, including the Cashie River, Ahoskie Creek, Joyce Creek, Pollock Swamp, Bear Swamp, and Burnt Mill Creek. The channelization projects are presented in Table 16, by county and miles effected. In the Albemarle Sound area, 281.1 miles of streams have been channelized.

Stream blockages such as dams, including beaver dams, culverts, and natural obstructions have eliminated or reduced access to large areas of both spawning and nursery habitat. Dams are the most common blockage, and one dam alone often denies access to large areas. For example, the Roanoke Rapids Dam located on the Roanoke River denies access to over 218 miles (350 km) of river (Collier and Odom 1989). The Quaker Neck Dam on the Neuse River has recently been removed, opening up 78 miles (125 km) of mainstem habitat and another 925 miles (1,488 km) of habitat along tributaries (Mike Wicker, US Fish and Wildlife Service, personal communication). Also, the Cherry Hospital Dam located on the Little River, a tributary of the Neuse, has been removed, allowing access to another 76 miles (122 km) of habitat (Mike Wicker, US Fish and Wildlife Service, personal communication). On the Cape Fear River, three lock and dams prevent upstream fish migration except during boat and fish lockages and periods of high water (Robin Hall, USCOE, personal communication). In addition to dams found on mainstem rivers, numerous smaller mill dams are found on creeks throughout eastern North Carolina. For example, Collier and Odom (1989) reported three such dams within the Chowan River basin, on Bennetts, Indian, and Rockyhock creeks. Water control structures

Table 16. Channelization projects in the Albemarle Sound area, by system, county and miles affected.

Project name	Counties	Miles affected
Ahoskie Creek	Bertie, Hertford, Northampton	65.7
Cutawhiskie Creek	Hertford, Northampton	53.9
Pollock Swamp	Chowan	25.0
Horse/Flat Swamp	Hertford	26.1
Hobbsville/Sunbury	Chowan, Gates, Perquimans	60.0
Gum Neck	Tyrrell	16.9
Folley Ditch	Gates	7.4
Burnt Mill Creek	Chowan, Perquimans	9.0
Bear Swamp	Perquimans, Chowan	17.1
Total		**281.1**

located on drainage canals to Lake Phelps (16,600 ac, 6718 ha) and Lake Mattamuskeet (40,015 ac, 16,194 ha) limit river herring migrations into these areas. Collier and Odom (1989) listed storm gates located on Western Canal, Thirtyfoot Canal, Old Canal, and Batava Canal at Lake Phelps as confirmed impediments to migration. In addition, Bee Tree Canal connecting Lake Phelps to the Scuppernong River has historically supported a significant spawning run of river herring and in the mid 1970s, a fish ladder was proposed for this canal (Kornegay and Dineen 1979). The water control structure located on Bee Tree Canal, along with those located on other canals, have been opened on an irregular basis, allowing river herring to enter the lake and apparently spawn. In the past when access was provided, large numbers juvenile herring were collected in the lake. At Lake Mattamuskeet, the wooden flap gates of the water control structures located on each of four drainage canals were replaced in 1989 with stainless steel gates. The new gates are heavy and open only slightly. These narrow openings create high water velocities which prevent herring from entering. This action subsequently reduced the herring run (Roger Rulifson, East Carolina University, personal communication), which had formerly supported a substantial dipnet fishery (Tyus 1974). Current efforts, including the installation of fish weirs and the replacement of the original wooden flap gates, are aimed at restoring river herring and estuarine species, such as blue crabs, to Lake Mattamuskeet (Rulifson and Wall 1998).

Although dams are the most common obstructions, road culverts may have more overall effect on river herring. Culverts are popular, low-cost alternatives to bridges when roads must cross small streams and creeks. Although the amount of habitat affected by an individual culvert may seem small, the cumulative impact of culverts within a watershed can be substantial (Collier and Odom 1989). Collier and Odom (1989) documented two culverts in Perquimans County that were confirmed impediments, with another 18 culverts suspected of blocking herring migration throughout the Albemarle Sound region. In 1998, a two-year study was initiated by the North Carolina Department of Transportation (DOT) to compare streams with culverts, bridges, and no crossings (Mary Moser, University of North Carolina at Wilmington, personal communication). The first year of sampling took place at over 200 sites within the Cape Fear River, Neuse River, and Albemarle Sound basins. Initial results showed that river herring were found upstream and downstream of bridge crossings, while no herring were found in sections of stream with culverts

(Mary Moser, University of North Carolina at Wilmington, personal communication).

Natural obstructions, such as beaver dams and vegetation blockages, are not nearly as common as anthropogenic barriers, and efforts to identify them have rarely been undertaken. Collier and Odom (1989) noted two vegetation blockages on Pollock Swamp Creek, Chowan County and Suttons Creek, Perquimans County, as well as one beaver dam on Eastmost Swamp, Bertie County. Odom et al. (1986) indicated that log and driftwood jams on the Meherrin River created barriers that prevented the upstream migration of anadromous species. However, due to aquatic weed control programs, snagging operations, and natural events such as hurricanes Bertha (1996), Fran (1996), and Bonnie (1998), these types of blockages can be temporary in nature. Nevertheless, such barriers most often occur on small streams and creeks, and therefore, can have an impact on river herring habitat (Collier and Odom 1989). Although blockages to the upstream migration of river herring can occur, the in-stream woody debris and vegetation often provide needed spawning and nursery habitat in many streams. Fertilized river herring eggs are initially adhesive and attach to vegetation and woody debris as a substrate. In addition, both juveniles and adults use this habitat as protective cover and as feeding sites. Invertebrates that also use this habitat provide an important food source for river herring. Future projects involving log salvage and snagging could result in the unnecessary elimination of habitat by removing woody debris and vegetation.

10. Principal Issues and Management Options

10.1 Stock Condition

The alewife and blueback herring stocks of the Albemarle Sound area are currently overfished as documented in Section 4.2.1 Stock Problems. The stocks cannot replace themselves through spawning at existing levels of mortality (recruitment overfishing). Natural mortality cannot be controlled through any fishery management system, but fishing mortality can be controlled through management. Therefore, any program implemented to improve the status of the stocks must affect fishing mortality. Numerous options are available, both for stock status targets and for strategies to reach those targets. Possible targets include MSY, minimum stock size threshold, and spawner/recruit relationship. Strategies include effort management, control of fishing mortality and harvest quotas.

Target stock status can range from maintenance of the existing depressed stock level to a robust stock such as existed during the late 1960s before oceanic foreign fishing took its toll. Strategies to achieve that range of targets also have a wide range: from status quo (do nothing) to a moratorium on directed fishing or possession of river herring for as long as required to achieve the stock status target.

A "do nothing"alternative will result in maintenance of a small fishery with little economic return to the participants. Full stock recovery will take a number of years, depending on many variables. The nature of the fisheries during a recovery period and thereafter would depend on the severity of management restrictions utilized to reduce fishing mortality and promote stock recovery, market conditions, economic conditions of the affected fishermen, and many other factors.

10.2 Habitat and Water Quality

Considerable habitat important to river herring has been degraded or lost in the Albemarle Sound area. Drainage and/or filling of wetlands adjacent to the rivers and creeks of the area has eliminated spawning areas. Channelization of small streams has had the same effect. Several small dams have eliminated access to upstream spawning areas. Nursery areas along the shorelines of the rivers and Albemarle Sound have been affected by dredging and filling, as well as by erection of bulkheads, although the degree of such impacts has not been measured. Major drainage work occurred during the 1960s and 1970s, but much less has been done since that time. Existing governmental regulatory systems make it very difficult to conduct major wetlands drainage projects today.

Migration of river herring may be impeded by culverts. These structures have been used to replace small bridges, and preliminary research has indicated that river herring are no longer found in the upper reaches of streams with culverts (Mary Moser, University of North Carolina at

Wilmington, unpublished data). However, it is unclear that the reduction in river herring distribution in these shallow streams can be attributed solely to installation of culverts. A study to determine the effects of low light on river herring migration behavior will be completed in December 1999. The results of this work will allow better assessment of the effects of various types of culverts on river herring migration.

Options to address these habitat concerns include establishing wooded buffers and conservation easements along area streams to protect the critical shoreline areas so they can continue to serve as spawning and nursery areas. Funding for habitat protection could come from the North Carolina Clean Water Management Trust Fund, North Carolina Wetlands Restoration Program, and the federal Conservation Reserve Enhancement Program (CREP). The MFC has defined anadromous fish spawning and nursery areas, but it has not yet designated any specific areas under those definitions. The WRC could enact the same definitions, and the DMF and WRC staffs could present specific, research-based areas to both commissions for official adoption. Then the EMC and CRC could enact rules to ensure the long-term integrity of such areas. If research shows negative impacts from the installation of culverts, the DOT could implement a mediation program to restore and maintain river herring spawning runs. All of these efforts would require expenditure of public and private funds. Policy decisions would be required to implement many of the options. The "no action" alternative would cost little in immediate costs, but the biological, social and economic benefits of restored habitats and resources would not be realized.

Despite the enactment of protective environmental regulations and the existence of both federal and state regulatory review processes, threats to the maintenance of river herring habitat quality and quantity are significant. Throughout the Albemarle Sound watershed, applications continue for alteration and/or filling of wetlands which serve a vital function in either maintaining the quality of surface runoff entering the rivers and estuary, or serve directly as river herring spawning and nursery areas. Loss of habitat quantity or quality which results from permitted actions has a cumulative adverse impact on the ability of the system to sustain river herring populations. Although mitigation requirements exist, understaffed and underfunded federal and state agencies frequently do not have the resources to adequately review and develop recommendations for each application, conduct follow-up inspections to ensure compliance, and undertake enforcement actions when violations are discovered. Efforts at industrial recruitment within this economically stressed basin also pose a threat to water quality. A recently proposed steel plate mill (Nucor, Inc.) on the Chowan River and paper mill on the Roanoke River (Wisconsin Tissue) both have the potential to adversely impact river herring resources unless adequate environmental safeguards are imposed to prevent water quality and habitat degradation.

During the 1970s, the Chowan River area and Albemarle Sound were plagued with extensive growths of nuisance blue-green algae, major fish kills, and outbreaks of fish diseases. The Chowan River was designated as Nutrient Sensitive by the EMC in 1979, and specific measures were developed to reduce excessive inputs of nutrients, especially nitrogen and phosphorus (DEM 1998a; 1982b). The major nitrogen sources were identified, and steps were implemented to greatly reduce inputs. The Farmers Chemical nitrogen fertilizer plant has since closed, although nitrogen leaching from the plant site remains a concern. Union-Camp pulp mill effluent has been greatly reduced and improved in quality; it is now discharged earlier in the year to reduce impacts on migrating fish during late winter and spring. Other discharges into the river have been removed or improved. Many farmers have adopted Best Management Practices (BMP) in their operations to reduce fertilizer use and control runoff from their fields. Incidence of blue-green algae blooms, fish kills, and fish disease outbreaks has been greatly reduced, but they still occur sporadically. There are still problems with non-point source (NPS) runoff and some discharges in the area, but the overall water quality of the area, especially Chowan River, is much improved.

Continued improvements in water quality will come primarily from control of NPS discharges through increased adoption of BMPs by farmers, restoration of wetlands and installation of stream buffers. Failure to aggressively reduce NPS discharges will lead to degradation of water quality as growth and development inevitably occur within the Albemarle Sound area. Continued upgrading or removal of sewage and industrial discharges is similarly required.

Both the MFC and WRC have officially adopted policies to protect and enhance habitat and water quality. The WRC adopted its "Policies and Guidelines for Conservation of Wetlands and Aquatic Habitats" in May, 1988. The MFC approved its "Policies for the Protection and Restoration of Marine and Estuarine Resources and Environmental Permit Review and Commenting" in April, 1999. The WRC staff bases its review of permits affecting habitat and water quality on the WRC policy, while the DMF is in the process of developing formal agency policy.

10.3 Assessment Data

The stock assessment used in this FMP is based on data for blueback herring in Chowan River, the largest single component of the Albemarle Sound area river herring resource. Full assessment of the resources, including alewife and blueback herring from the entire area, will require major expansion of research and monitoring activities. Fishing effort data from all gears, commercial and recreational, must be obtained on a continuing basis. Biological data (length, sex, age, spawning history) are required for each adult fish sampled from the fisheries. In addition to these fishery-dependent sampling efforts, fishery-independent sampling must be initiated throughout the spawning season to obtain data on the biological parameters of the total stock for comparison with data from the catch. Current fishery-independent sampling of juveniles must be expanded to fully cover the nursery habitat.

Issues concerning water quality effects on larval and juvenile river herring can only be answered through field and laboratory research to determine hatching success and juvenile survival in different areas under varying natural and altered conditions. Such work should pay particular attention to adequacy of food sources for larval and juvenile river herring, considering species composition, amount, and temporal and spatial availability. Water quality parameters (dissolved oxygen, pH, alkalinity, temperature, turbidity, and others) must be examined for influences on each life history stage within the Sound. Utilization of spawning habitat should be examined relative to simple presence/absence of spawners, as well as the more complex physical and chemical features which may be associated with use or non-use of a given stream area for spawning.

Existing DMF sampling work should serve as a basis for expanded biological research and monitoring. The commercial fisheries trip ticket database would help identify those fishermen to monitor for commercial fishing effort. Sales of the new Recreational Commercial Gear License (RCGL) will provide an initial license frame for sampling recreational fishermen who use commercial fishing gear such as gill nets. The WRC Special Devices License database will similarly help identify those fishermen taking river herring in Inland Waters so their catches and effort can be examined.

10.4 Socioeconomic Data

Every management decision made by the MFC, WRC, and DMF has socioeconomic effects. People react to those decisions as they decide whether or not to make certain expenditures, go fishing, etc. Those individual decisions add up to community impacts, which together generate statewide effects. The DMF/WRC have no program to periodically gather data to aid in estimating socioeconomic impacts before decisions are made or to determine impacts which actually occur. The DMF has a staff economist; the WRC does not. The DMF could begin regular sampling of licensees for data with which to develop socioeconomic baselines from which to estimate impacts of decisions. Failure to initiate such work would continue to leave the decision-making process open to criticism for failure to consider the human dimensions of decisions.

10.5 Education

The river herring fishery today is but a fraction of the fishery which existed 20-30 years ago. Its history, even though it was North Carolina's largest food fish fishery for many decades, is poorly known beyond the immediate Albemarle Sound area . The decline of the fishery might serve as a model of declining fisheries affected by both environmental problems and overfishing. The general public should be educated concerning both the history and potential future benefits which can come from a recovered fishery.

11. Recommended Management Program

11.1 Goals: To manage the Albemarle Sound area river herring fishery in a manner that is biologically, economically, and socially sound while protecting the resource, the habitat, and its users. The management plan for river herring will be adaptive and involve regular reviews and responses to new information about the current state of the resource, the habitat and its users.

To achieve an interim spawning stock biomass (SSB) level for the Albemarle/Roanoke system river herring that coincides with a 4 million pound SSB level for the Chowan River stock. (This level of SSB is considered the Minimum Stock Size Threshold (MSST)).

To achieve for the long-term a spawning stock biomass (SSB) level for the Albemarle/Roanoke system river herring that coincides with an 8 million pound SSB level for the Chowan River stock. (This level of SSB is considered the Biomass capable of producing MSY (Bmsy)).

11.2 Optimum Yield

Optimum yield, OY, is defined by the FRA as the amount of fish that will provide the greatest overall benefit to the state; is prescribed on the basis of MSY as reduced by relevant factors; and, in the case of an overfished fishery, will provide for rebuilding to a level consistent with producing MSY. The river herring stock assessment indicates that MSY for a recovered stock is approximately 2 million pounds, consequently the target OY for a healthy river herring population must be less than 2 million pounds. Furthermore, the assessment indicates that the stock is at extremely low abundance and is overfished, and that recruitment must improve before the stock can rebuild to a level capable of producing MSY. Because the stock is overfished, the allowable harvest, or rebuilding OY, must provide for stock rebuilding. Therefore, the rebuilding OY for river herring is not to exceed 300,000 pounds of commercial harvest. The recreational harvest will be limited to 25 fish possession limit. According to stock projections incorporating the stock-recruitment relationship, this level of harvest may rebuild the stock to the threshold spawning stock biomass (minimum stock size threshold, MSST) of 4 million pounds in 14 years and to the MSY biomass in 24 years. This level of harvest should not be exceeded until the JAI reaches a three year moving average of 20 or the spawning stock biomass exceeds the MSST of 4 million pounds. Observations gathered over the period of stock recovery and increasing abundance will provide important information relevant to the stock's current growth potential that may lead to alternative estimates of MSY and accompanying OY values in future assessments.

11.3 General Objectives:

1. Identify and describe fishery and population attributes necessary to sustain long-term stock viability.

2. Restore river herring stocks in the Albemarle Sound area to viable status.

3. Protect, restore and enhance spawning and nursery area habitat.

4. Manage the fishery in a manner to sustain long-term stock viability, traditional harvest and forage uses, and prevent recruitment overfishing.

5. Initiate, enhance, and/or continue programs to collect and analyze biological, social, economic, fishery, and environmental data needed to effectively monitor and manage the river herring fishery.

6. Promote a program of education and public information to help the public understand the causes and nature of problems in the river herring stock, its

habitats and fisheries, and the rationale for management efforts to solve these problems.

11.4 Strategies

All new work and expansion of programs will require additional personnel, equipment and operating funds.

11.4.1 Population Attributes:

1. Determine juvenile abundance indices (JAI) annually for the Albemarle Sound area.

2. Maintain up-to-date data bases on size, age, and sex composition of the harvest.

3. Update the stock assessment analysis annually.

4. Determine spawning repetition annually.

Action:

1. Validate JAI time series.

11.4.2 Stock Restoration:

1. Restore blueback herring juvenile abundance to a three-year moving average of at least 20 within six years, to at least 60 within twelve years and at least 100 within eighteen years as measured by the DMF juvenile abundance index (JAI).

2. Restore alewife juvenile abundance to a three-year moving average of at least 3 within six years, and at least 6 within twelve years as measured by the DMF juvenile abundance index (JAI).
3. Restoration targets for the Chowan River blueback herring spawning stock biomass (SSB) (Section 13, Appendix 1) :
    a. restore SSB to MSST = 4 million pounds (mlb) within 14 years
    b. restore SSB to 6 mlb in 19 years
    c. restore SSB to the 8 mlb biomass capable of producing MSY in 24 years

4. Restore the Chowan River blueback herring spawning stock age composition so that it contains at least 6% repeat spawners within six years, at least 10% repeat spawners within twelve years, and 14% within eighteen years.

5. Restore recruitment of age three fish to at least 3.5 million fish within five years (as estimated from the stock assessment) and to a three-year moving average of at least 8 million fish within 10 years.

6. Restore river herring runs through adult transplant and/or hatchery operations in specific streams to be determined by spawning area surveys.

7. Upon restoration manage fishery at F=OY.

Action:

1. Specific stock restoration objectives will be achieved through Fisheries Management Alternatives, Section 11.4.4.

2. Once SSB reaches the MSST of 4 million pounds, MFC directs DMF to recommend measures to achieve the target biomass capable of producing MSY, that equals 8 million pounds, and an ultimate harvest of OY.

11.4.3 Habitat and Water Quality:

1. Update spawning and nursery area surveys.

2. Maintain, restore and improve habitat and water quality to increase growth, survival and reproduction of river herring.

3. Identify and remove physical obstructions and water quality impediments to river herring migration.

4. MFC and WRC designate river herring spawning and nursery areas in their respective jurisdictions, so these areas can be protected and/or restoration measures can be implemented.

5. Support implementation of recommendations of DWQ basinwide water quality management plans.

6. Support implementation of habitat and water quality recommendations of Comprehensive Conservation and Management Plan (CCMP), Albemarle-Pamlico Estuarine Study (1994); and the Estuarine Shoreline Protection Stakeholders report (1999).

7. Protect vital habitat and water quality through establishment of buffer strips, conservation easements, habitat restoration and similar actions.

8. Identify and remediate aquatic habitat losses and other impacts associated with past stream channelization projects in conjunction with Natural Resources Conservation Service (NRCS).

Action:

1. Conduct a spawning area survey in one drainage basin, annually beginning spring 2001.

2. Develop and implement a CHPP for river herring spawning and nursery areas.

3. Develop and implement drainage area habitat restoration plans, using the Edenton Bay Plan as a model. Possible funding sources include: Clean Water Management Trust Fund, North Carolina Wetlands Restoration Program, Conservation Reserve Enhancement Program (CREP), and other sources.

4. Conduct a survey to update Collier and Odum (1989) - "Obstructions to Anadromous Fish Migration."

5. Based on No. 3 above, implement actions to alleviate identified impediments.

6. DMF and WRC recommend to their respective Commissions designation of documented river herring spawning and nursery areas in their respective jurisdictions.

7. Environmental Management Commission (EMC) should take appropriate steps to achieve established water quality objectives, especially those relating to nutrient inputs from both atmospheric and surface sources, nuisance algae blooms and fish kills.

8. Coastal Resources Commission (CRC) should take appropriate steps to achieve established habitat objectives, especially those relating to protection and restoration of river herring spawning and nursery areas.

9. Implement an automated water quality monitoring system (temperature, salinity, dissolved oxygen, pH, etc) throughout the Albemarle Sound River Herring Management Area (ASRHMA).

10. The EMC should require all NPDES permit holders in the ASRHMA to demonstrate their effluent is not toxic to blueback herring eggs and larvae by the next permit renewal using standard methods.

11. Develop BOD loading models and budgets for Albemarle Sound and each of its principle tributaries.

12. Establish and achieve objectives to increase the use of BMPs in agriculture in the Albemarle Sound area.

11.4.4 Fishery Management Alternatives

1. Five alternative management strategies:

    (a) Status quo- Maintain the current harvest and allocation of 450,000 pounds total and regulations. Implement a 25 fish Recreational Commercial Gear License (RCGL) daily limit. This alternative results in continued overfishing of the stock, which violates the FRA.

(b) Quota harvest- Reduce the harvest quota to 300,000 pounds, allocation of 200,000 pounds to Chowan River pound net fishery, 67,000 pounds to Albemarle Sound management area gill net fishery and 33,000 pounds to the Fisheries Director's discretion. Implement a 25 fish RCGL daily limit.

(c) By-catch level of 100,000 pounds- Establish a 100,000 pound by-catch allocation for the ASRHMA to be 50,000 pounds to the Chowan River pound net fishery, 25,000 pounds to the gill net fishery and 25,000 pounds to the Fisheries Director's discretion. No increase in pound net effort will be allowed, the gill net fishery will be restricted to a 3 1/4 inch stretched mesh minimum mesh size, and river herring in either fishery may not exceed 25% of the total catch weight. Possession limits for RCGL holders would be 10 fish per person per day.

(d) Fixed exploitation rate- The annual quota would be set by proclamation based on the annual fishing mortality target applied to the current stock abundance that varies from year to year. Allocation would be as follows: 66% to the Chowan River pound net fishery, 24% to the management area gill net fishery, and 10% to be allocated to the discretion Fisheries Director's. Possession limits of 25 fish per person per day for RCGL holders.

(e) Moratorium- No possession of river herring would be allowed in any fishery in the ASRHMA. No river herring pound nets would be allowed to be set. Gill nets would be restricted to a minimum mesh size of 5 1/4 inch stretched mesh from January 1 through May 31.

2. Manage the recreational fishery in a manner that reflects its historical

importance while providing for sufficient spawner escapement and juvenile recruitment.

3. Identify streams/creeks where populations are depressed or non-existent for enhancement and/or restoration purposes.

Action:

1. The MFC approved management alternative is to allow an annual commercial quota (calendar year) for river herring in the Albemarle Sound River Herring Management Area of 300,000 pounds allocated as follows:

   (1) 200,000 pounds to the pound net fishery for the Chowan River Management Area;

   (2) 67,000 pounds to the Albemarle Sound River Herring Management Area gill net fishery; and

   (3) 33,000 pounds to be allocated at the discretion of the Fisheries Director.

2. It is unlawful to possess more than 25 blueback herring or alewife, (river herring) in the aggregate, per person per day taken for recreational purposes.

3. Effective January 1, 2001, it would be unlawful to use drift gill nets with a stretched mesh less than 3 inches from January 1 through May 15 in the ASRHMA.

4. No gill nets less than 3 inch stretched mesh will be allowed in the ASRHMA during January 1- May 15. Gill nets of 3 inch stretched mesh will be limited to no more than 400 yards until the interim SSB level (4 mlb) for Chowan River is achieved.

5. Preclude expansion of pound net effort within the Albemarle Sound Management Area from February through May, until the interim SSB (4 mlb) level for Chowan River is achieved.

6. Enforce the requirement for removal of Chowan River Pound Net Management Area pound net stakes from abandoned sets. Abandoned sets are defined as sets not permitted for the 1999 fishery. Location of sets will be through GPS.

7. If rules implemented by the MFC pursuant to this FMP result in less pound nets being set in Chowan River than were permitted in 1999, the MFC should provide a means for the reestablishment and use of those pound net sets when the stock is restored.

8. If management targets for SSB, JAI and repeat spawners are not met as provided, implement fishing effort reductions necessary to achieve those targets, using appropriate management techniques, including limited entry or a moratorium.

9. WRC should implement a no sale provision for river herring taken with Special Device Licenses and eliminate gill nets in Inland Waters in the ASRHMA.

10. Based on spawning area surveys, prepare and implement a plan to restore spawning runs in designated areas.

11.4.5 Data collection

1. Continue and enhance existing data collection programs (juvenile survey, size, age and sex composition) to monitor the stocks.

2. Enhance fishery-dependent data collection programs to better monitor the size, age and sex composition of the harvest, including a process to collect harvest and effort data on a real time basis.

3. Design and implement fishery- independent data collection programs adequate to monitor the status of the stocks.

4. Quantify recreational landings and fishing effort from Coastal, Joint and Inland waters of the ASRHMA.

5. Request that National Marine Fisheries Service (NMFS) continue to monitor river herring harvest from the oceanic Atlantic mackerel and Atlantic herring fisheries and report those data to ASMFC and DMF.

6. Design and implement research to evaluate the impacts of water quality on larval and juvenile stages of river herring.

7. Assess impacts of other species (specifically striped bass) population dynamics on river herring.

Action:

1. Expand fishery-dependent sampling of adult river herring to include gill net

fisheries throughout the ASRHMA and pound net fisheries outside the CRHMA.

2. Enhance existing fishery-independent gill net sampling to gather biological data throughout the river herring spawning run and throughout the ASRHMA.

3. Using DMF Recreational Commercial Gear License and WRC Special Devices License databases, design and implement surveys to estimate the recreational fishing catch and effort.

4. Design and implement a program to collect biological data from the recreational fisheries for river herring.

5. Fund research to evaluate impacts of water quality on larval and juvenile river herring, including phytoplankton and zooplankton abundance trends.

6. Design and conduct studies of multi-species effects on river herring, specifically abundance trends of top predators, such as striped bass.

11.4.6 Education and Information

1. Utilize the MFC Northeast Citizens Advisory Committee as the primary citizens group for discussion of Albemarle Sound river herring management strategies and issues.
2. Prepare an annual stock status report and post it on DMF website.

3. Widely distribute FMP to the public.

11.5 Review Cycle

As provided in the FRA, this plan will be reviewed and revised by the MFC at least every three years, in conjunction with advisors.

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SECTION 13

APPENDIX 1

STATUS OF BLUEBACK HERRING IN THE CHOWAN RIVER 1972-1998
STOCK ASSESSMENT

Status of Blueback Herring
in the
Chowan River, North Carolina
1972-1998

by

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Abstract.

One of the largest freshwater fisheries in the world was once that for shad and herring in North Carolina's Chowan River, but currently only the blueback herring (*Alosa aestivalis*) stock supports catches of any magnitude. Acknowledging declining catches and juvenile abundance, the North Carolina Division of Marine Fisheries is developing a river herring management plan. A quantitative analysis of population abundance and exploitation rates is an important component of the management plan. Although blueback herring are landed in other areas of the Albemarle Sound by a variety of gears, the largest fishery, both in the present and historically, is that of the Chowan River pound nets. Catch at age data from the Chowan River pound net fishery were used to estimate exploitation rates and abundance from 1972 - 1998. Cohort and annual catch curves provided initial estimates of mortality, while a spreadsheet based catch at age model incorporating a multinomial error distribution provided estimates of annual recruitment, abundance at age, and fishing mortality. Bootstrapping and log-likelihood profiling were used to evaluate the precision of model estimates. A Beverton-Holt stock-recruitment model was fit and estimated model parameters were used to project population conditions under various management strategies. Maximum Sustained Yield (MSY) was estimated using stock-recruitment model parameters, a biomass model, and a stochastic stock-recruitment model. A juvenile abundance survey conducted by the DMF was validated using estimates of recruitment provided by the catch at age analysis. Total mortality varied without trend between 1972 and 1994, averaging Z=1.5 for both catch curve analyses and the catch at age model. Quotas implemented since 1995 have apparently reduced exploitation to an average rate of Z=1.1. Recruitment averaged 28 million fish from 1972 – 1985, but has since declined to around 4 million fish. As a result, spawning stock biomass has declined from 14.6 million pounds in 1972 to 1.3 million pounds in 1998. Based on average results from the models considered, the Chowan River pound net fishery could harvest an MSY of 2.1 million pounds at Fmsy=0.5 from an equilibrium spawning stock biomass just under 6 million pounds. However, excessive exploitation combined with poor recruitment has significantly reduced abundance over the last 15 years and led to much lower catches than were supported historically or are possible from a viable stock. Even if exploitation is reduced significantly, population growth will be minimal until recruitment improves significantly.

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I. Introduction

River herring (alewife *Alosa pseudoharengus* and blueback herring *Alosa aestivalis*) once supported large fisheries in Albemarle sound but landings have declined dramatically in recent years. Concern over reductions in both landings and juvenile survey values led to imposition of seasonal closures and harvest quotas in the early 1990's and initiation of a North Carolina Marine Fisheries Commission Fishery Management Plan to comprehensively manage the fishery (Winslow 1995). A quantitative analysis of stock status is necessary to determine current conditions and evaluate potential management strategies for the FMP.

Historically, both alewife and blueback herring have been taken by a variety of gears throughout Albemarle Sound with the largest harvest component being blueback herring in the Chowan River pound net fishery. In the 1970's and early 1980's the bulk of the fisheries were sampled by the DMF, but the virtual elimination of landings of alewife and blueback herring from the Albemarle Sound and many of its tributaries since the mid-1980's led to a reduction in fishery-dependent sampling efforts after 1993 (Winslow 1995). As a result, only data from the Chowan River pound net fishery is currently adequate to conduct a population assessment. However, since pound net landings of blueback herring have accounted for 75% of the total river herring landings since 1972 and over 95% of the total since 1994 (Table 1), an analysis of pound net landings of blueback herring should provide a reasonable representation of the status of the Albemarle Sound blueback herring stock.

The objectives of this assessment are to estimate fishing mortality and abundance at age of the blueback herring stock, evaluate potential biological reference points for the FMP, and project future stock conditions and yields under various management scenarios. This assessment is intended to provide a sound biological basis for the FMP and serve as a framework for future assessment updates.

II. The Fishery

Commercial Landings

Commercial landings fluctuated substantially through the mid-1980's then dropped drastically, showing no evidence of recovery since (Table 1, Figure 1). From 1972-1985, landings averaged 4.5 million pounds and ranged between 2 and 8 million pounds. Substantially lower landings between 1986 and 1994 resulted in an average for the period of only 1.2 million pounds. Since implementation of seasonal restrictions in 1995, landings have averaged only 0.31 million pounds with a range between 0.19 and 0.39 million pounds.

Commercial Fishery Sampling Intensity

Length, weight, and age samples of the blueback herring catch from the Chowan River pound net fishery are available from fish house sampling conducted since 1972. If available, unculled samples of at least 30 fish are obtained weekly during the fishing season. This information is combined with the total landings to construct the catch at age matrix (Table 2) Although the total number of samples declined with landings, in recent years sampling has exceeded 100 lengths per 200 tons of landings (Table 3). No weight samples was taken from

1973-1980; the weight at age for these years was taken from a length-weight equation fit to data from 1981-1997 (Ricker 1958)(Table 4). In recent years, age sampling has far exceeded 25 ages per 200 tons of landings. Due to difficulties that have arisen in obtaining sufficient unculled samples from dealers as the harvest has decreased, in 1998 DMF worked with several cooperating fishermen to allow sampling of herring directly. These efforts increased sampling rates in recent years. To investigate the possibility that seasonal restrictions could affect the size and age composition of the harvest, DMF contracted with the fishermen to continue fishing the nets after the season closed to provide additional samples. Lengths sampled after the season were similar to those taken during the season (S. Winslow, pers. comm.).

Commercial Fishery Effort

Aerial surveys during the fishing season are used to estimate total pound net effort for 1977-1998 (Winslow 1995). Total effort is the number of pound nets fished each week summed over the entire season. Since no effort data are available prior to 1977, the average total effort from 1977-1984 was used as an estimate of the effort for 1972-1976. While the maximum number of pound nets set in any given week has decreased drastically from a high of 624 in 1977 to only 73 in 1995, the total weeks fished has differed little over the years other than in 1997 when nets were only set for 5 weeks (Figure 2). Therefore, the overall decrease in total effort is due more to fewer nets set than to a reduction in the length of the fishing season. Effort has varied without trend since the implementation of a harvest quota in 1995, thus CPUE has varied in accordance with harvest trends in recent years.

Recreational Fishery

Although there is some recreational fishing effort on the stock in inland waters, the magnitude of recreational landings are unknown at this time.

Research Survey Indices

The DMF conducts several fishery-independent surveys to monitor both adult and juvenile anadromous fish in Albemarle Sound. Nursery area sampling with seines and trawls began in 1972 specifically to monitor river herring juvenile abundance. This sampling provides an annual Juvenile Abundance Index (JAI) calculated from the mean CPUE at a set of core seine stations. Declining JAI values during 1972-1998 provide the first indication that reduced landings are related to declining population abundance (Table 6, Figure 3)(Winslow 1998). The overall average JAI for 1972-1998 is 83.5, however, the average has declined from 149 for 1972-1985 to only 13 since 1986. Although the JAI increased slightly in 1996 and 1997, the 1998 value of 0.44 is the third lowest in the time series.

A trawl survey designed to monitor striped bass juveniles, initiated by Dr. W.W. Hassler of NCSU in 1955 and continued through the present by the DMF, also captures juvenile blueback herring (Hassler et al 1981, Trowell and Winslow 1998)(Table 7). However, since this survey has historically caught few river herring, its value as an indicator of population status is limited in light of the dedicated seine survey.

Some adult blueback herring are captured in DMF's Albemarle Sound gill net survey, which, like the Hassler trawl survey, is designed to monitor striped bass (Trowell and Winslow 1998). Because this survey is conducted throughout the sound, it is likely that those fish captured are from stocks spawning in several tributaries, not just the Chowan River. This greatly limits the usefulness of the survey as an abundance index of the Chowan River component of the stock.

III. Estimation Procedures

Catch Curve Analysis

Initial estimates of total mortality (Z, or fishing + natural mortality) were obtained through catch curve analysis. A catch curve is a basic approach to analyzing catches at age wherein a linear regression is fit to the declining limb of log transformed catch at age data (Ricker 1958, Ricker 1975, Hilborn and Walters 1992). Catch curves may be applied to annual catches or to individual cohorts. Since annual catch curves assume constant recruitment and it is very unlikely that this assumption is valid in this instance, the catch curve analysis was also applied to individual cohorts. A cohort based catch curve allows for changes in recruitment and may therefore be more applicable to this stock. Catch curves are a proven method of estimating total mortality, but because they cannot provide estimates of recruitment and abundance at age, more sophisticated models are necessary to meet the assessment objectives.

Catch at Age Analysis

A spreadsheet based catch at age analysis incorporating a multinomial error distribution was used to estimate fishing mortality and abundance at age. This is a flexible approach to analyzing catch at age data that was initially developed in the late 1980's and has been used extensively for many analytical assessments (Fournier and Archibald 1982, Deriso et al. 1985, Methot 1989, Kimura 1990, Methot 1990). The Solver routine of Excel was used to iteratively solve a model based on estimates of both total catch and the proportion of the catch at each age. Maximum likelihood estimates for the model parameters were found by minimizing the following expression, developed by Fournier and Archibald (1982) and termed the "multinomial maximum likelihood" model by Kimura (1990):

$$-L = \sum_{ij} n_i p_{ij} \log(\hat{p}_{ij}) + \sum_i [\log(c_i) - \log(\hat{c}_i)]^2 / (2\sigma^2) + \text{constant}$$

where

c_i = observed catch in year i
n_i = number aged in year i
p_{ij} = proportion at age$_j$ in year i
σ^2 = variance of catch at age.

The model estimates 57 parameters: 1972-1994 average fishing mortality, 1995-1998 annual fishing mortality, selectivity for ages 3 and 4, annual recruitment (estimated as abundance at age-3), and abundance at ages 4-7+ in the initial year (1972). The input data consists of 135 catches at age. Initial mortality values for the analysis were provided by the catch curves. The actual variance of the catch at age is unknown, so to force the model to fit the predicted catch fairly close, σ^2 was set at 0.001. Confidence intervals for estimated fishing mortality, recruitment, and selectivity were obtained through 500 bootstrap trials (Hilborn and Walters 1992, Davison and Hinkley 1997).

Although various auxiliary data can be incorporated, in this application of the model the only input data used were annual catches at age and the number of fish aged annually. Fishery effort data and JAI survey values were not used in estimating population parameters so that these values could be used to investigate effort trends in relation to population abundance and to validate the JAI.

Natural Mortality

Past assessments of this stock have assumed a wide range of natural mortality rates. Crecco and Gibson (1990) used a value of 1.0 in an initial ASMFC assessment of Atlantic Coast river herring stocks. A NC DMF assessment of the Chowan River stock, prepared by Schaaf (1998), assumed natural mortality was 0.3. Both the Hoenig (1983) and Pauly (1980) methods of estimating natural mortality yield estimates of 0.51 (Hilborn and Walters 1992). Since these analytical approaches provide an estimate within the range of the previously assumed values, for this assessment the assumed instantaneous rate of natural mortality is 0.5.

Maturation Rates

To calculate spawning stock biomass from abundance at age estimates, a schedule of maturity rates at age is necessary. Estimates of maturation rates are usually based on studies in which the population is sampled and the proportion mature at any given age is calculated. While this approach is feasible when both mature and immature individuals can be sampled, estimating maturity is problematic when dealing with an anadromous stock for which it is difficult to obtain unbiased samples of mature and immature fish. In the case of this stock, immature blueback herring are not available for sampling because they move to offshore waters and migrate along the Atlantic coast. This possibly explains why there are no published maturity schedules for river herring, while several references to fecundity are available including Street 1969, Loesch 1987, and Jessup 1983. In the few studies conducted on spawning grounds that address maturation rates (Havey 1961, Marcy 1969), maturation information is presented in terms of the number of times fish of a given age have spawned previously or as the number of fish of a given age that are spawning for the first time. In a NC DMF survey of anadromous species offshore, 76 scale samples were obtained from blueback herring between the ages of 2 and 8 between January and April 1971. Most bluebacks sampled had not spawned, but of 21 fish that had spawned previously, 33% spawned first at age-3, 62% at age-4, and 5% at age-6 (Holland and Yelverton 1973). Although the results of these various studies indicate that blueback herring mature between the ages of 3 and 5, there are not sufficient data for calculating a maturity schedule because there is no information on the abundance of fish of each age in the population. Further, since most of the studies are conducted on the spawning grounds, only mature fish are sampled and there is no way to directly determine how many fish of a given age are immature.

Lacking any published maturity schedules for blueback herring, spawning mark at age data were modeled to estimate maturity at age. Since blueback herring develop a spawning mark when they enter freshwater, it is possible to determine how many times a given fish has spawned previously. If no mark is found on a mature fish, it is assumed to be a virgin spawner. The spawning mark data was combined over all years and corrected for non-random age sampling to generate observed values of the number of fish by the number of spawning marks and age. A maturity schedule was developed using a model fit by least squares to estimate a 2 parameter curvilinear function that predicts the proportion mature at age (Table 8).

Population Modeling and Stock Projections

Fishery biological reference points are evaluated through several population models, including yield per recruit, spawning stock ratios, and biomass and age-based maximum sustained yield analyses. A Beverton-Holt stock-recruitment model is fit to estimated SSB and recruitment at age-3 values to generate estimates of model parameters (Beverton and Holt 1957). These parameters are used to calculate recruitment from predicted SSB values so that future yield and population trends can be examined and values of maximum sustained yield (MSY) estimated. Yield per recruit analysis is used to evaluate growth overfishing and to estimate biological reference points such as F_{max} and $F_{0.1}$ using the Thompson-Bell equilibrium approach (Ricker 1958). Inputs include estimated selectivity at age, estimated proportion mature at age, mean weight at age, and fishing and natural mortality rates. Spawning stock ratios are calculated in a method similar to that of Gabriel et al. (1989) with the exception that biomass is based on the entire spawning stock, rather than just females.

Blueback herring catch and catch per unit effort (CPUE) data from the Chowan River pound net fishery were analyzed using a non-equilibrium biomass dynamic model to estimate MSY, biomass at MSY (B_{msy}), and the fishing mortality rate necessary to harvest MSY (F_{msy}) (Hilborn and Walters 1992, Davison and Hinkley 1997). Since no effort data are available for the period 1972 – 1976, the average effort during 1977 –1984 was used as an estimate of effort in those years. Reliability of the model is evaluated by log-likelihood profiling (Hilborn and Walters 1992). This technique entails fixing one parameter at different levels and fitting the remaining parameters to determine how much the fit is degraded as the fixed parameter is changed from the estimated value. The change in error sum of squares is considered a chi-square value and is used to determine probabilities.

MSY can also be estimated by projecting a stock to equilibrium over a range of fishing mortality levels. The age structure and biomass of the population are calculated with standard population equations based on estimated selectivity at age, an estimated maturation schedule, average weight at age, and natural mortality. Two estimates of incoming recruitment are considered: 1) calculated from the stock-recruitment relationship parameters, and 2) chosen stochastically from observed values. The stochastic model projected the population forward 50 years with 50 trials run for each fishing mortality level. Future recruitment is determined through selection from past observed values over a range of SSB levels. To determine appropriate limits on the SSB ranges, observed recruitment and SSB were plotted and then tabulated into three categories: 1) SSB below 2.5 million pounds, and 2) SSB 2.5 to 10 million pounds, and 3) SSB greater than 10 million pounds. These values were selected due to the clear thresholds between 2 and 4 and above 10 million pounds of SSB. An excel spreadsheet macro was used to randomly select recruitment for future years from observed values within the appropriate SSB category. Equilibrium values of SSB, recruitment, and yield for the given F value are based on the average over the 50 trials of the value observed in the 50th year. Since the stochastic model constrains the stock at low levels when the population begins at its current low abundance, a higher starting level was used to bump SSB to the high category. Unlike the biomass model in which MSY is calculated directly from model parameters, these equilibrium approaches require calculating yield over a range of fishing mortality values and than determining at what level of exploitation yield is maximized.

Management alternatives are evaluated by comparing future fishery yields and stock parameters such as abundance and spawning stock biomass for various management strategies. Starting with the 1998 abundance estimates provided by the catch at age model, a population model is used to project changes in abundance for different levels of exploitation. Mean weights at age are based on the 1972-1998 averages and selectivity is taken from the catch at age model. Estimates of initial abundance at age and the exploitation rate for 1998 are based on the catch at age model estimates. Since the fishing season is complete for 1999 and any proposed management changes will only impact 2000 and beyond, the exploitation rate for 1999 is fixed at the 1995-1998 average of F=0.6. Recruitment for years 2 and 3 (1999 and 2000) is fixed at the level estimated for 1998. Estimates of recruitment beyond year 3 are obviously required, and are provided by either the stochastic stock recruitment selection procedure or the Beverton-Holt stock recruitment model. For the stochastic runs, 25 projections of the stock over a 30 year analysis period were made for each fishing mortality or fixed harvest scenario. Runs incorporating more projections were evaluated, but did not offer an increase in precision. The average F or harvest and SSB predicted in each year is presented graphically along with 95% confidence intervals. Incorporating the stochastic recruitment function only requires assuming that future recruitment will be similar to the observed conditions over the specified ranges of spawning stock biomass. Using the stock-recruitment model implies the assumption that any gains in SSB will in turn lead to gains in recruitment.

IV. Results

Overall abundance of the Chowan River stock of blueback herring is at an historic low and fishing mortality has exceeded sustainable levels over most of the last 27 years. Strong recruitment to age 3 during the 1970's and mid 1980's supported the population in spite of excessive fishing mortality, but apparent recruitment failure in the late 1980's allowed spawning stock biomass to decline to the extremely low levels from which it has never recovered. A slight drop in the average fishing mortality since 1995 has yet to provide any substantial gains in either population abundance or spawning stock biomass, and both recruitment and overall abundance remain at record low levels. Although blueback herring from Albemarle Sound are reported to reach age 10 (Kornegay 1978), in recent years the age structure is becoming increasingly truncated. Until the mid-1980's an occasional age-9 fish appeared in the catch and age-8 fish were fairly common. Since 1983 the oldest fish observed has been 7 years old and in several years the maximum observed age was 6.

Catch Curve Total Mortality

Results from the annual catch curve analysis suggest that total mortality averaged 1.51 from 1972-1998 (Figure 4). A test of the slopes of the annual catch curves failed to indicate a significant difference, supporting the hypothesis that fishing mortality varied without trend over the period. Cohort based catch curves were plotted by fishing year to illustrate both the steep decline in abundance and the relative similarity of the slope of the decline of each cohort (Figure 5). Average 1972-1998 total mortality from catch curves applied to cohorts was 1.55

with a 90% confidence interval for the mean of 1.31 – 1.79 (Figure 6). By subtraction of natural mortality, the estimated fishing mortality is 1.05.

Potential effects of regulatory changes were examined by comparing the slopes of cohorts that were exploited both before and after the changes. Since the rule changes were implemented in 1995, cohorts of 1986 and earlier were not affected, while those from 1990 – 1992 should exhibit a change of slope (which represents exploitation) if the regulations have impacted exploitation rates. Comparing the slope of the 1983-1986 cohorts with the slope of the 1990-1992 cohorts indicates that the mean Z has dropped from 1.6 to 1.2, indicating about a 25% decrease in total mortality. If natural mortality is assumed constant, this suggests that fishing mortality has declined in recent years. Plotting the log-transformed catch of the 1990-1992 cohorts by the log-transformed catch of the 1983 cohorts as in Figure 7 clearly illustrates the decrease in slope, and thus the exploitation rate, of the recent cohorts. The solid line represents y=x, or a slope of 1 and the points represent the 1990-1992 cohorts. If the points had fallen along, or parallel to, the line, then the appropriate conclusion would be that the exploitation rates of the two periods were similar. However, since the points are below the line on the left of the graph and above the line on the right of the graph, the conclusion follows that the slopes are different and exploitation has changed.

Catch at age Model Exploitation Rates, Selectivity, and Abundance at Age

The catch at age model allows estimation of abundance at age and selectivity in addition to estimates of exploitation rates. The model is configured to fit the total observed catch fairly closely (Figure 8). Examining annual plots of observed and predicted catch indicates that the model predicts the catch well in most years (Figure 9). An exception is 1985, where the observed and predicted catches are quite a bit different. The high observed catch and estimated catch curve Z for this year suggest that the exploitation rate in 1985 was probably considerably higher than the 1972-1994 average.

Recruitment is estimated at age 3 since virtually no fish younger than this appear in the catch and there is no offshore survey data available to estimate the population of the sub-adults. Recruitment averaged 28.6 million age-3 fish a year between 1972 and 1985, but since 1986 it has only averaged around 5 million fish (Table 8, Figure 10). Strong year classes of the late 1960's sustained the stock through the mid-1970's, then poor 1975-1977 cohorts contributed to the decline in the late 1970's. Exceptional recruitment of the 1978 - 1981 cohorts, averaging 30.5 million fish, allowed the stock to rebuild in the early 1980's, but another series of poor cohorts from 1983-1986 combined with sustained high fishing mortality lead to a decline in overall stock abundance. Recruitment has been low over the last 10 years, only averaging 4.6 million fish a year. Moreover, any modest gains in recruitment since the early 1980's supported catches over the short term and were quickly removed by high fishing mortality. For example, although the 1987 and 1988 year classes were the best in the last 10 years, these two cohorts alone supported over 70% of the catch between 1990 and 1993. In more recent years, the 1993 year class supported nearly 10% of the catch in 1996, nearly 40% of the catch in 1997, and over 50% of the catch in 1998.

A catch at age model estimating annual fishing mortality rates suggested that fishing mortality varied without trend between 1972 and 1994; this conclusion is also supported by the catch curve analyses above. To reduce the number of parameters estimated by the model and provide a more robust estimate of the long term average F than would be obtained from averaging values estimated annually, for the final model run a constant F was fit for the period 1972-1994. As shown in Figure 9, in most years the average F predicts catches that are similar to the observed values. To account for the possibility that regulatory changes since 1995 have impacted exploitation rates, fishing mortality was estimated annually for 1995 - 1998 (Table 9). Estimated fishing mortality for 1972-1994 is 1.01 which is equivalent to an annual exploitation rate attributable to fishing of 52%. Average fishing mortality has dropped slightly since 1995 to 0.59, largely due to the estimated value in 1997 of 0.27. Fishing mortality increased slightly in 1998 to 0.58 with a 90% confidence interval of 0.27 – 0.90. A separability assumption is included in the catch at age model that allows separation of exploitation into year and age effects. Selectivity is fixed at 1 for ages 5-7+ and estimated by the model at 0.02 and 0.44 for ages 3 and 4 respectively (Table 10).

Spawning stock biomass (SSB) based on 1972-1997 mean weight at age, the estimated maturity schedule, and estimated numbers at age shows a general decreasing trend over the 1972-1998 period (Table 10, Figure 11). From 1972-1985 SSB varied between 4.43 and 14.6 million pounds and averaged 8.2 million pounds. It then dropped to just 1.4 million pounds in 1990. A slight increase in 1991 and 1992 can be attributed to the 1987 and 1988 year classes reaching maturity, but continued poor recruitment further reduced SSB to a record low in 1995 of 0.91 million pounds. SSB has increased slowly each year since 1995, reaching 1.3 million pounds 1998. The recent increase is largely due to the 1993 year class being the best in the last 7 years. However, given that the 1994 and 1995 cohorts are among the lowest observed, it is unlikely that this slight increase in 1998 will be maintained as these poor cohorts move through the population.

Stock Recruitment Relationship

Because the goals of this assessment include estimating MSY and evaluating the impact of future management changes, some means of predicting future recruitment for inclusion in population modeling and projections is desirable. A common approach is to fit a deterministic stock-recruitment relationship that can be used to predict recruitment from spawning stock biomass. There are a variety of models available to describe the relationship between spawning biomass and recruitment, and the first step in selecting an appropriate model is to observe the potential relationship graphically. It is apparent from a plot of spawning stock and recruitment that strong year classes are much more likely when SSB is above 4 million pounds and poor year classes are to be expected when SSB is below 2.5 million pounds (Figure 12). There is some indication that recruitment is related to spawning stock biomass, since higher recruitment values are more common at higher stock sizes. Two of the most commonly used stock-recruitment models are those of Ricker and Beverton-Holt. The primary difference between the two is in the expected recruitment at higher spawning stock levels, with the Ricker model predicting that recruitment will decline and the Beverton-Holt model predicting that recruitment will reach an asymptote. Since there is no indication of declining recruitment at larger stock sizes, a Beverton-Holt model was used to quantify the relationship between spawning stock and recruitment with the model fit incorporating an arithmetic error assumption (Table 11, Figure 13). Initially, both arithmetic and logarithmic error assumptions were considered. The difference in the two approaches is related to how the observed recruitment points are distributed relative to SSB and the predicted curve. Although many stocks exhibit lognormal variation and there is a strong theoretical basis for such an assumption (Hilborn and Walters 1992), the plot of recruits vs. SSB (Figure 12) suggests that, over the 4 to 10 million pounds of SSB range of most of the observations, the variation in recruitment is as great for lower stock sizes as it is for higher stock sizes. Also, when annual labels are applied to the recruitment points, as in Figure 16, it is clear that after the strong year classes of 1980 and 1981 recruitment was influenced strongly by some factor other than stock size. While the logarithmic model may fit a line closer to the 1983-1986 cohorts, this may not accurately represent the relationship between recruits and SSB and may reflect other events that affected the stock at that time. Also, the logarithmic model did not appear to account for the occasional high recruitment events that may be important to the productivity of the stock. Overall, the arithmetic model tended to predict recruitment values that were about 40% higher than those predicted by the lognormal error model. This is because the arithmetic error model gives equal emphasis to all recruitment values and thus its estimates of recruitment at a particular stock size are higher than the estimates provided by the logarithmic error model. Because the error associated with high recruitment is magnified by the logarithmic transformation, the logarithmic error model fits the lower recruitment values more closely as shown above for the 1983-1986 cohorts. However, the danger in relying on predicted recruitment from the arithmetic model is that if it is biased toward overestimating recruitment at any given stock size the predictions of stock growth and MSY will be overestimates. On the other hand, if the occasional high recruitment values observed when the SSB exceeds 4 million pounds are typical of a healthy stock, then the arithmetic solution may be appropriate. Regardless of how the stock-recruitment model is constructed, the threshold at 4 million pounds cannot be ignored and more emphasis should be placed on restoring the stock to the threshold than on any particular stock-recruitment model option.

Validation of the Juvenile Abundance Index

An objective of this assessment is to determine whether the juvenile abundance index is a valid indicator of cohort strength. A linear regression was used to establish the relationship between JAI values and the predicted abundance of a given cohort at age-3. The JAI value for 1981 is an apparent outlier and was not used in this analysis. It is suspected that drought conditions in that year had an adverse impact on survey values, for the 1981 cohort represents one of the lowest JAI values yet the catch at age model estimates this cohort as having the highest age-3 abundance. Age-3 abundance and the JAI are highly correlated ($r=0.77$), and the linear regression indicates that 60% of the variation in age-3 abundance can be explained by the JAI ($r^2 = 0.60$, $p<.001$) (Figure 14). This analysis suggests that the JAI is a valid indicator of cohort strength and has potential value as a management tool and stock indicator.

V. Biological Reference Points

Yield per Recruit

A yield-per-recruit (YPR) analysis is one method of estimating appropriate fishing mortality levels. Such models can be used to illustrate how a stock changes in response to different levels of exploitation and changes in selectivity. The reference points provided by YPR are related to growth overfishing and include F_{max} (the level of exploitation at which yield per recruit is maximized) and $F_{0.1}$. YPR models are often extended to examine spawning potential and calculate $F_{\%SPR}$, which is a class of references related to the proportion of the maximum spawning biomass per recruit that is retained. Since YPR models are based on exploitation rates and size at age, no stock-recruitment information is necessary. While this is a benefit for analyzing stocks for which there is no clear relationship between spawning stock and recruitment, it is a potential disadvantage when considering stocks such as this one that exhibit a strong stock-recruitment relationship (Deriso 1987). In fact, one of the major drawbacks to YPR models is that they cannot account for recruitment effects and recruitment overfishing (Hilborn and Walters 1992). Further, some stocks have growth, selectivity, and maturity patterns that prevent yield from reaching a maximum. All of these factors affect this YPR analysis, suggesting that the results are not especially useful (Table 12; Figure 15). F_{max} is undefined since the yield never reaches a clear asymptote, and the values of other references appear excessive, with $F_{0.1}$ estimated at F=1.0 and $F_{40\%SPR}$ at F=1.6. Given the fact that this stock declined sharply when fishing mortality was sustained at around F=1, these reference values provide little real guidance in establishing management targets and clearly fail to account for the decline in recruitment observed from the current truncated age structure and low stock sizes.

Spawning Potential Ratios

One approach to integrating the stock-recruitment information with a YPR analysis is presented in Gabriel et al (1985). The YPR analysis provides a value for the spawning stock biomass per recruit (SSB/R) that will be produced at any given level of exploitation. The SSB/R can then be plotted on the stock recruitment plot as a straight line that goes through the origin and has a slope of R/SSB. The line represents the level of recruitment that is necessary to sustain the stock at the particular fishing mortality rate. Any recruitment values above the line represent years in which recruitment is greater than that needed for replacement and the excess can contribute to stock growth. Any values below the line represent years in which recruitment is less than that needed for replacement. Several lines can be plotted and used to examine potential exploitation rates relative to the recruitment history of the stock. A line with recruitment points equally distributed above and below can be considered to represent a replacement level of given the observed recruitment. Years in which recruitment was not sufficient to replace the losses from natural mortality can be illustrated by plotting a line corresponding to F=0. Applying these principles to the YPR and recruitment information from this stock indicates that a fishing mortality below F=0.3 would have been necessary to sustain this stock given the observed 1972-1998 recruitment patterns (Figure 16). Also, age-3 abundance for 1983-1986 was insufficient to sustain the stock even if there had been no fishing mortality. Since a stock-recruitment relationship is available for this stock, the analysis can be carried further by superimposing the predicted recruitment values on the plot as well (Figure 17). The stock would theoretically stabilize at any point where a given SSB/R line intersects the stock-recruitment curve. These equilibrium points can then be compared with those suggested by the MSY analysis which is addressed below.

Estimation of Maximum Sustained Yield

As noted previously, estimation of maximum sustained yield is approached several ways: 1) a biomass dynamic model, 2) a deterministic model based on the arithmetic SRR values, and 3) a stochastic model based on observed recruitment. Since each of these methods addresses the potential yield of the stock in different ways, there is no clear way to determine which model presents the "right" answer. Each model must be considered in light of the available data and its particular strengths and weaknesses.

As with most models, there are certain caveats associated with biomass modeling. Usually, MSY and F_{msy} are estimated fairly precisely, while absolute levels of biomass and fishing mortality are less precise. This is because few data sets allow reliable estimation of catchability, or q (Hilborn and Walters 1992). The estimated starting biomass is usually imprecise, thus it usually takes several years for the biomass series to stabilize. Any inferences about trends in biomass should not be based on the initial years of the analysis. Just as with most other population dynamics models, biomass models perform best when there is significant contrast in the catch and effort data series. However, there is little contrast in the available data – while the catch and stock have declined significantly, there is no apparent period of rebuilding which would allow the model to estimate the populations growth rate and there is no period of increasing effort. Rather, this data series exhibits two distinct periods of catch and effort (Figure 2). During the early years of the time series is a period of high effort and varying but high catch per effort, while the more recent years show lower and more consistent CPUE and effort. Plotting CPUE and catch illustrates that both CPUE and catch declined over much of the time series and are thus correlated although effort has changed considerably (Figure 18). In recent years the relationship may be changing, as CPUE is increasing in spite of low catches and low biomass (Figure 19). This trend may be reflecting altered effort and fishing behavior related to changes in fishery regulations. Such trends are relevant to the model because they result in a data series with inadequate contrast and, subsequently, little information about the individual parameters is provided by the data. This may contribute to the model's tendency to interpret the increasing CPUE since the early 1990's as suggesting an increase in stock biomass, a result that is not supported by either the catch at age model or the fishery independent juvenile abundance data. Further, it is generally accepted that models of this type do not estimate absolute levels of biomass and fishing mortality very well (Hilborn and Walters 1992, Prager 1994). However, much of the imprecision in the estimates can be removed by evaluating the relative levels of biomass and fishing mortality (Figure 20).

Results of the biomass dynamic model suggest that MSY is 2.75 million pounds with a 90% confidence interval approximately between 2.4 and 4.2 million pounds. Biomass at MSY is estimated at 14.9 million pounds and the annual exploitation rate to achieve MSY is around 0.2 (Table 13). Estimated B_{msy} from a biomass dynamic model represents total stock biomass; since catch at age estimates of total and spawning stock biomass indicate that SSB is approximately 50% of the total biomass when the total is around 15 million pounds, the spawning stock biomass at MSY is estimated at 7.5 million pounds.

To estimate MSY using the deterministic stock-recruitment relationship, the Beverton-Holt stock recruitment model parameters are used to calculate incoming annual recruitment from SSB. As noted above, the stock is projected forward until it reaches equilibrium for a given exploitation rate. Plotting yield and SSB over a range of mortality rates indicates the rate at which yield is maximized (Figure 21). This approach results in an MSY of 1.74 million pounds, harvested at F_{msy}=0.6 from a stock with 4.86 million pounds of SSB (Figure 21).

To estimate MSY using the stochastic stock-recruitment model, incoming recruitment values are selected from the observed values over the range of SSB levels. The details of this method are presented under the estimation procedures. Just as with the fitted stock-recruitment relationship approach, the stock is projected to equilibrium conditions over a range of exploitation rates and the expected yield and SSB are plotted (Figure 22). This method suggests that MSY is 1.9 million pounds and Fmsy is F=0.6. Since future recruitment values are selected from observed values, the model will not always generate the same results each time it is run. Therefore, as noted in the methods, multiple runs are made and the average yield and SSB are reported. This approach has several advantages. First, the multiple runs provide a range of potential answers that can be used to construct confidence intervals around the parameter estimates (Table 14). Secondly, the only assumption that is required regarding future recruitment is that it will be similar to observed conditions over a particular range of SSB. And thirdly, the estimated parameters are not affected by any bias or error that may be associated with the stock-recruitment relationship parameters.

The various approaches were presented to the River Herring Plan Development Team in significant detail (Carmichael MS 1999). Given the range of potential estimates, the PDT decided to base MSY, Fmsy and Bmsy on the average of the methods considered (Table 13).

VI. Stock projections

The goal of projection exercises is to determine how a stock may respond to particular management changes by projecting population growth and catches in future years using standard population models. Future recruitment is based on both the stochastic model and the deterministic estimates provided by the Beverton-Holt stock-recruitment model. It cannot be stressed enough that the assumed or estimated future recruitment values will greatly influence the results, especially in later years. As a general rule, short term projections are fairly reliable since the first few years are influenced heavily by the initial abundance at age, which, as stated earlier, is provided in the model output and is based on the observed population. In longer term projections, the results become increasingly dominated by the future recruitment assumption and therefore increasingly uncertain. This basic tenet of stock projections is especially important for this stock. The catch is typically dominated by 4 and 5 year old fish, yet age 3 is the first age that can be estimated. Virtually no fish older than 7 appear in the catch. Therefore, once a projection has been extended out 5 years, the abundance of every age in the population is directly dependent on the assumed recruitment value. Also, once the projection is extended 3 years, the abundance of the dominant ages (ages 4 and 5) is directly dependent on the assumed recruitment value. Clearly, for this stock, the accuracy of even relatively short term projections is heavily dependent on the accuracy of future recruitment assumptions. Although it makes presentation and interpretation of the projection results more difficult, the strong influence of the recruitment assumption on projection results necessitates considering more than one option.

Based on discussions with the Plan Development Team, three different management scenarios are considered. The first two consider constant harvest strategies of 1)maintaining the status quo harvest level of 450,000 pounds and, and 2) reducing the total harvest to 300,000 pounds or 100,000 pounds. These levels were suggested by the PDT as representing an option for a slightly reduced harvest and an option for a primarily bycatch fishery. The final scenario is based on a constant exploitation rates strategy, and considers 3 optional rates corresponding to 1) the replacement level suggested in the SPR analysis of F=0.3, 2) the 1995-1998 average of F=0.6, 3)a no harvest scenario of F=0. Given the reduced biomass of this stock, consideration of other alternatives such as fixed harvest levels greater than the current quota or fixed mortality levels corresponding to Fmsy are not appropriate at this time. Each alternative scenario is analyzed using both the stock-recruitment model and the stochastic recruitment model to select future recruitment. Results from both recruitment model assumptions are presented separately and then comparisons are made for the two approaches.

Before projections could be prepared a time frame needed to be established over which to project the stock. While it is becoming common in fisheries management at this time to base management plans on a 10 year schedule for reaching B_{msy}, for some stocks this is an unreasonable goal and other alternatives must be considered. To establish an appropriate time frame for the projections of this stock, the F=0 scenario was evaluated to determine how long it would take the stock to reach the interim biomass target of 4 million pounds and the Bmsy level of 6 million pounds. Projections based on the stock-recruitment recruitment relationship indicate that the stock could reach 4 million pounds in 11 years and 6 million pounds in 15 years. The stochastic approach indicated that neither 4 million pounds nor 6 million pounds will be reached. This is because the average observed recruitment of 3.5 million fish at the current low SSB levels (below 2.5 million pounds) is not sufficient to rebuild the stock to the 4 million pound threshold or even to 2.5 million pounds. Comparing these results from the two different methods of estimating future recruitment clearly illustrates the how the recruitment assumption affects projection outcomes. While the stochastic approach may best represent short-term changes in the population, it does not appear to represent long-term trends very well. Since the best available estimate of the minimum rebuilding time, or T_{min}, is 15 years, a 10 year maximum rebuilding time (T_{max}), is not appropriate. An alternative suggested in Restrepo et al (1998) is to base T_{max} on T_{min} plus one mean generation time. Using an equation developed by Goodyear (1995), the mean generation time for Chowan River blueback herring is 6 years. Added to the estimated T_{min} of 15 years, a suggested T_{max} value for this stock is 21 years. To encompass these time frames, projection scenarios are presented over a 30 year period.

Proposed management alternatives were first examined by predicting future recruitment from the Beverton-Holt stock-recruitment relationship. The projections are grouped by the overall management approach of either fixed harvest or fixed exploitation. The results for each level of harvest or exploitation rate are combined on a single graph to facilitate comparisons. A summary of the number of years it will take to reach the potential biomass targets of 4, 6, and 8 million pounds is provided in Table 15. These projections indicate that, for the fixed harvest levels considered, it will take between 11 and 17 years for the spawning stock biomass to reach the initial target of 4 million pounds, 16-30+ years to reach B_{msy} = 6 million pounds,,and 19-30+ years to reach 8 million pounds (Figure 23). Under all 3 fixed harvest options, growth in SSB is extremely slow in the first few years due to the effects of the poor cohorts that dominate the population at the present time. Fishing mortality will actually increase in the next few years if the current harvest is maintained, and will decrease slightly under either of the reduced harvest options (Figure 24). Since fixing the exploitation rate allows harvest to increase as the stock abundance increases, this strategy increases the time it will take to reach the biomass targets (Figure 25). The poor cohorts now in the population cause catches to decrease in the next few years for any of the fixed F rates considered. Recruitment values predicted by the model are higher than those observed over the last few years, so after around 2001 SSB and allowable harvest begin to increase. However, except for the F=0 option, the gains are considerably less than those suggested by the fixed harvest scenarios above. These scenarios indicate only minor differences in SSB for either the F=0 or the harvest=100,000 pounds alternatives. Also, by preventing increases in harvest as stock abundance increases, the fixed harvest scenarios offer the greatest probability of increased SSB.

The outlook for the stock is quite a bit different when based on the stochastic recruitment model. Observed recruitment when SSB is below 2.5 million pounds only averages 3.5 million fish. While this level of recruitment may maintain the stock at a very low abundance, as the projections show, it will not allow SSB to increase significantly under any harvest or exploitation rates. At least one recruitment event close to the long term average of 17 million fish is needed before the stock will begin to recover. Whereas the stock-recruitment relationship predicts gains in recruitment from any slight increases in SSB, the preponderance of poor recruitment events at the current low levels SSB prevents the stochastic model from predicting any real improvements in the stock. If harvest is fixed at 450,000 pounds, SSB will stabilize at less than one million pounds in a few years. For the other harvest levels, SSB will decrease somewhat before stabilizing at just over one million pounds for a harvest of 300,000 pounds and at around 1.5 million pounds for the bycatch harvest of 100,000 pounds (Figure 27). Fishing mortality will stabilize around the long-term average to sustain a 450,000 pound harvest, will decrease to about 0.4 for the 300,000 pound harvest, and will decrease to below 0.2 at the bycatch harvest (Figure 28). Trends in SSB observed from projecting fixed exploitation rates are similar to those for fixed harvest rates, with SSB stabilizing around 1.5 million pounds at F=0 and dropping to less than 1 million pounds for F=0.6 (Figure 29). The expected harvest under the fixed F rates will stabilize at around 250,000 pounds if F=0.3 and around 375,000 pounds if F=0.6 (Figure 30).

Potential yields expected from this stock in the coming years are overwhelmingly dependent on future recruitment. Although projections based on the stock-recruitment relationship suggest that SSB could improve in the near future, these results should be viewed with caution since recruitment over the last 10 years has been less than that predicted by the stock recruitment model. Therefore, the stochastic model may provide a more realistic representation of the conditions that can be expected. Over the next few years SSB will likely decrease as a series of poor cohorts move through the population. If this lower SSB results in continued poor recruitment, then SSB will continue to decline and it will be difficult to maintain current harvest levels without an increase in fishing mortality. Results from the stochastic model clearly indicated that recruitment must improve considerably before the stock will improve. However, reviewing the JAI values for the 1995-1998 cohorts offers little promise of a substantial increase in recruitment to age-3 over the next few years. Although the 1996 value approaches the 1986-1998 average, it is still far from the overall average of 83.5 and the 1972-1985 average of 149. Recovery times could increase significantly over the next few years if the stock continues to decline.

VII. Discussion

Exceptionally strong recruitment through much of the 1970's and early 1980's sustained the Chowan River stock of blueback herring in spite of very high fishing mortality. Much of the variability in landings, population abundance, and spawning stock biomass over this period can be attributed to trends in recruitment. Several poor year classes in succession during the mid-1980's could not support the high fishing mortality at that time and therefore the stock declined to historic low levels. By 1988 SSB dropped below an apparent threshold at 4 million pounds. Since then, recruitment has been at record low levels and the stock has shown no signs of recovery. Although catches have dropped, the low stock abundance has resulted in sustained high mortality through the mid-1990's that has kept the stock at very low levels and prevented any gains in SSB from the few slightly stronger year classes of the early 1990's.

This analysis suggests that the long term decline in landings is related to a decline in population abundance and that a fishing mortality rate averaging over 1 is not sustainable. It is apparent that sustained high exploitation has significantly reduced SSB over the last 25 years to the extent that current levels are insufficient to produce even moderate recruitment. The slight decrease in fishing mortality over the last 4 years has not changed the trend of declining SSB and poor recruitment. The stock is at such low abundance that any significant recovery seems unlikely in the next few years. Furthermore, stronger year classes such as that of 1993 are supporting current catch levels and therefore cannot make any real contribution to sustained population growth. While current management measures are decreasing exploitation rates somewhat, the average mortality remains above the long-term stock replacement rate. Stock-recruitment models suggest that the spawning stock biomass may need to increase to at least 2.5 million pounds and possibly to 4 million pounds before any real gains in recruitment may be expected. This represents a nearly 2 to 3-fold increase over current levels.

It has been suggested that excessive harvest of river herring by offshore fisheries are to blame for the decline in Albemarle Sound stocks since the 1980's. Harris and Rulifson (1991) investigated ocean landings of river herring and compared them to total domestic river herring landings from coastal rivers by attempting to separate riverine and state territorial seas landings from true offshore harvest. Results, reviewed for the NC MFC in Carmichael (MS), indicate that total 1978 – 1987 ocean landings of river herring ranged between 688 and 66 thousand pounds, accounting for 11 to 0.5% of the river herring landings. The range is somewhat misleading, since in most years ocean landings are around 2% of the total. The unusually high value of 11% observed in 1978 is attributed to low coast-wide landings and unusually high ocean landings in Massachusetts. States having significant ocean landings of river herring are Massachusetts, Virginia, New York, and North Carolina, with the harvest taken as bycatch in other fisheries. Other known sources of blueback harvest are not included in the coastal statistics. For example, blueback herring migrate as far North as the Bay of Fundy, and are thus vulnerable to further harvest by Canadian fisheries. Other losses can be attributed to both joint-venture and directed foreign vessel fisheries which harvest some blueback herring as bycatch, mostly in Atlantic Mackerel fisheries. At the time of the Harris and Rulifson report, these fisheries were limited to 220,000 pounds of river herring, and between 1981 and 1989 bycatch in these fisheries ranged between 16 and 220 thousand pounds. While much of the decline in river herring stocks along the Atlantic Coast during the 1970's has been attributed to offshore fisheries (Street and Davis 1976, Rulifson et al. 1987, Crecco and Gibson 1990, Hightower et al. 1996), given the low landings in offshore fisheries as compared to domestic directed fisheries since the 1980's and the fact that such fisheries are harvesting both alewife and blueback herring from many different stocks, it seems unlikely that ocean landings of river herring contributed significantly to the harvest of Chowan River blueback herring during the 1980's. Furthermore, in light of continued excessive exploitation by directed fisheries within Albemarle Sound, it seems unlikely that offshore fisheries are the primary cause of the continued low abundance of Chowan River blueback herring.

A major source of uncertainty in this assessment is the total harvest. The harvest used to construct the catch at age analysis includes only landings in the Chowan River pound net fishery. Landings from other fisheries that harvest blueback herring from this stock, such as the gill net fishery in Albemarle Sound and the recreational fishery in inland waters, are not included. Because pound nets are a non-selective gear and the pound net fishery accounts for 95% of the total known harvest, estimates of mortality rate should not be especially biased by the omission of some landings. However, indicators of absolute abundance, such as recruitment and spawning stock biomass, may be underestimated to some unknown extent. This bias will also be reflected in estimates of MSY. Again, since the pound net fishery dominates harvest of this stock, the amount of bias should be fairly low.

Previous assessments of this stock, also based on landings from the Chowan River pound net fishery, have reported exploitation rates similar to those in this analysis. Crecco and Gibson (1990) used models based on stock-recruitment parameters to estimate an average F for 1983-1987 of 1.1. In a CAGEAN catch at age model covering 1972-1995, Schaaf (1998) reported an average F for 1972-1995 of 1.17. That report also noted a truncated age structure, that both SSB and recruitment had declined substantially since the 1970's, and that fishing moralities in excess of F_{msy} continued to jeopardize the stock. Schaaf reported a drop in fishing mortality for 1995 as a result of seasons restrictions and harvest quotas. According to this analysis, that trend continues through 1998.

Results of the yield per recruit analysis do not appear especially useful, due primarily to F_{max} being undefined and the high exploitation rates associated with $F_{0.1}$ and the SPR references such as $F_{40\%}$ and $F_{30\%}$. Given the fact that this stock declined sharply when fishing mortality was sustained at around F=0.8, these reference values appear excessive. There are several possible explanations for the high YPR reference point estimates. The weight at age does not increase very much between the ages of 3 and 9, so much of the biomass is tied up in younger ages that have low selectivity (and thus are not fully exploited by the fishery) and high exploitation rates that remove most of the older fish do not therefore result in a large decline in SSB per recruit. Since natural mortality is high, few recruits reach the older ages even if F=0. Thus the fairly low virgin spawning stock biomass per recruit coupled with low selectivity of younger fish and little increase in weight at age for older ages prevents increasing fishing mortality from drastically reducing overall SSB. This makes the stock appear to be able to support quite high levels of fishing mortality without a strong decline in biomass. YPR results would perhaps differ if the analysis of MSP was based on fecundity, rather than biomass. Crecco and Gibson (1990) suggest that the high fecundity of blueback herring may enable herring to support much higher fishing mortality than American shad. As support of this theory, they cite the fact that American shad and blueback herring have roughly the same lifetime fecundity, yet shad outweigh herring by an order of magnitude. However, in the Thompson-Bell YPR analysis presented by Crecco and Gibson (1990), both YPR and biomass per recruit fail to reach clear asymptotes. Another difficulty with YPR analysis for this stock is the clear presence of a stock-recruitment relationship. Often, if a stock is dominated by the SRR, YPR analysis is misleading. When there is a relationship between recruitment and stock abundance, F_{max} is larger than the fishing mortality that produces MSY, unless strong density dependence exists (Deriso 1987). The stock-recruitment plot for this stock indicates a clear lack of density dependence. Another limitation of yield per recruit theory is that it does not take stock-recruitment information into account (Deriso 1987, Hilborn and Walters 1992), and growth-overfishing references such as F_{max} and $F_{0.1}$ must be evaluated within the context of the demands such references could place on the potential reproductive output.

Combining stock-recruitment information with the YPR results suggests that, if future management strategies are based on YPR estimated growth overfishing reference points, the stock could be overexploited. As shown by Deriso (1987) and Hilborn and Walters (1992), the strong stock-recruitment relationship exhibited by this stock must be taken into consideration when developing management strategies. Given the past recruitment history, fishing mortality must be held below 0.3 to achieve replacement. Furthermore, since this value is based on the entire series of observed recruitment values, if the current trend of lower than expected recruitment continues even F=0.3 may be excessive.

Although biomass dynamic models are a powerful tool for analyzing abundance data and provide a means of estimating MSY, there are some drawbacks associated with the model structure. Biomass models perform best when there is significant contrast in the catch and effort data series, but most stocks exhibit a "one-way trip" of declining catches (Hilborn and Walters, 1992). This data series is no different, for there is no period of stock growth for the model to compare with the period of stock decline to generate reliable estimates of the growth parameter and carrying capacity. A bothersome feature of the biomass model fit to this stock is its tendency to interpret increased CPUE in recent years as corresponding to an increase in overall biomass. Given the conflicting evidence in the available indices of abundance and the catch at age model, it is difficult to place much confidence in this result. Since the model is fit to CPUE data, it is possible that bias in that information are somewhat responsible for the suggested trends in biomass. Estimates of CPUE for this fishery have received significant criticism, due both to changes in regulations and changes in fishermen's behavior (e.g. setting, but not fishing, nets due to "use it or lose it" clauses). It is possible that the increase in CPUE is the result of changing regulations, the passive nature of the pound net gear, and the significant decrease in overall effort. In most fisheries the gear must "find" the fish so if the abundance of fish decreases then they become more difficult to locate. The theory that a declining stock will be more difficult to catch and lead to decreased catch for increasing effort is one of the foundations of CPUE analysis. However, being an anadromous species that spawns in a relatively small area and migrates along a single path, even a decreasing population of blueback herring likely remains quite vulnerable to the gear. And since the total number of nets has decreased by 2 orders of magnitude, it is possible that there is much less competition between nets, and that the remaining nets are placed in the best locations. Under such conditions, it is not surprising that each given net can still account for considerable catches. Given the simplistic nature of the biomass dynamic approach, the lack of adequate contrast in the history of the fishery, the nature of the fishery, and the contrasting results of other population models, it seems likely that the increase in predicted biomass is an artifact of the available data and not representative of the actual stock biomass. Thus, it is very likely that CPUE in recent years is not proportional to biomass. One possible solution for future assessments is to fit the biomass model with either the JAI or the gill net survey data as indices of abundance, or to configure it to evaluate all the available indices together.

The equilibrium-based approaches to estimating MSY provide results that are quite a bit different than those from the biomass model. However, it is encouraging that the two recruitment assumptions estimate similar values for MSY, F_{msy} and B_{msy}. This is largely because both methods estimate about the same average recruitment at higher stock sizes. The equilibrium models may provide better estimates of future yield and target exploitation rates since they are more closely related to observed recruitment. Also, as noted above, there are several data caveats associated with the biomass model that make those results potentially less reliable.

Other assessments of this stock have also attempted to estimate MSY. According to the analysis prepared by Crecco and Gibson (1990), an MSY of 7 million pounds is possible from the entire Albemarle Sound stock, harvested at $F_{msy} = 1.1$. However, this estimated exploitation rate is apparently excessive given results of the age-structured catch curve and catch at age models that indicate that the stock declined substantially when exploitation exceeded 1. Hightower et al. (1996) used a biomass dynamic model applied to a series of CPUE data dating back to the mid 1800's and estimated MSY for the Albemarle Sound stock at 12.7 million pounds. This estimate is significantly larger than that suggested by this assessment, however, much of the difference is likely attributable to their analysis including landings of both alewife and blueback landings throughout the system. Moreover, the authors point out that historical yields of this magnitude may not be feasible under present conditions. In comparing his results to those of Hightower et al., Schaaf (1998) noted that blueback herring from the Chowan River pound net fishery accounted for around 48% of the total Albemarle Sound river herring landings. Applying this correction factor reduces the potential pound net MSY to 6 million pounds, still nearly 3 times the estimate of the current biomass model. However, much of the discrepancy in the estimates is related to the predicted carrying capacity of the stock, since the Fmsy of suggested by the two approaches is very similar. Schaaf's (1998) estimates of MSY and Fmsy, at 2.3 million pounds and F=0.8, are similar to the estimates provided in this assessment.

Projections of future fishing mortality and catch levels clearly indicate that little improvement in the stock can be expected until recruitment improves. Also, regardless of the level of harvest or exploitation, a series of poor cohorts will move through the population in the next few years and SSB will decline through at least the year 2000. How SSB responds in 2001 and beyond will depend on the level of exploitation and whether future recruitment improves or stays at the current average. Comparing the two alternative approaches to predicting future recruitment shows that the stock-recruitment model predicts steady increases in recruitment and SSB if the exploitation does not exceed F=0.3 or the harvest does not exceed 450,000 pounds. Conversely, the stochastic model based on observed recruitment suggests that neither recruitment nor SSB will improve until a year class of at least average strength occurs. Also, for harvest levels greater than 300,000 pounds and exploitation rates greater than F=0, it is possible that the long-term SSB will stabilize below the current level.

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Table 1. NC River herring landings and Chowan River pound net landings, 1972-1998.

Year	Total River Herring pounds	Total Blueback pounds	Total Pound net pounds	Percent Pound net landings	Mean weight pounds	Percent Blueback sampled	Total Catch numbers
1972	10,594,117	8,231,629	8,032,839	0.758	0.4042	0.78	20,363,410
1973	7,350,578	5,792,255	5,759,159	0.783	0.4172	0.79	13,884,518
1974	5,736,905	4,819,000	4,735,300	0.825	0.3969	0.84	12,142,629
1975	5,031,756	2,666,831	2,633,461	0.523	0.3660	0.53	7,285,468
1976	5,734,776	4,817,212	4,791,389	0.835	0.3974	0.84	12,120,866
1977	7,418,218	7,121,489	7,001,059	0.944	0.4261	0.96	16,714,989
1978	5,615,113	4,323,637	4,050,767	0.721	0.4429	0.77	9,763,117
1979	4,303,663	2,194,868	2,118,907	0.492	0.4460	0.51	4,921,447
1980	5,382,954	3,498,920	3,388,983	0.630	0.4593	0.65	7,617,644
1981	3,314,447	2,088,102	2,041,319	0.616	0.4789	0.63	4,359,843
1982	7,459,968	5,445,777	5,388,115	0.722	0.4354	0.73	12,507,282
1983	4,405,915	2,423,253	2,380,262	0.540	0.4069	0.55	5,956,053
1984	4,561,503	3,247,790	3,205,420	0.703	0.3589	0.71	9,049,529
1985	8,871,391	6,830,971	6,757,805	0.762	0.3768	0.77	18,130,028
1986	5,767,874	4,487,406	4,344,802	0.753	0.3986	0.78	11,257,649
1987	2,334,719	1,774,386	1,773,684	0.760	0.3695	0.76	4,801,701
1988	2,259,888	1,310,735	1,296,041	0.573	0.3475	0.58	3,771,004
1989	908,145	581,213	580,844	0.640	0.3536	0.64	1,643,806
1990	710,849	489,064	488,746	0.688	0.3792	0.69	1,277,173
1991	1,202,535	1,031,775	870,348	0.724	0.3354	0.86	3,075,916
1992	1,135,340	804,956	804,956	0.709	0.3533	0.71	2,278,148
1993	801,115	567,991	567,282	0.708	0.3635	0.71	1,562,613
1994	390,852	390,852	385,437	0.986	0.2774	1.00	1,408,922
1995	280,681	280,681	268,534	0.957	0.3379	1.00	830,610
1996	404,884	404,884	398,476	0.984	0.3843	1.00	1,053,594
1997	201,928	201,928	191,991	0.951	0.4264	1.00	473,548
1998			368,667		0.3340	1.00	1,101,362

Table 2. Number of blueback herring at age landed in the Chowan River pound net fishery,1972-1998.

YEAR \ AGE	3	4	5	6	7+	Sum (3-9)
1972	3,463,302	7,728,025	6,517,914	2,352,378	301,791	20,363,410
1973	609,732	4,553,269	4,929,395	3,254,753	537,369	13,884,518
1974	125,560	4,886,185	4,330,173	2,538,488	262,223	12,142,629
1975	190,280	4,958,701	1,923,176	198,798	14,513	7,285,468
1976	354,726	6,144,407	4,654,402	805,114	162,217	12,120,866
1977	0	4,384,858	10,078,202	1,816,140	435,789	16,714,989
1978	260,665	3,444,138	5,021,707	763,513	273,094	9,763,117
1979	209,628	1,072,062	2,209,701	1,171,851	258,205	4,921,447
1980	40,901	1,697,287	2,861,666	2,018,912	998,878	7,617,644
1981	19,580	920,821	1,671,494	1,030,063	717,885	4,359,843
1982	1,027,384	5,918,199	2,801,163	1,573,438	1,187,098	12,507,282
1983	448,603	3,035,315	2,080,419	351,876	39,840	5,956,053
1984	1,054,265	4,013,551	3,346,091	635,622	0	9,049,529
1985	573,864	2,511,223	10,317,409	4,554,865	172,667	18,130,028
1986	245,195	2,703,555	5,014,043	2,974,390	320,466	11,257,649
1987	261,620	2,583,543	1,303,999	538,213	114,326	4,801,701
1988	529,807	2,259,583	778,316	156,093	47,205	3,771,004
1989	209,553	924,866	425,759	83,628	0	1,643,806
1990	407,126	560,133	252,362	51,261	6,291	1,277,173
1991	786,731	1,371,874	711,753	166,948	38,610	3,075,916
1992	78,672	1,317,041	691,089	179,035	12,311	2,278,148
1993	66,024	262,210	898,560	282,730	53,089	1,562,613
1994	254,389	643,723	393,400	100,637	16,773	1,408,922
1995	23,644	323,960	446,828	22,888	13,290	830,610
1996	103,564	373,949	387,701	145,665	42,715	1,053,594
1997	65,398	184,069	138,230	77,543	8,308	473,548
1998	38,060	352,055	580,415	102,286	28,545	1,101,362

Table 3. Sampling intensity.

YEAR	Ages	Length's	landings pounds	Weight's	len/200mt	age/200t
1972	412	862	8,032,839	863	43	21
1973	333	806	5,759,159	0	56	23
1974	232	579	4,735,300	0	49	20
1975	148	501	2,633,461	0	76	22
1976	217	467	4,791,389	0	39	18
1977	118	421	7,001,059	0	24	7
1978	200	379	4,050,767	0	37	20
1979	331	434	2,118,907	0	82	62
1980	371	455	3,388,983	0	54	44
1981	345	668	2,041,319	668	131	68
1982	141	245	5,388,115	244	18	10
1983	171	299	2,380,262	299	50	29
1984	133	240	3,205,420	240	30	17
1985	129	210	6,757,805	210	12	8
1986	118	198	4,344,802	198	18	11
1987	132	210	1,773,684	210	47	30
1988	136	247	1,296,041	247	76	42
1989	77	131	580,844	131	90	53
1990	133	205	488,746	205	168	109
1991	127	209	870,348	209	96	58
1992	164	293	804,956	293	146	81
1993	82	130	567,282	130	92	58
1994	71	84	385,437	84	87	74
1995	79	125	268,534	125	186	118
1996	82	109	398,476	109	109	82
1997	75	114	191,991	114	238	156
1998	464	464	368,667	115	503	503

Table 4. Weight at age in pounds, 1972-1998.

YEAR\ AGE	2	3	4	5	6	7	8	9	Annual
1972		0.3787	0.3940	0.4211	0.4259	0.4337			0.4042
1973		0.3228	0.3735	0.4285	0.4708	0.4797	0.4746		0.4172
1974		0.3164	0.3569	0.4080	0.4476	0.5011			0.3969
1975		0.3229	0.3477	0.4061	0.4610	0.5678	0.5678	0.5678	0.3660
1976		0.3626	0.3686	0.4126	0.5145	0.5487			0.3974
1977			0.3825	0.4285	0.4909	0.5223	0.5853		0.4261
1978		0.4043	0.4314	0.4558	0.4533	0.5600			0.4429
1979		0.3552	0.4041	0.4519	0.4779	0.4948	0.5779		0.4460
1980		0.4044	0.4106	0.4431	0.4828	0.5374	0.5759		0.4593
1981		0.2728	0.4141	0.4603	0.5059	0.5567	0.5995	0.6655	0.4789
1982		0.3459	0.3987	0.4493	0.5084	0.5585	0.5831	0.7496	0.4354
1983		0.3446	0.3839	0.4291	0.5284	0.5530	0.6944		0.4069
1984		0.2972	0.3345	0.3898	0.4528				0.3589
1985		0.3036	0.3432	0.3724	0.4094	0.5115			0.3768
1986		0.3019	0.3475	0.4055	0.4293	0.5101			0.3986
1987		0.3121	0.3383	0.3978	0.4546	0.4826			0.3695
1988	0.2646	0.2996	0.3332	0.3865	0.4749	0.5051			0.3475
1989		0.2850	0.3214	0.3968	0.4503				0.3536
1990	0.2260	0.3401	0.3859	0.4043	0.5006	0.6173			0.3792
1991		0.2804	0.3276	0.4134	0.5374	0.6327			0.3354
1992		0.2860	0.3365	0.3763	0.4101	0.4722			0.3533
1993		0.2972	0.3361	0.3611	0.3986	0.4353			0.3635
1994		0.2390	0.2556	0.2839	0.4533	0.4905			0.2774
1995		0.3126	0.3156	0.3442	0.4401	0.5420			0.3379
1996		0.2602	0.3474	0.4120	0.4651	0.4815			0.3843
1997		0.2710	0.3407	0.5232	0.5572	0.7165			0.4264
1998		0.263	0.301	0.3425	0.4127	0.4887			0.3616
mean	0.2453	0.3146	0.3567	0.4076	0.4672	0.5280	0.5823	0.6610	0.3900

Table 5. Chowan River pound net effort, 1972-1998.

YEAR	Maximum Number of Pound Nets	Weeks Fished	Total Effort in pound net-weeks	Pound Net Catch	CPUE pounds per pound net week
1972			4387	8,032,839	1831
1973			4387	5,759,159	1313
1974			4387	4,735,300	1079
1975			4387	2,633,461	600
1976			4387	4,791,389	1092
1977	624	9	4854	7,001,059	1442
1978	383	10	3645	4,050,767	1111
1979	502	12	4996	2,118,907	424
1980	500	9	3090	3,388,983	1097
1981	525	10	4120	2,041,319	495
1982	480	11	4461	5,388,115	1208
1983	486	12	4895	2,380,262	486
1984	480	12	5040	3,205,420	636
1985	421	12	3708	6,757,805	1822
1986	451	12	4241	4,344,802	1024
1987	501	11	4969	1,773,684	357
1988	506	12	4689	1,296,041	276
1989	348	9	3063	580,844	190
1990	360	11	3077	488,746	159
1991	226	11	2037	870,348	427
1992	180	12	1669	804,956	482
1993	197	11	1729	567,282	328
1994	175	8	1173	385,437	329
1995	73	8	484	268,534	555
1996	95	10	555	398,476	718
1997	102	5	461	191,991	416
1998	75	11	463	368,667	796

Table 6. Blueback herring JAI, 1972-1998.

Year	JAI
1972	320.46
1973	362.93
1974	83.27
1975	123.36
1976	157.36
1977	103.20
1978	77.33
1979	174.12
1980	222.63
1981	1.00
1982	68.94
1983	228.67
1984	18.87
1985	139.69
1986	13.78
1987	25.05
1988	10.95
1989	0.02
1990	9.16
1991	21.75
1992	0.93
1993	67.30
1994	0.00
1995	1.18
1996	14.87
1997	7.24
1998	0.44

Table 7. Trawl survey CPUE of blueback herring, 1972-1998.

Year	Trawl Survey catch per tow JAI
1972	10.84
1973	37.93
1974	7.14
1975	37.29
1976	11.43
1977	11.76
1978	42.96
1979	2.00
1980	16.00
1981	0.00
1982	38.90
1983	13.90
1984	3.80
1985	0.20
1986	8.90
1987	14.70
1988	1.90
1989	0.20
1990	27.60
1991	4.86
1992	0.05
1993	39.10
1994	0.38
1995	0.09
1996	107.80
1997	90.50
1998	0.09

Table 8. Estimated male, female, and combined maturation schedules. Based on analysis of spawning marks data.

Age	Male Maturation Proportion	Female Maturation Proportion	Combined Sexes Maturation Proportion
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.06	0.06	0.13
4	0.26	0.62	0.48
5	0.67	0.98	0.84
6	0.92	1.00	0.97
7	1.00	1.00	1.00
8	1.00	1.00	1.00

Table 9. Estimated abundance at age in numbers.

Year	3	4	AGE 5	6	7+	Sum (3-9)
1972	36,795,624	28,798,514	16,672,272	4,750,183	589,320	87,605,913
1973	24,034,931	21,772,509	11,177,253	4,405,903	1,184,311	62,574,908
1974	22,761,949	14,221,821	8,450,327	2,953,760	1,239,919	49,627,775
1975	45,020,187	13,468,578	5,519,760	2,233,128	930,165	67,171,818
1976	46,654,508	26,639,104	5,227,413	1,458,681	701,624	80,681,329
1977	22,475,197	27,606,156	10,339,145	1,381,424	479,159	62,281,081
1978	14,191,138	13,298,903	10,714,477	2,732,277	412,680	41,349,476
1979	17,930,820	8,397,104	5,161,558	2,831,464	697,557	35,018,504
1980	7,995,680	10,609,929	3,259,077	1,364,021	782,743	24,011,449
1981	39,042,168	4,731,161	4,117,916	861,261	476,156	49,228,662
1982	15,509,974	23,101,823	1,836,254	1,088,222	296,641	41,832,914
1983	34,505,451	9,177,479	8,966,259	485,258	307,165	53,441,612
1984	61,538,503	20,417,381	3,561,955	2,369,471	175,761	88,063,071
1985	13,192,858	36,413,234	7,924,376	941,301	564,537	59,036,305
1986	9,294,383	7,806,407	14,132,672	2,094,137	333,997	33,661,597
1987	7,428,827	5,499,623	3,029,816	3,734,775	538,564	20,231,604
1988	2,766,887	4,395,745	2,134,509	800,675	947,834	11,045,650
1989	3,383,141	1,637,207	1,706,073	564,077	387,822	7,678,320
1990	11,346,622	2,001,854	635,431	450,856	211,133	14,645,896
1991	6,886,841	6,713,962	776,958	167,922	146,830	14,692,513
1992	2,178,998	4,075,045	2,605,817	205,323	69,813	9,134,996
1993	4,305,927	1,289,345	1,581,603	688,627	61,026	7,926,527
1994	3,275,457	2,547,880	500,420	417,963	166,274	6,907,994
1995	2,625,339	1,938,136	988,881	132,244	129,585	5,814,184
1996	5,649,977	1,567,311	883,050	352,186	83,347	8,535,872
1997	3,438,378	3,353,215	642,141	258,093	109,135	7,800,962
1998	3,148,964	2,071,734	1,804,941	311,883	170,197	7,507,720

Table 10. Estimated fishing mortality rate and confidence intervals.

Year	F	90% Confidence Interval	Total Annual Exploitation Rate	Fishing Annual Exploitation Rate
1972	1.01	0.82-1.20	78%	52%
1973	1.01			
1974	1.01			
1975	1.01			
1976	1.01			
1977	1.01			
1978	1.01			
1979	1.01			
1980	1.01			
1981	1.01			
1982	1.01			
1983	1.01			
1984	1.01			
1985	1.01			
1986	1.01			
1987	1.01			
1988	1.01			
1989	1.01			
1990	1.01			
1991	1.01			
1992	1.01			
1993	1.01			
1994	1.01			
1995	0.64	0.16 – 1.12	68%	38%
1996	0.88	0.50 – 1.26	75%	48%
1997	0.27	0 – 0.79	54%	19%
1998	0.58	0.27 – 0.90	66%	35%

Table 11. Spawning stock biomass and recruitment by cohort based on catch at age analysis.

Year	SSB Pounds	Recruits by cohort (est. at age-3)
1969		37.775
1970		24.020
1971		22.860
1972	14,658,461	45.502
1973	11,236,314	47.762
1974	8,337,979	22.041
1975	7,623,870	14.572
1976	9,343,361	17.704
1977	10,089,414	8.240
1978	8,015,481	39.088
1979	5,642,241	15.638
1980	4,334,143	34.926
1981	4,520,098	62.451
1982	5,869,962	12.757
1983	6,483,093	9.935
1984	8,439,608	7.336
1985	10,217,910	2.705
1986	7,718,047	3.438
1987	4,294,360	11.43
1988	2,515,429	6.908
1989	1,489,283	2.242
1990	1,360,700	4.273
1991	1,857,395	3.231
1992	1,813,063	2.584
1993	1,290,451	4.985
1994	1,028,607	3.055
1995	914,848	3.016
1996	1,014,317	
1997	1,114,928	
1998	1,345,225	

Table 12. Yield-per-recruit analysis for blueback herring.

Based on the Thompson-Bell method, M=0.5, 1972-1998 mean weights, catch at age estimated selectivity, and maturation estimated from spawning marks.

F	Yield	SSB	Biomass	YPR	SSB/R	B/R	% MSP	Reference point
0	0.00	524.5	937.27	0.000	0.525	0.937	100.0%	
0.05	18.39	491.8	903.65	0.018	0.492	0.904	93.8%	
0.1	33.85	463.1	874.12	0.034	0.463	0.874	88.3%	
0.2	58.14	415.7	825.03	0.058	0.416	0.825	79.3%	
0.3	76.09	378.5	786.22	0.076	0.379	0.786	72.2%	F70%
0.4	89.77	348.8	755.05	0.090	0.349	0.755	66.5%	
0.5	100.50	324.8	729.60	0.100	0.325	0.730	61.9%	F60%
0.6	109.13	305.0	708.51	0.109	0.305	0.709	58.2%	
0.7	116.25	288.6	690.78	0.116	0.289	0.691	55.0%	
0.8	122.25	274.7	675.68	0.122	0.275	0.676	52.4%	
0.9	127.38	262.8	662.66	0.127	0.263	0.663	50.1%	F50%
1	131.86	252.6	651.30	0.132	0.253	0.651	48.1%	
1.1	135.80	243.6	641.31	0.136	0.244	0.641	46.4%	F0.1
1.2	139.31	235.7	632.42	0.139	0.236	0.632	44.9%	
1.3	142.48	228.7	624.46	0.142	0.229	0.624	43.6%	
1.4	145.35	222.5	617.27	0.145	0.222	0.617	42.4%	
1.5	147.98	216.8	610.74	0.148	0.217	0.611	41.3%	
1.6	150.39	211.7	604.77	0.150	0.212	0.605	40.4%	F40%
1.7	152.63	207.0	599.29	0.153	0.207	0.599	39.5%	
1.8	154.71	202.8	594.22	0.155	0.203	0.594	38.7%	
1.9	156.65	198.8	589.53	0.157	0.199	0.590	37.9%	
2	158.46	195.2	585.16	0.158	0.195	0.585	37.2%	
2.5	166.13	180.4	567.05	0.166	0.180	0.567	34.4%	
3	172.13	169.6	553.34	0.172	0.170	0.553	32.3%	
3.5	177.03	161.3	542.47	0.177	0.161	0.542	30.7%	F30%

Table 13 Estimated MSY, B_{msy}, F_{msy}, and SSB_{msy} for the various population models.

Method	MSY million pounds	Fmsy	SSBmsy million pounds
Equilibrium/Beverton-Holt SRR	1.7	0.6	4.9
Equilibrium/Stochastic Recruitment	1.9	0.6	5.2
Biomass Dynamic Model	2.8	.21[1]	7.5[2]
Mean	2.1	.47	5.8

1. Based on conversion of the estimated annual exploitation to an instantaneous exploitation for compatibility with the other estimates.
2. Based on adjustment of total stock biomass of 15 million pounds.

Table 14. Estimated MSY, Bmsy, Fmsy, and associated 95% confidence intervals for the stochastic estimation.

Parameter	Value	95% ci Upper Bound	95% ci Lower Bound
MSY (million pounds)	1.9	2.30	1.28
Fmsy	0.6		
Biomass at MSY (million pounds)	5.21	6.22	4.21
Recruits at MSY	14,954,938	15,810,311	8,953,910

Table 15. Estimated length of recovery to various biomass targets under the fixed harvest and fixed exploitation strategies.

Values are based on the Beverton-Holt stock-recruitment model projections.

Strategy	Time in Years to Reach Recovery Target: 4 million pounds	6 million pounds	8 million pounds
Fixed Harvest			
450,000 pounds	17	22	25
300,000 pounds	14	19	24
100,000 pounds	11	16	21
Fixed Exploitation Rate			
F=0.6	29	30+	30+
F=0.3	16	26	30+
F=0.0	11	15	19

Figure 1. Chowan River blueback herring pound net landings in pounds, 1972-1998

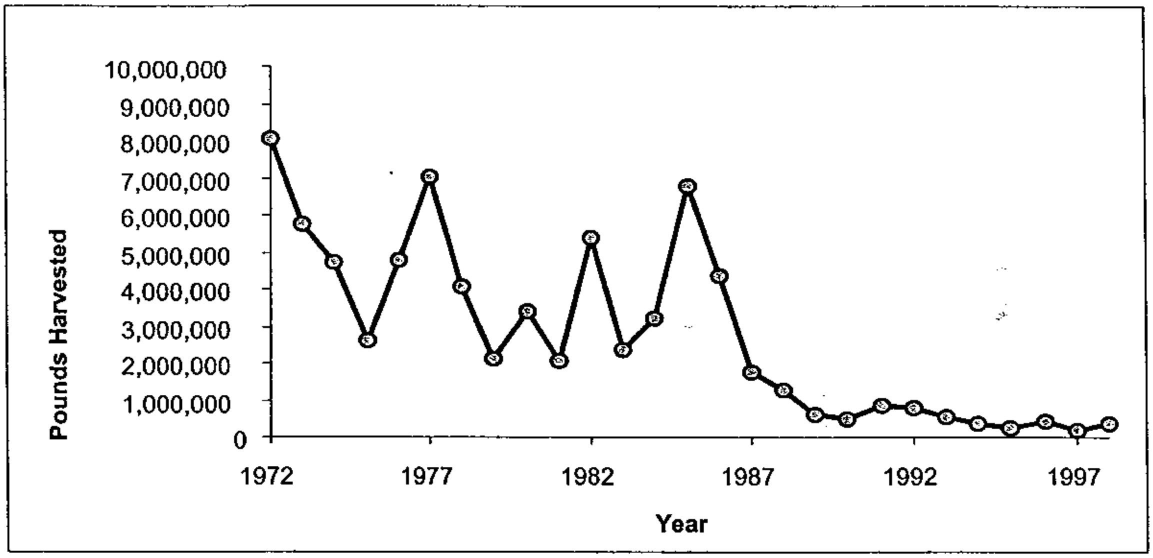


Figure 2. Pound net fishery catch, effort, and CPUE 1972-1998.

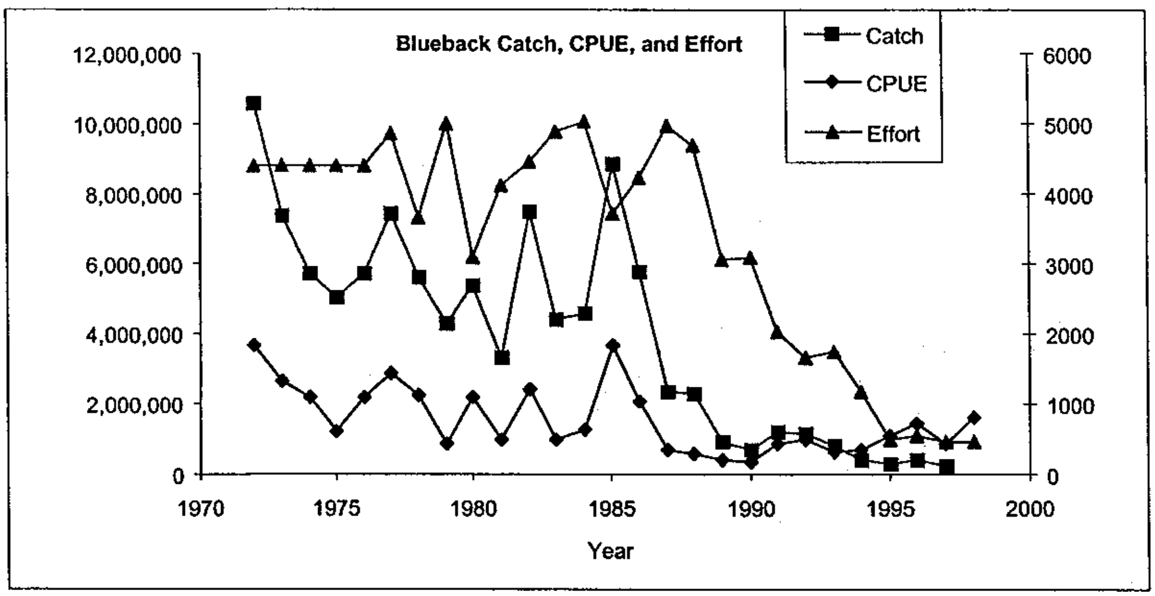


Figure 3. Albemarle Sound blueback herring JAI 1972-1998.

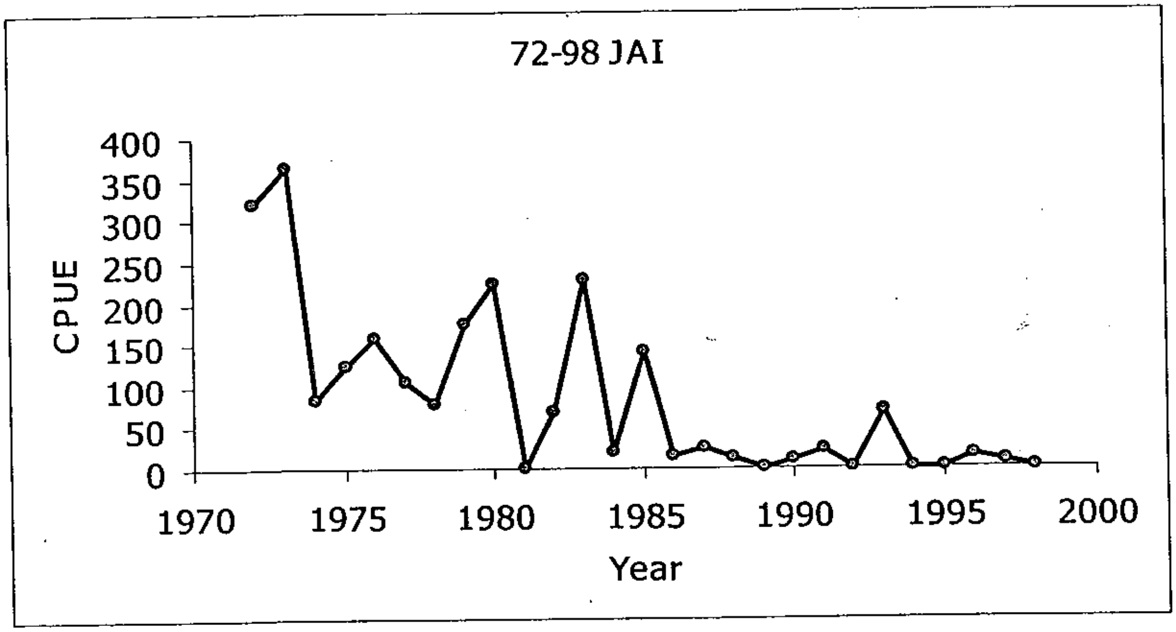


Figure 4. Total mortality estimates from annual catch curves.

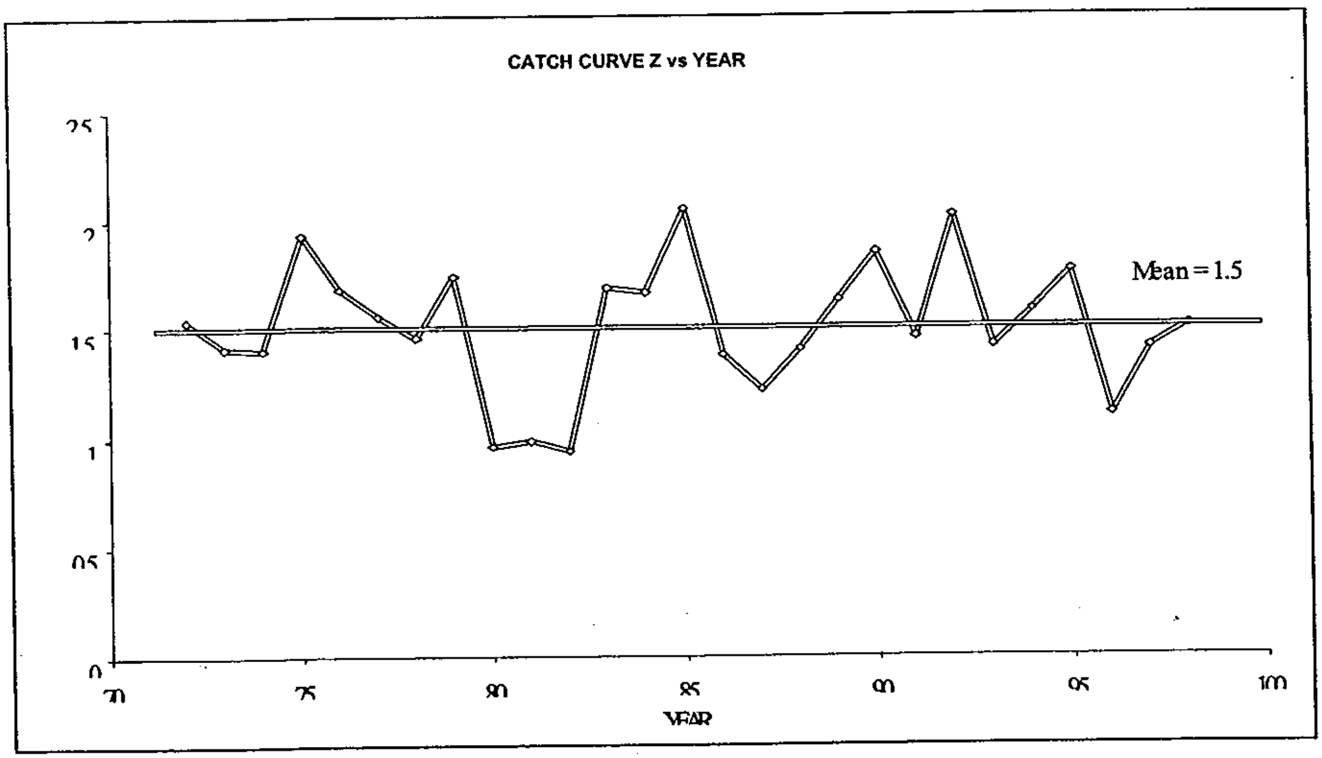


Figure 5. Plot by fishing year of cohort based catch curves. Each curve follows an individual cohort from recruitment to elimination from the population.

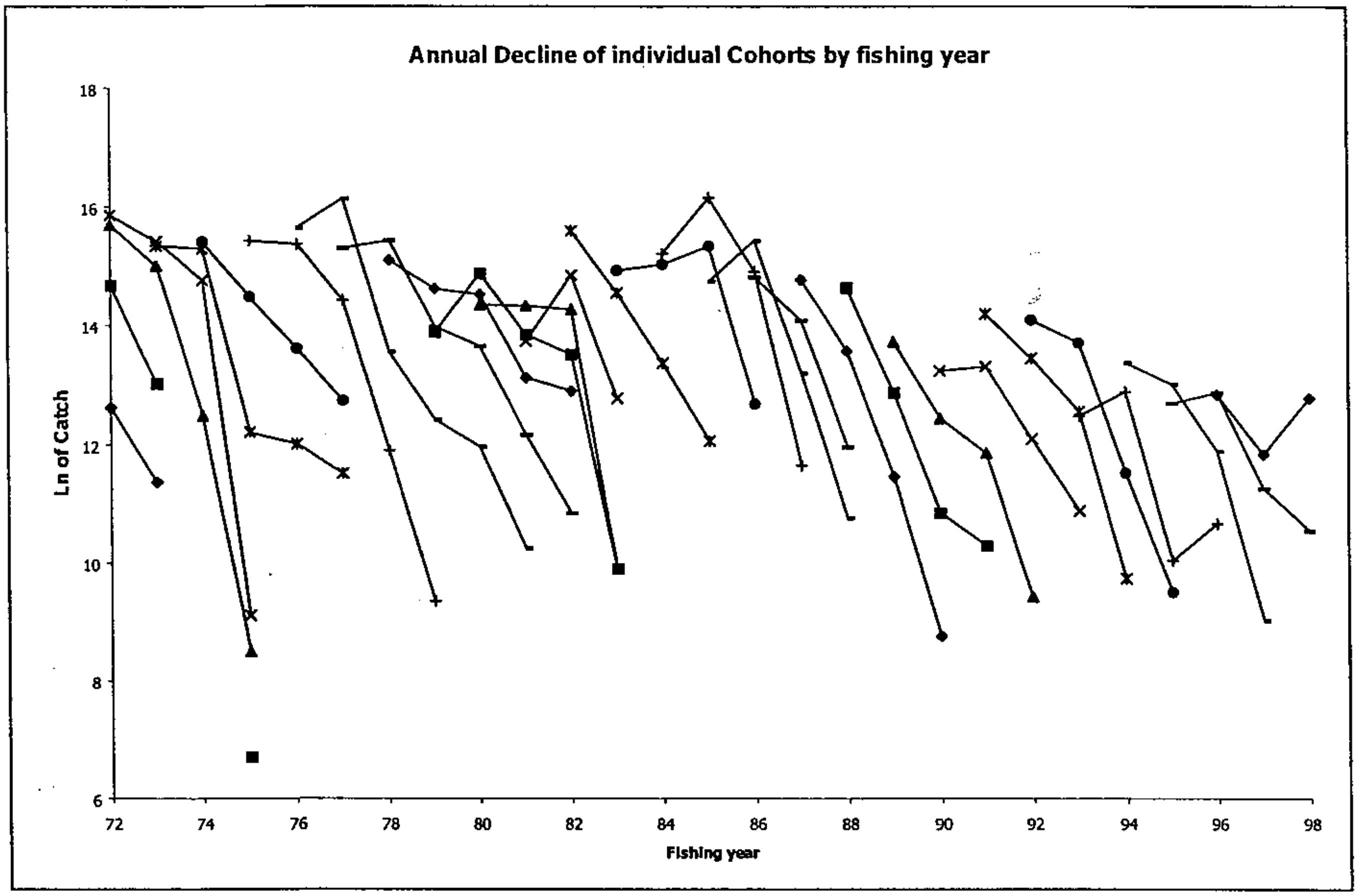


Figure 6. Mean and annual total mortality estimates from cohort catch curves

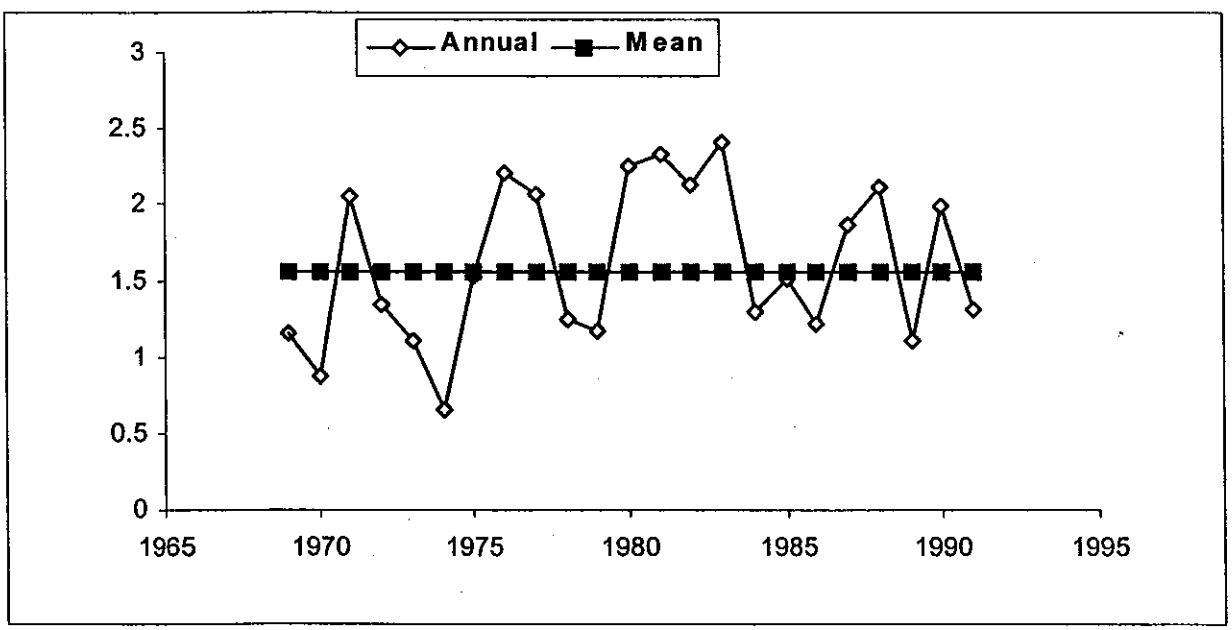


Figure 7. Plot of logarithmic mean catch at age for the 1990-1992 cohorts vs. the 1983 cohorts.

The line represents y=x, the expected slope if exploitation were equivalent in the two periods, and the points represent the ln of catch at age for 1990-1992 cohorts.

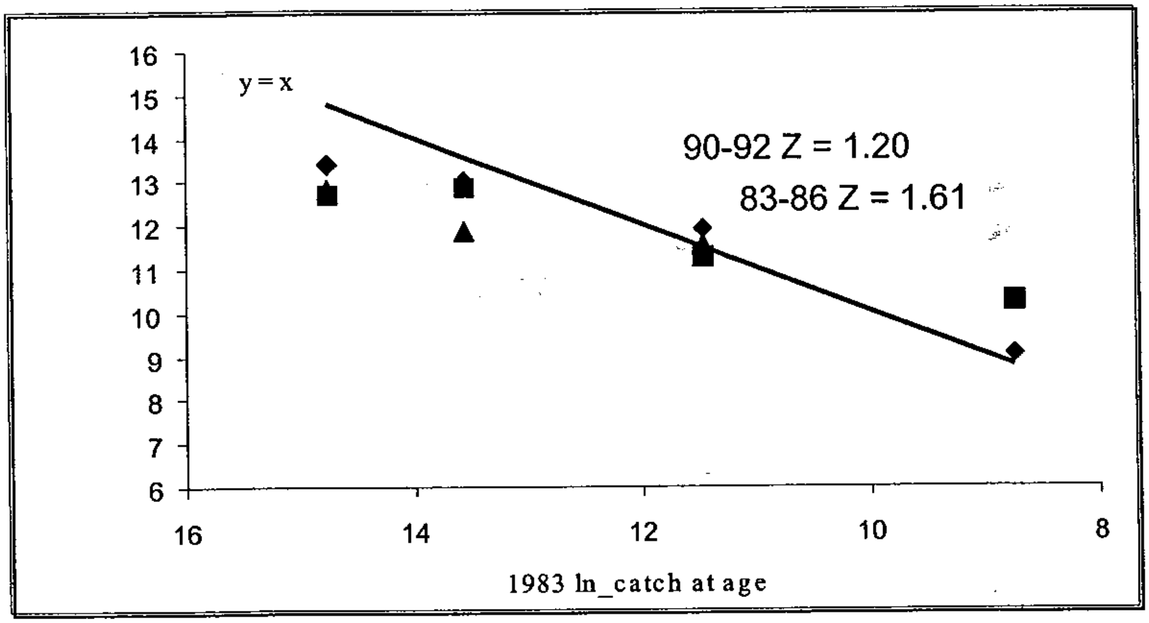


Figure 8. Observed catch and catch-age model predicted catch in pounds for 1972-1998.

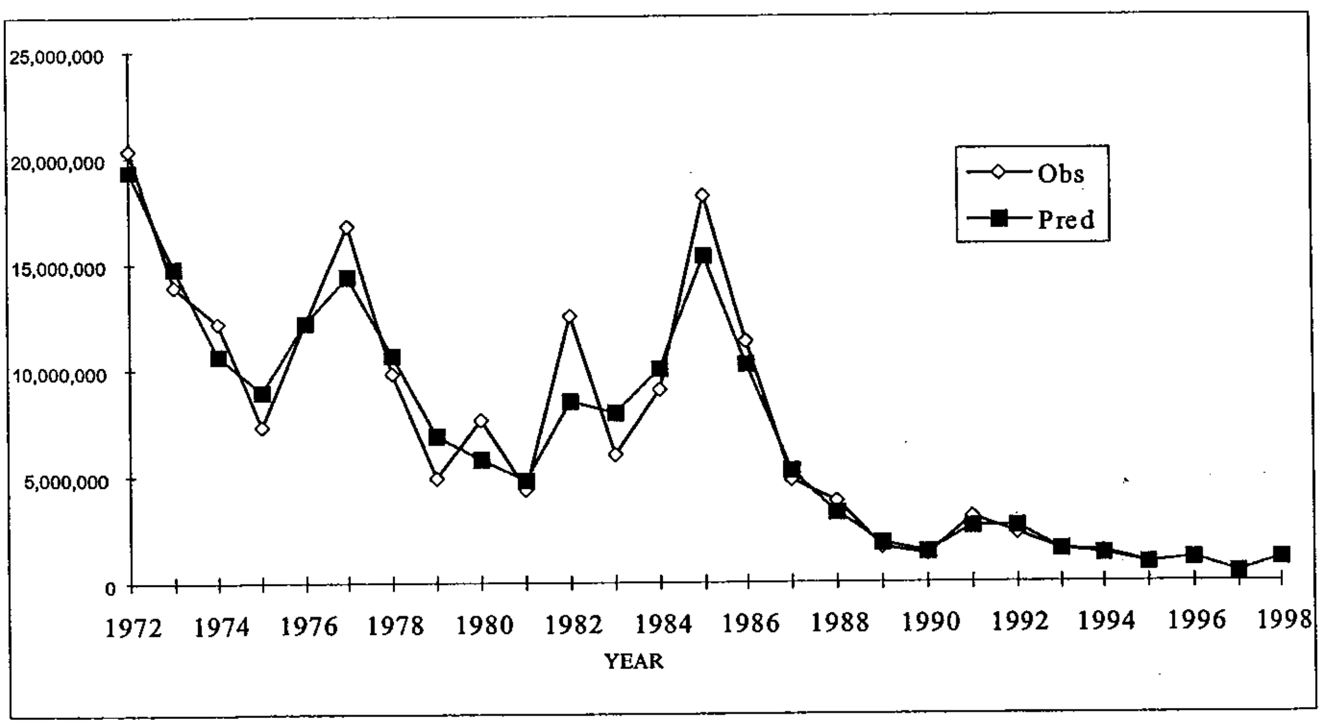


Figure 9. Annual plots of observed and predicted catch.

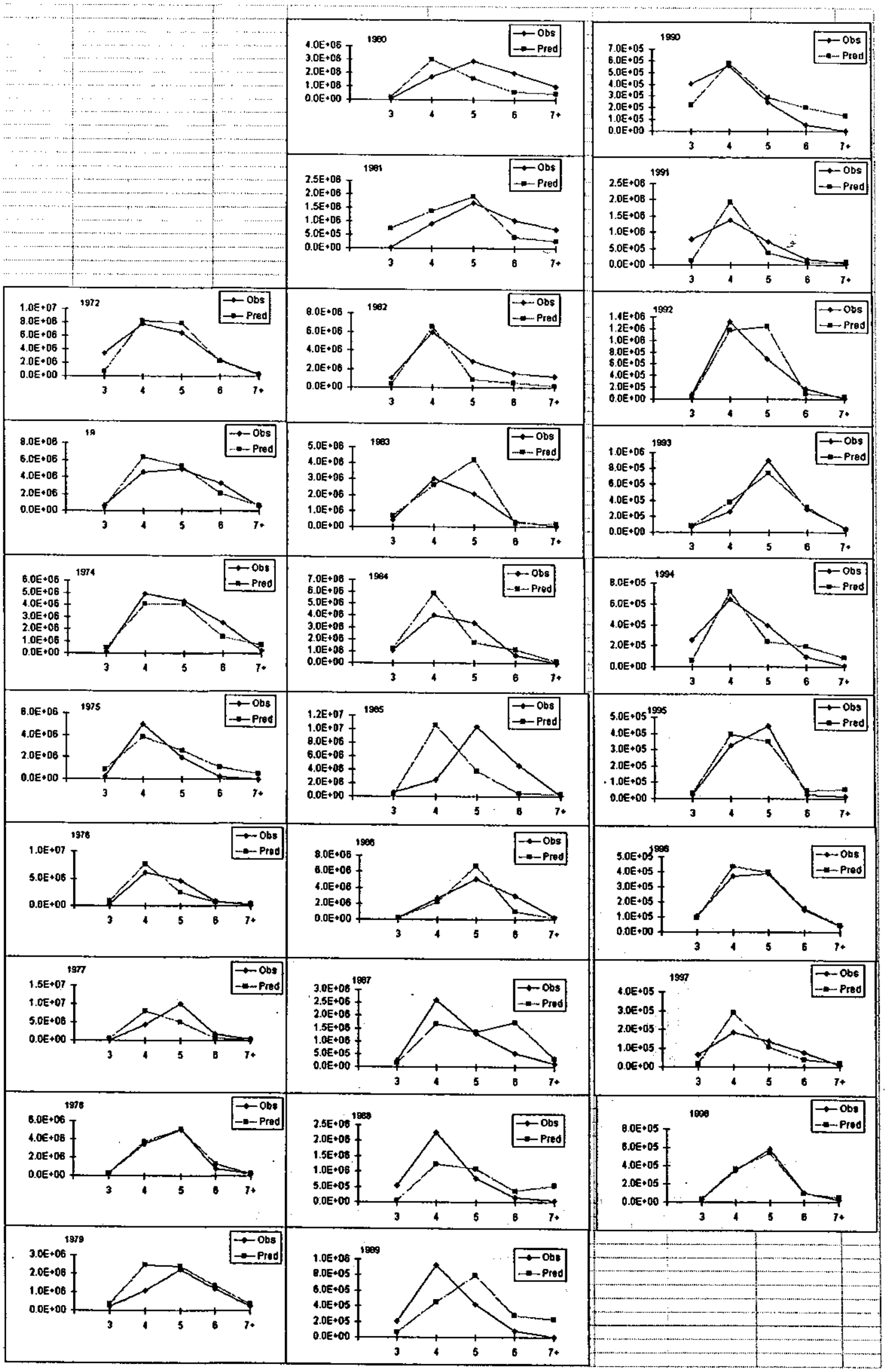


Figure 10. Annual estimates of recruitment, in numbers of age-3 fish, 1972-1998.

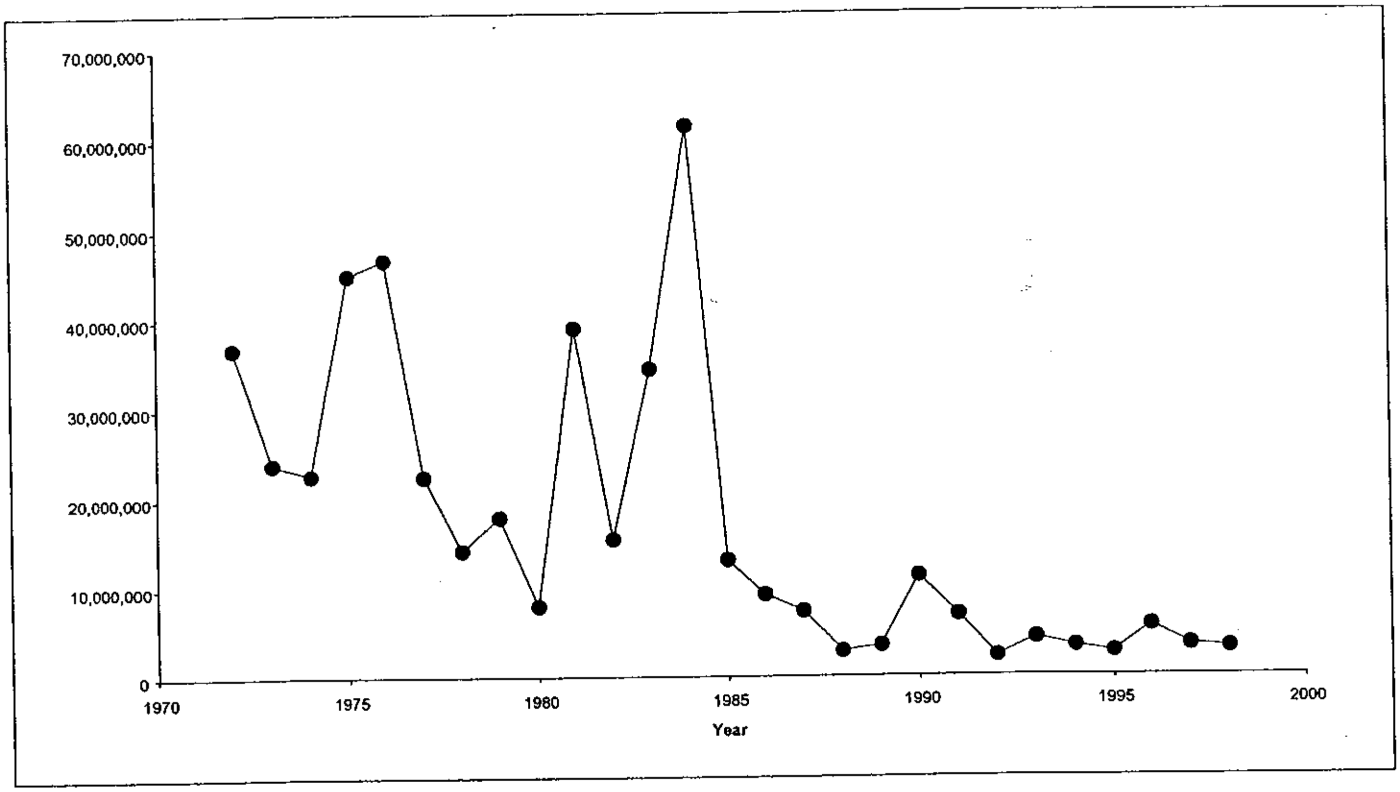


Figure 11. Annual estimates of spawning stock biomass, in pounds x 10,000, 1972-1998.

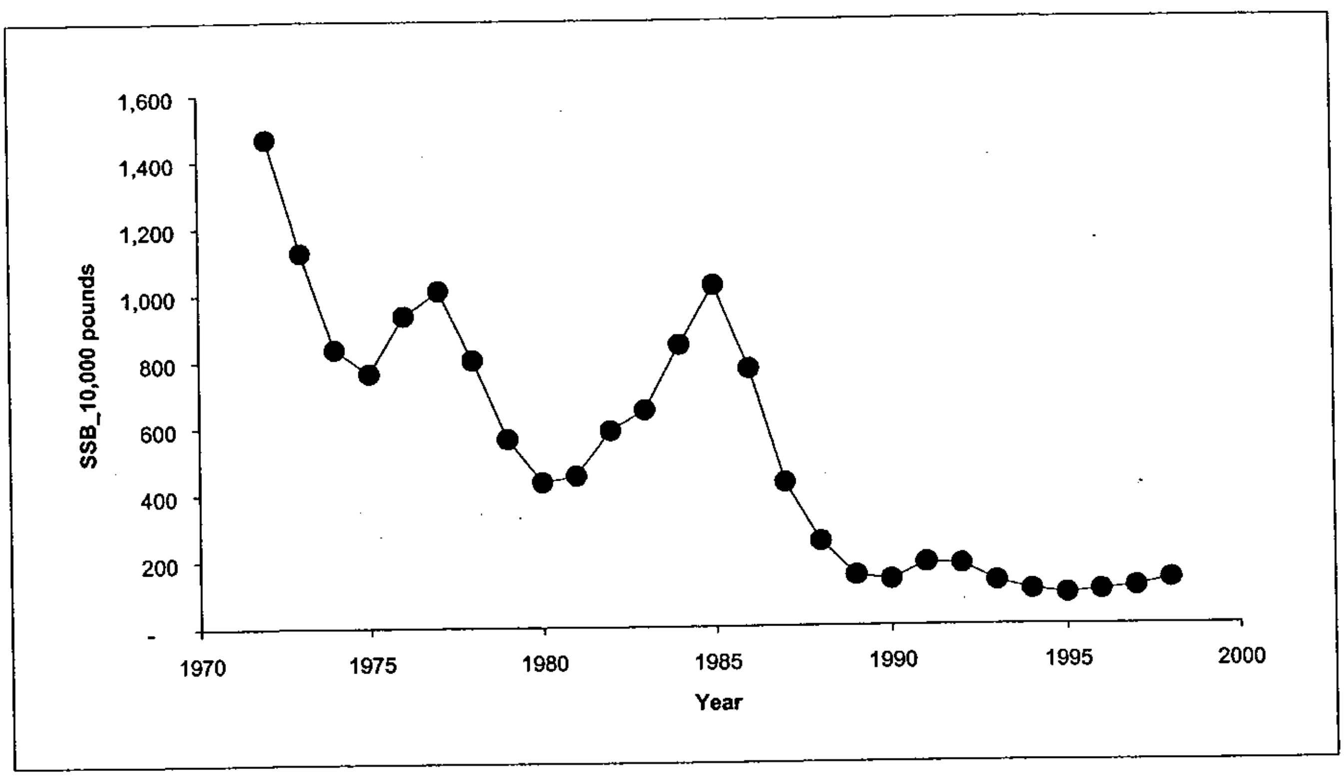


Figure 12. Number of recruits at age-3 vs. spawning stock biomass.

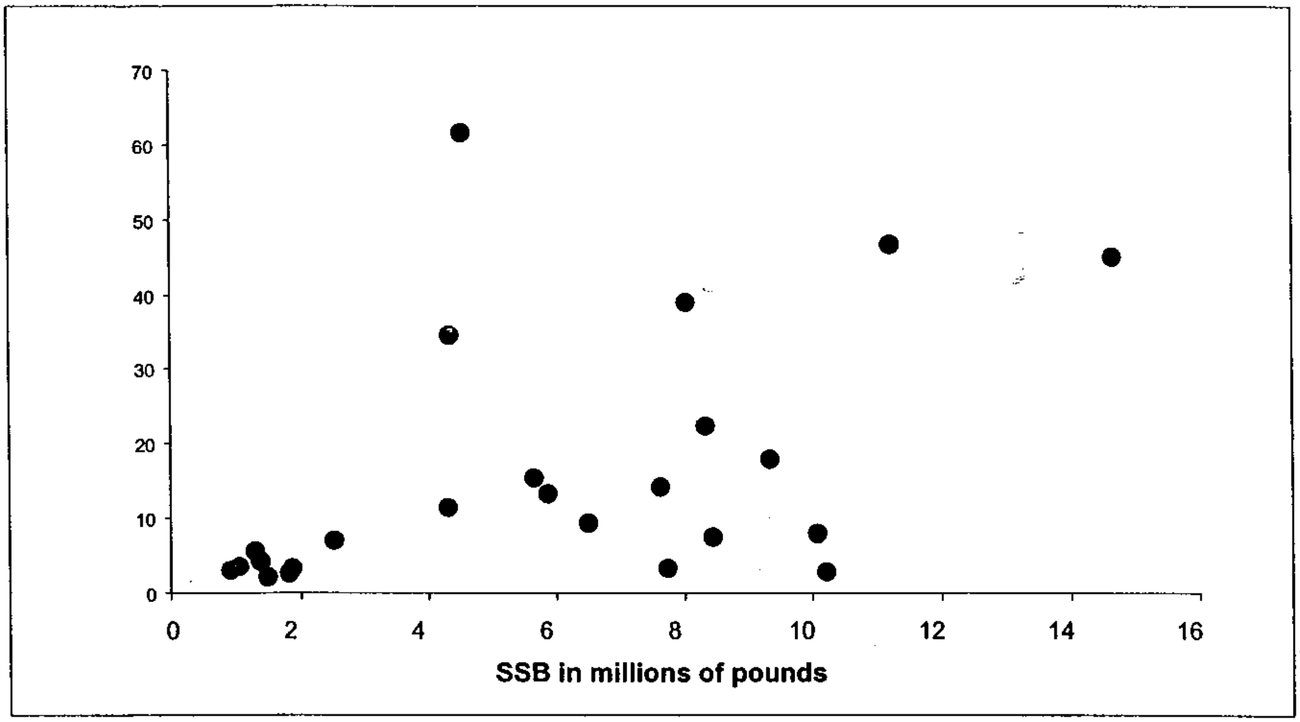


Figure 13. Observed recruitment and fitted stock-recruitment relationship.

Circles represent observed recruitment values and solid line represents fitted stock-recruitment relationship.

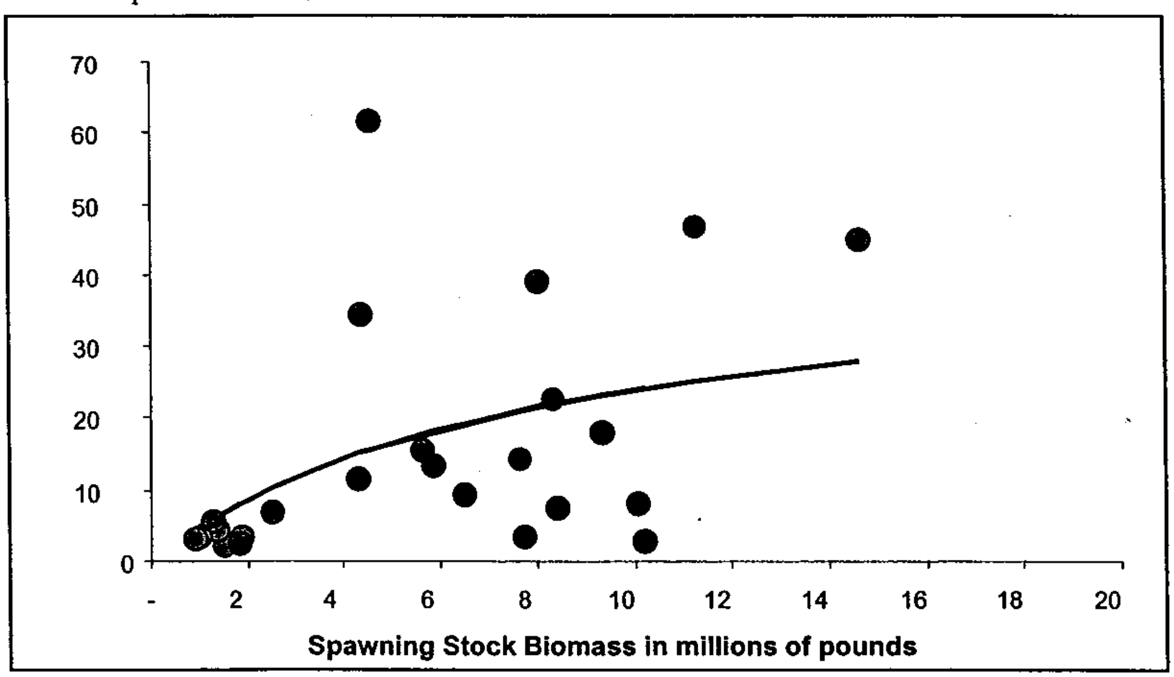


Figure 14. Age-3 abundance vs. JAI values and fitted regression line.

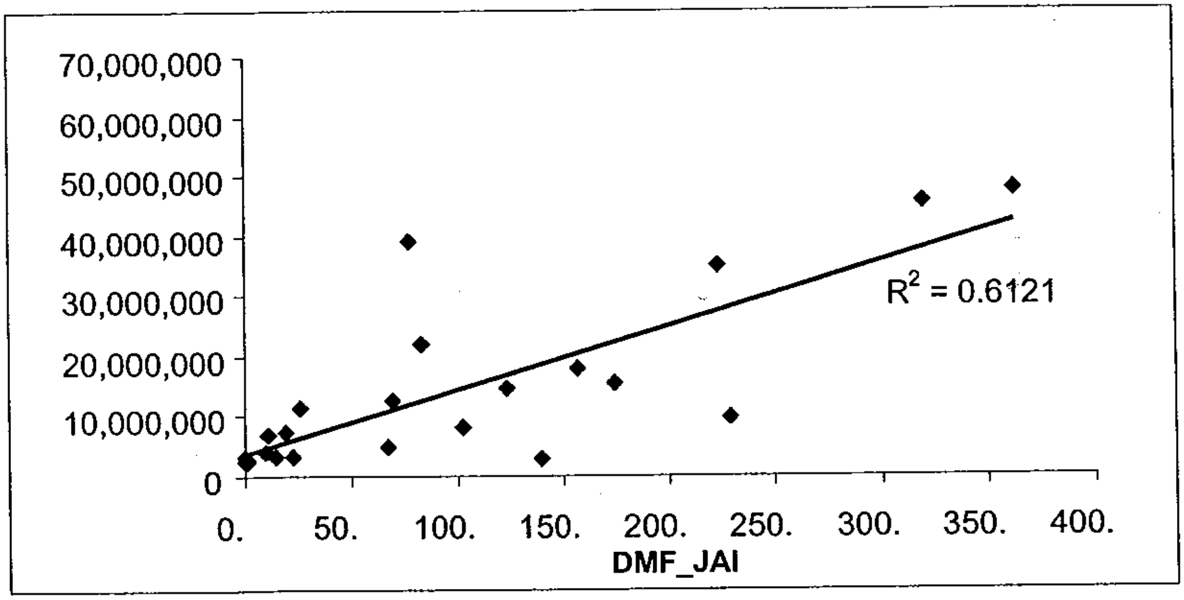


Figure 15. Yield and SSB per recruit for various fishing mortality levels.

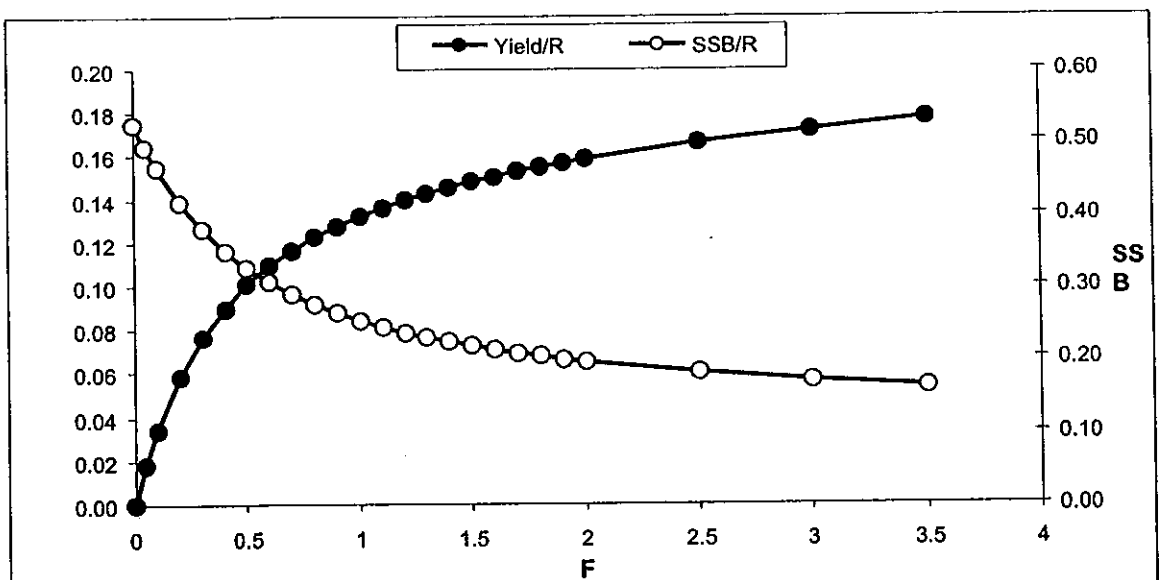


Figure 16. Stock-recruitment plot combined with spawning stock biomass per recruit levels.

Solid line represents the replacement R/SSB, dashed lines represent R/SSB for 1998 and F=0, circles represent observed recruitment, and labels refer to cohorts.

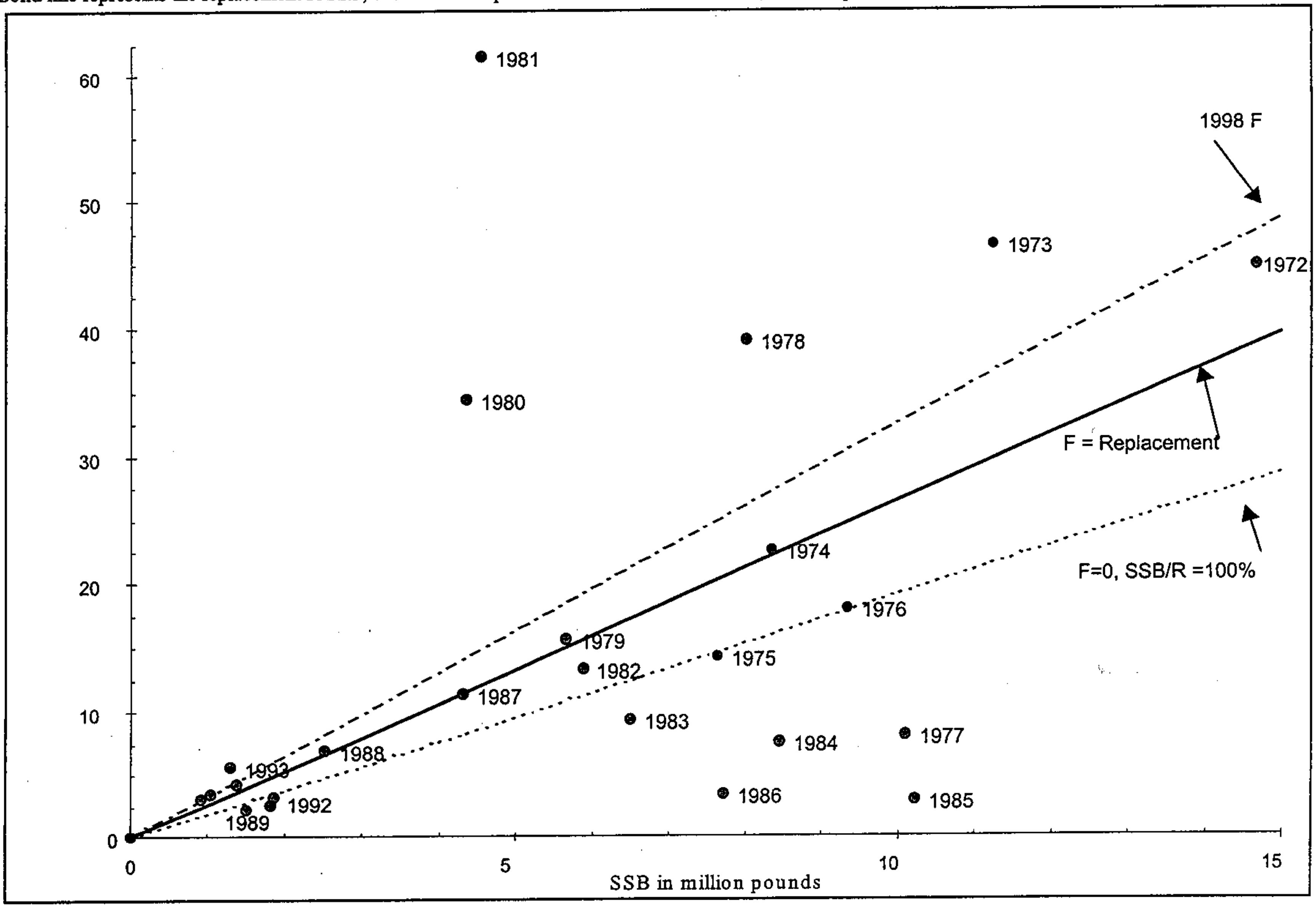


Figure 17. Stock-recruitment plot with spawning stock biomass per recruit levels and predicted recruitment.

Solid curved line represents predicted recruitment, straight lines represent R/SSB, from top to bottom, for F=1, F=0.3, and F=0 , circles represent observed recruitment values, labels on circles correspond to cohorts, and arrows represent intersection of R/SSB lines indicating expected stock equilibrium points for the particular F values.

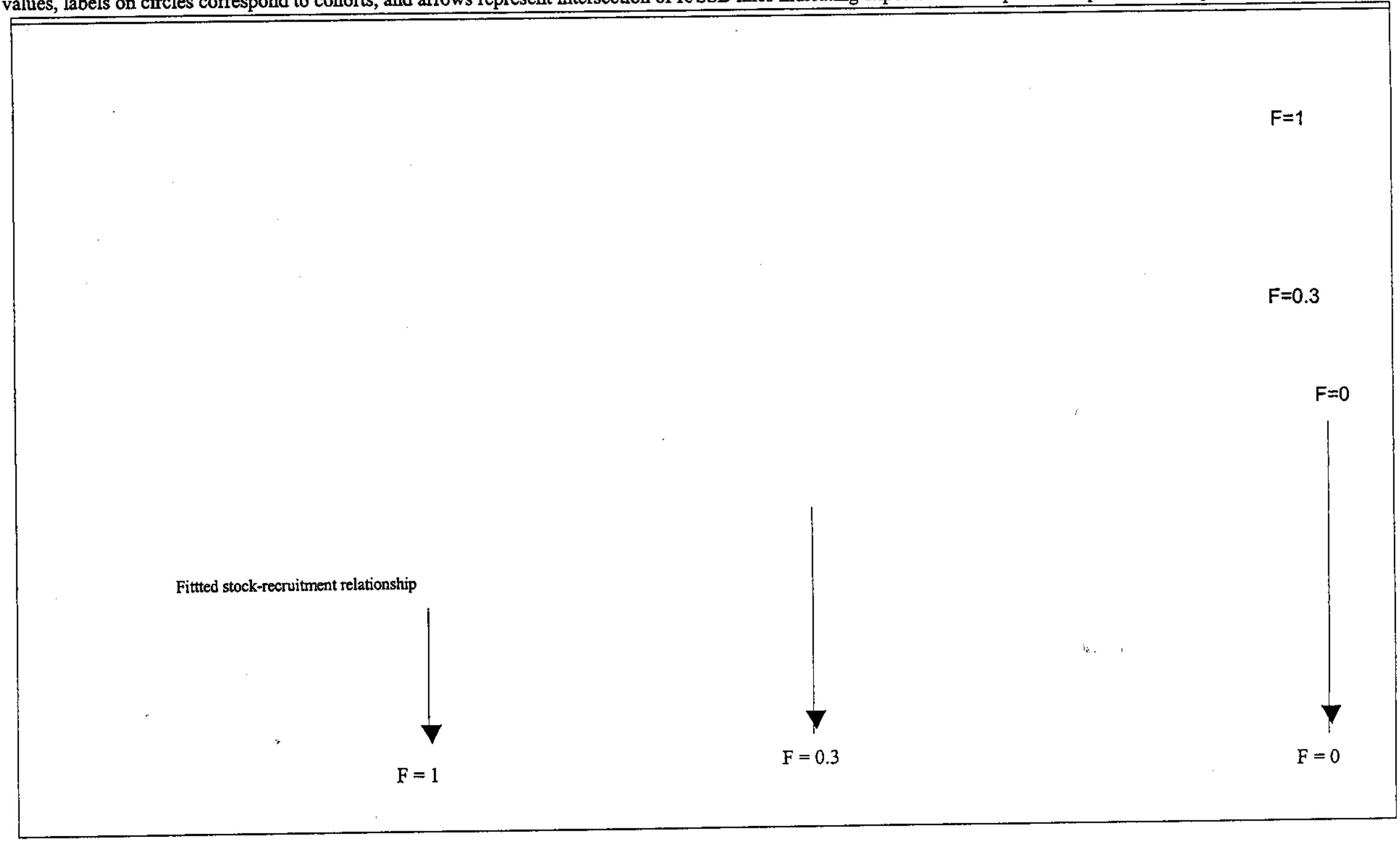


Figure 18 CPUE vs. total catch for the Chowan River Pound net fishery.

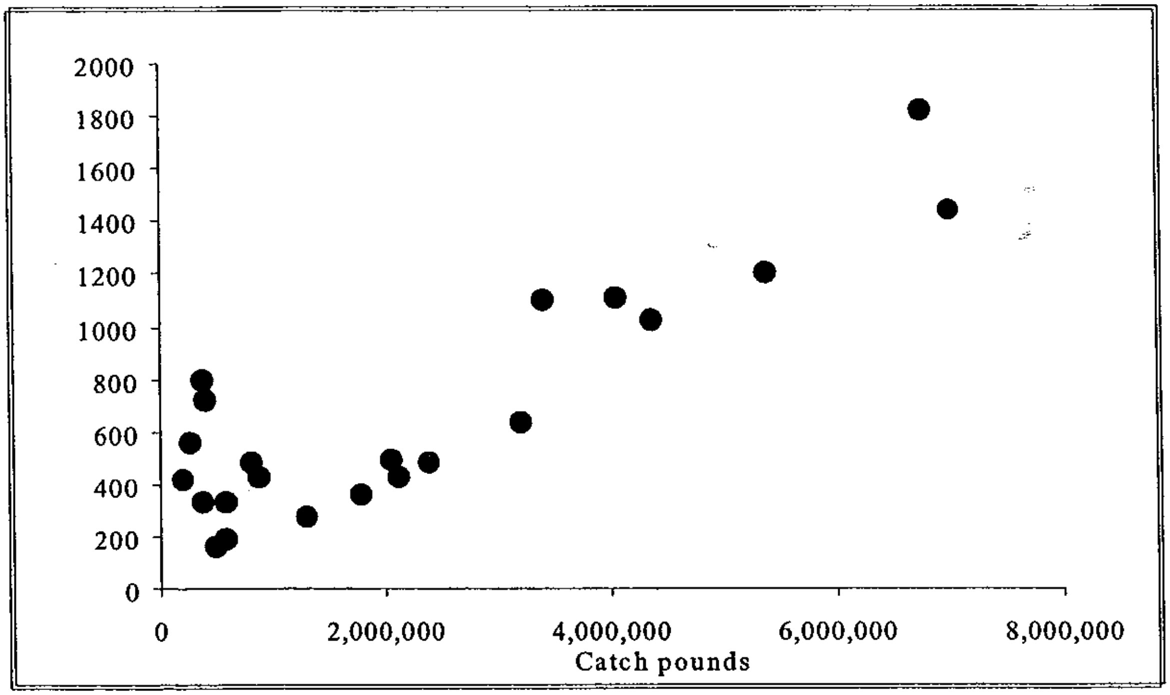


Figure 19. Observed and predicted annual CPUE from the biomass dynamic model.

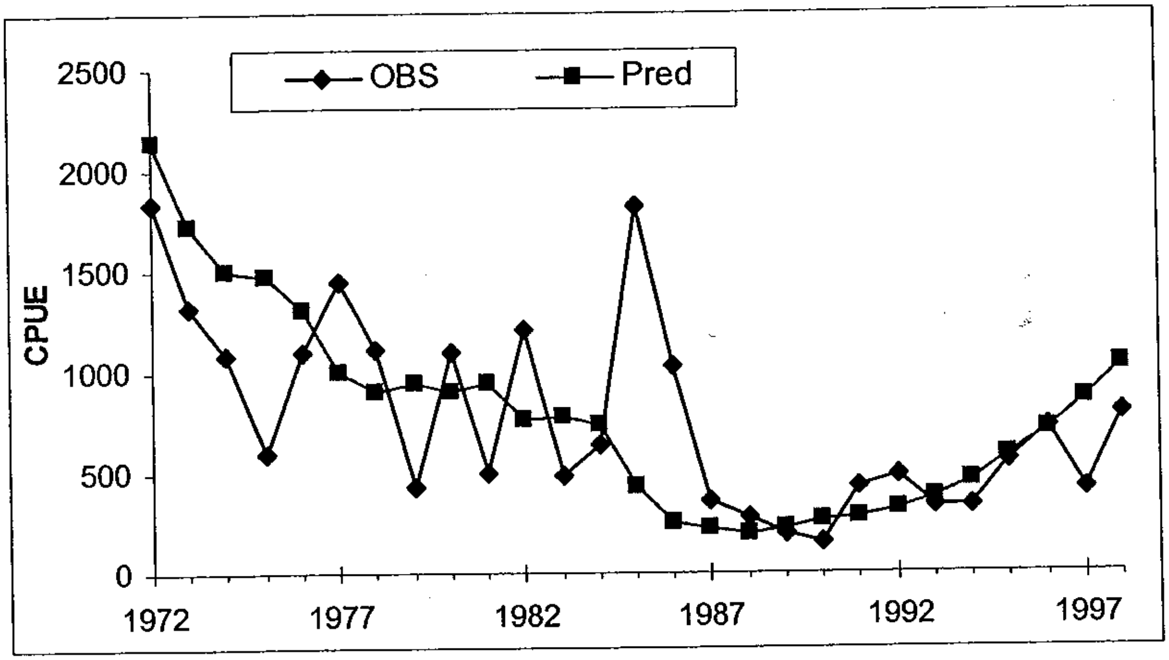


Figure 20. Relative fishing mortality and biomass predicted by the biomass dynamic model.

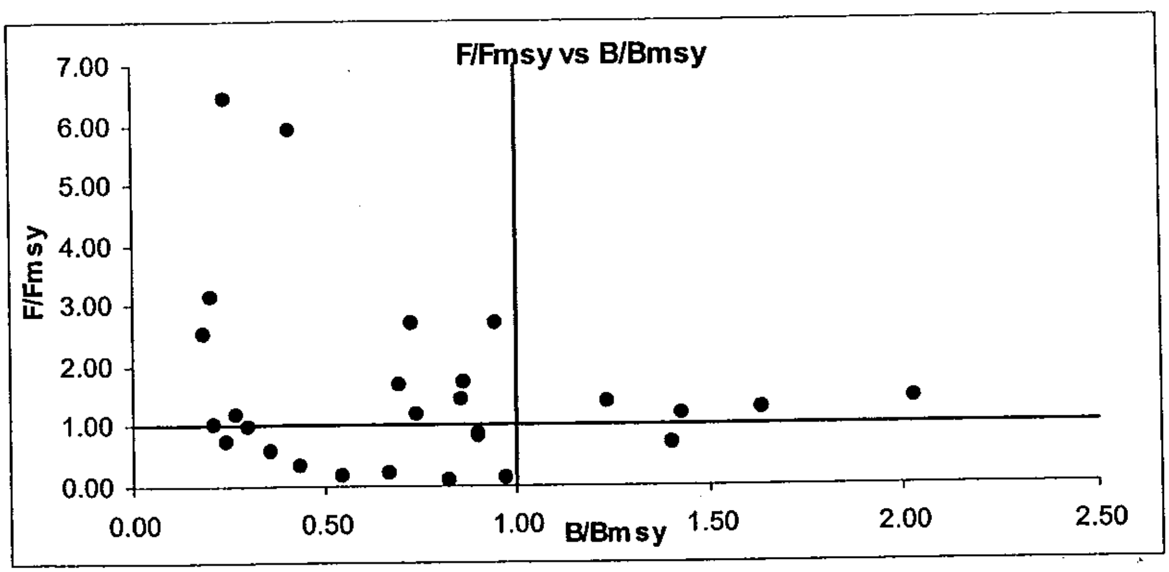


Figure 21. Yield and SSB at equilibrium for various fishing mortality rates based on stock recruitment parameters.

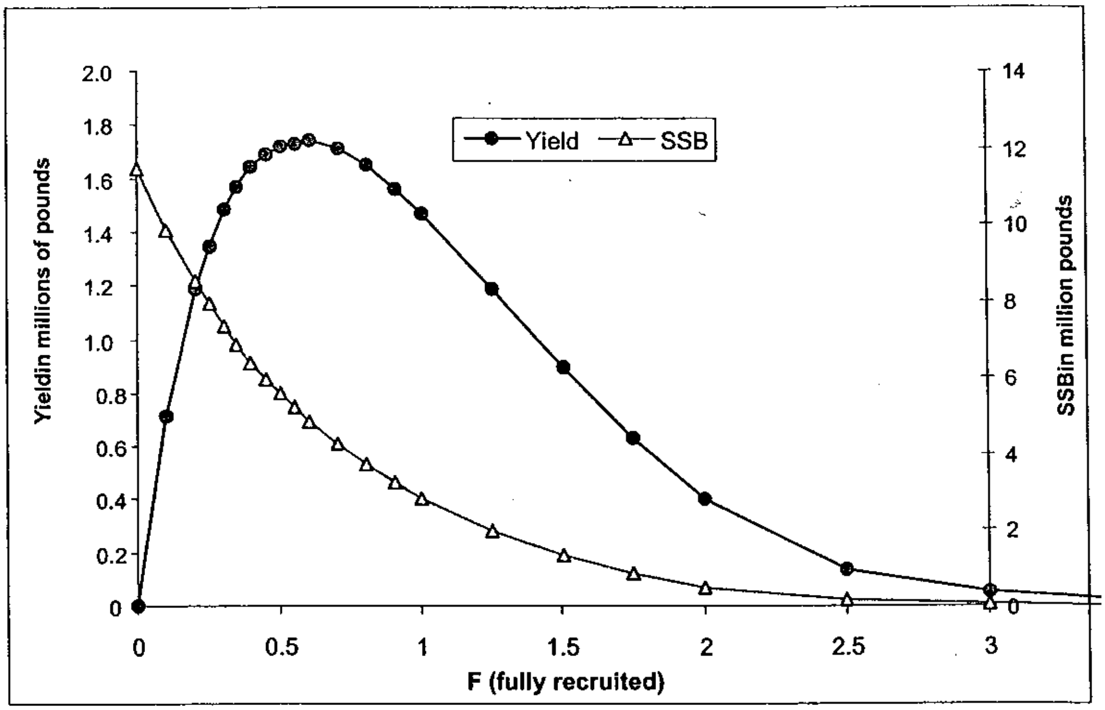


Figure 22. Yield and SSB with 95% confidence bounds at equilibrium for various fishing mortality rates based on the stochastic stock recruitment model.

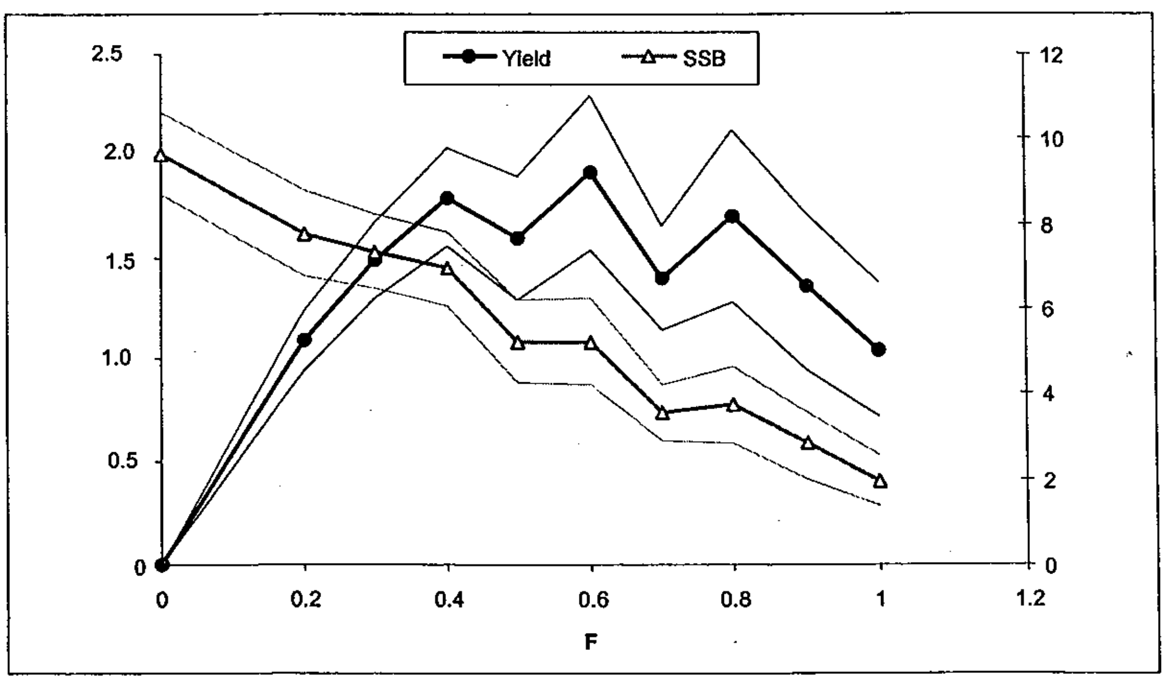


Figure 23. 30 year projection of SSB for fixed quota scenarios, based on SRR predicted recruitment.

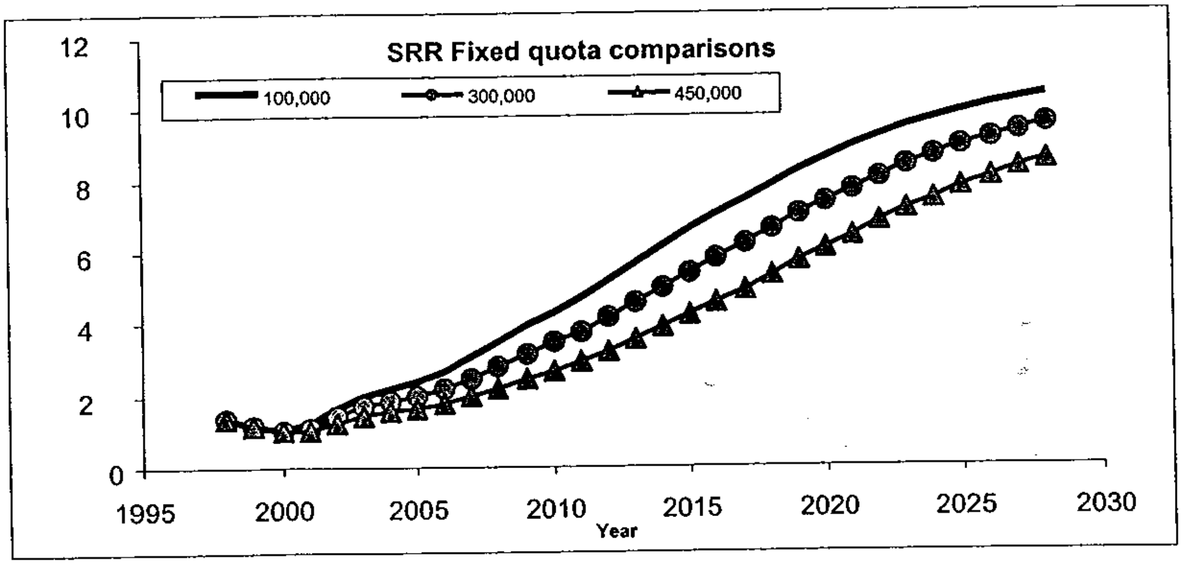


Figure 24. 30 year projection of F for fixed quota scenarios, based on SRR predicted recruitment.

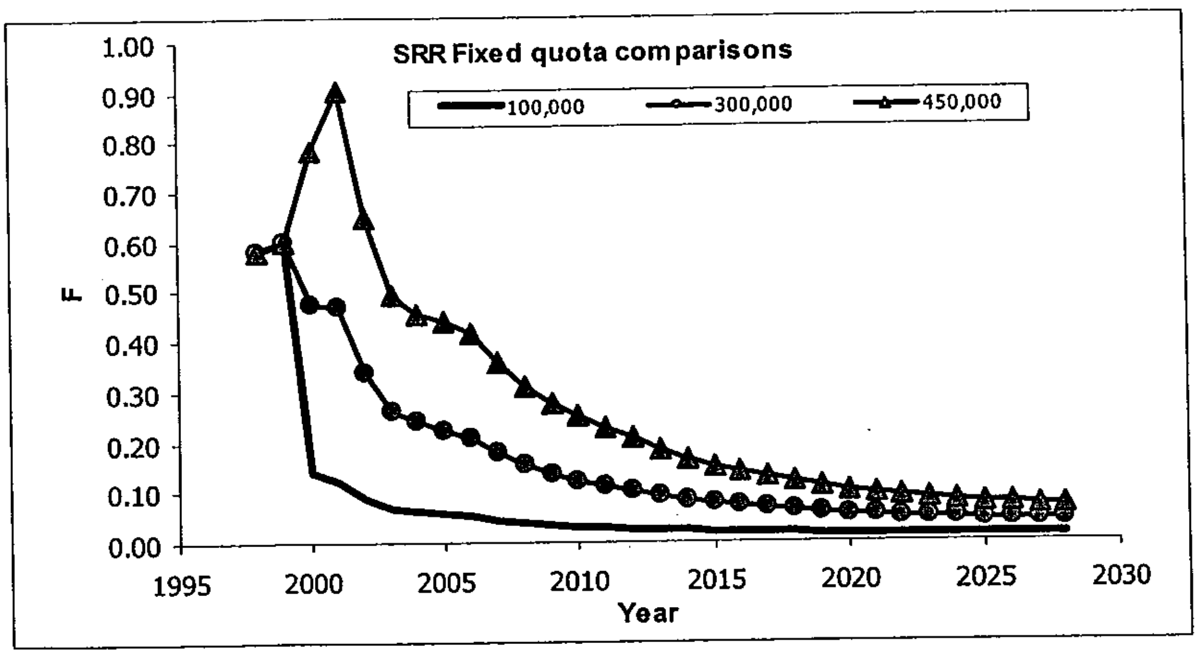


Figure 25. 30 year projection of SSB for fixed exploitation rate scenarios, based on SRR predicted recruitment.

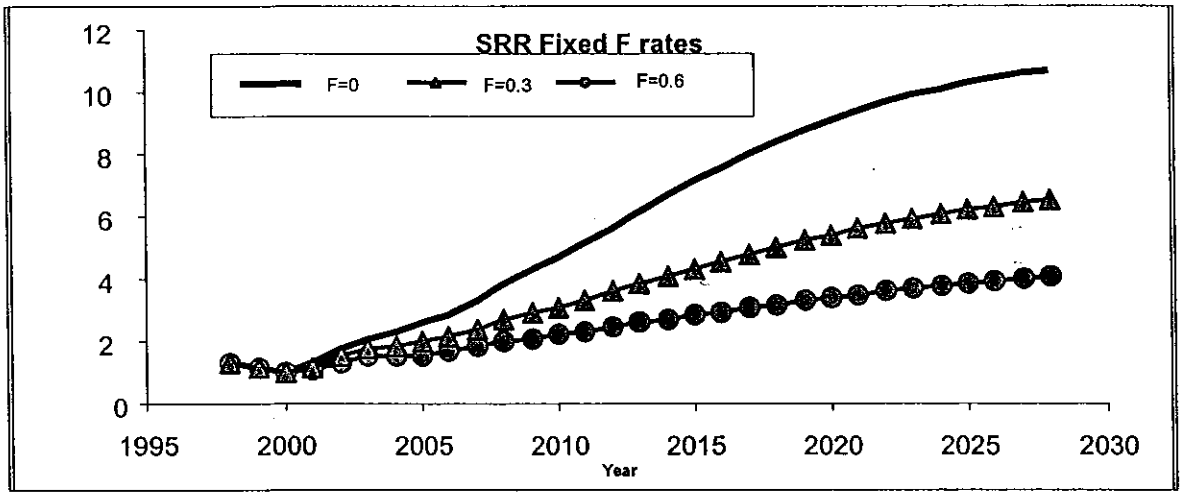


Figure 26. 30 year projection of allowable harvest for fixed exploitation rate scenarios, based on SRR predicted recruitment.

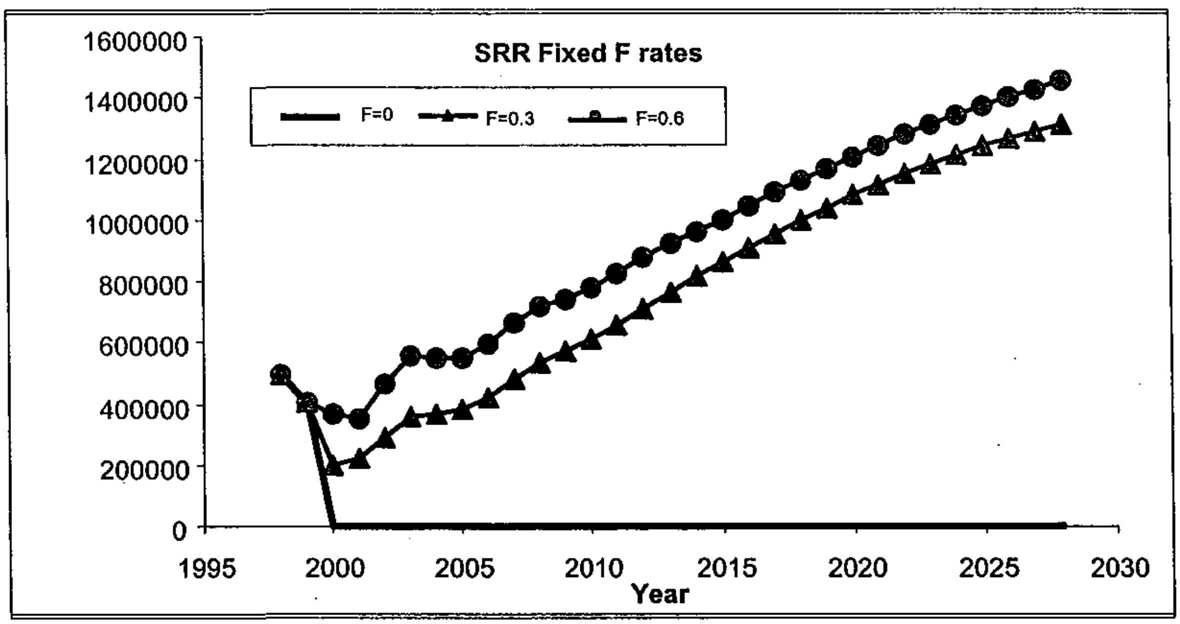


Figure 27. 30 year projection of SSB for fixed harvest scenarios, based on the stochastic recruitment model.

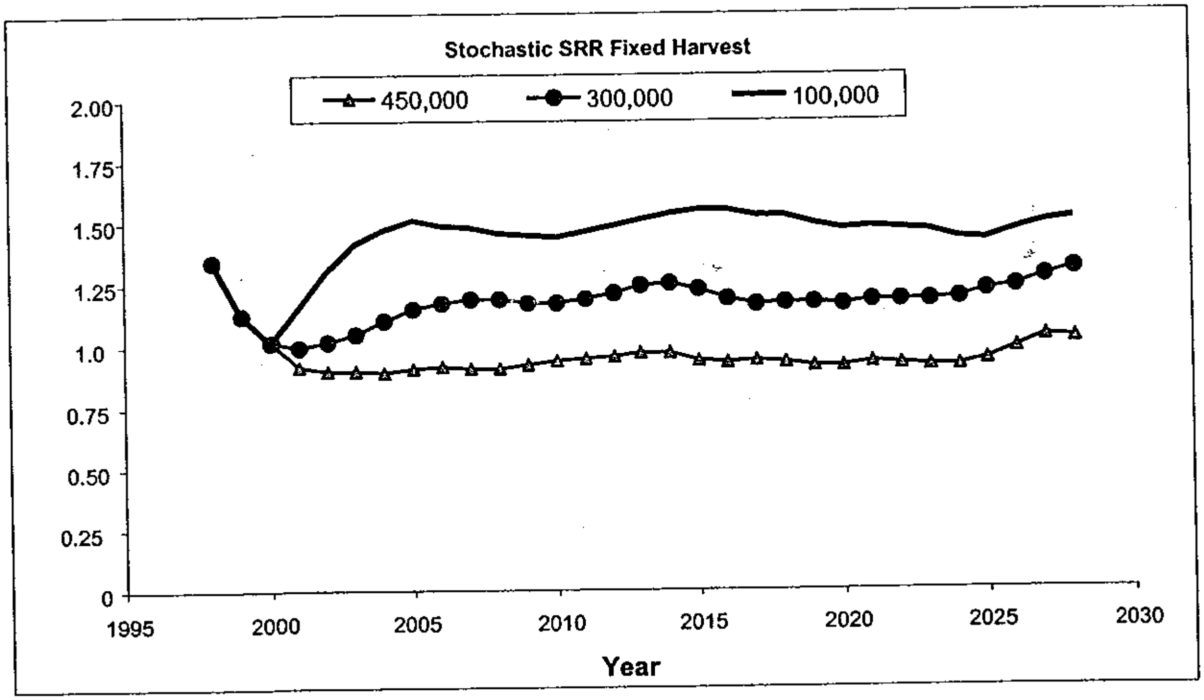


Figure 28. 30 year projection of F for fixed harvest scenarios, based on the stochastic recruitment model.

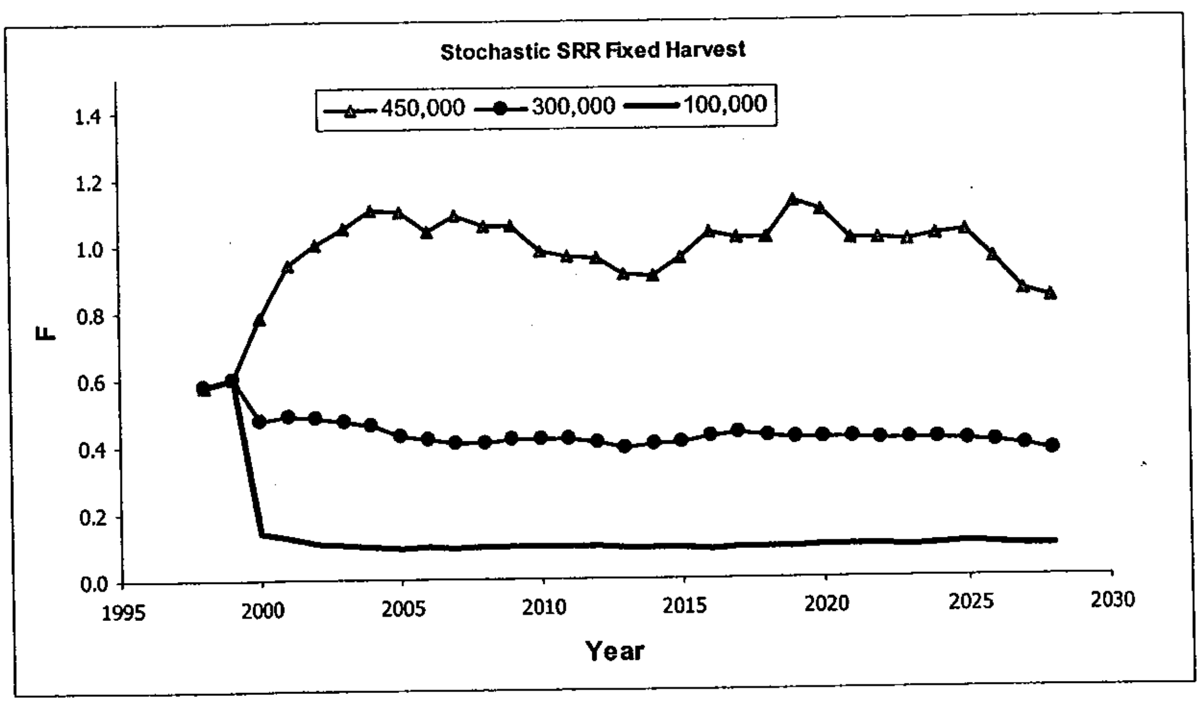


Figure 29. 30 year projection of SSB for fixed exploitation rate scenarios, based on the stochastic recruitment model.

Heavy lines represent mean of 50 runs, light lines represent 95% confidence intervals in the mean.

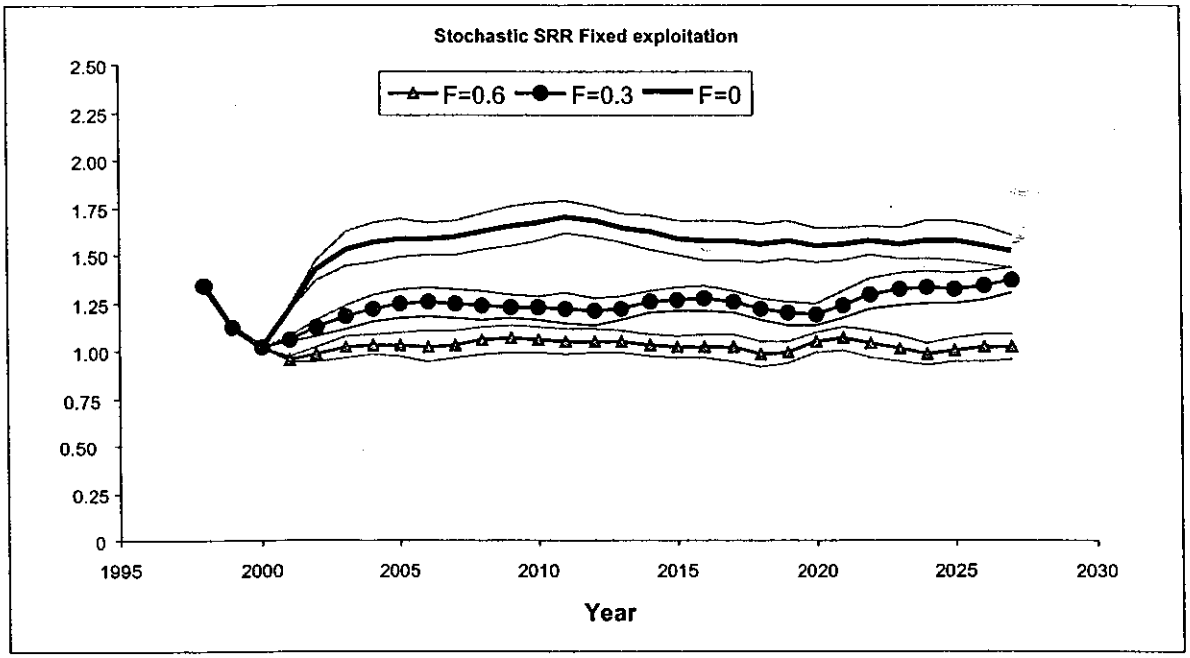
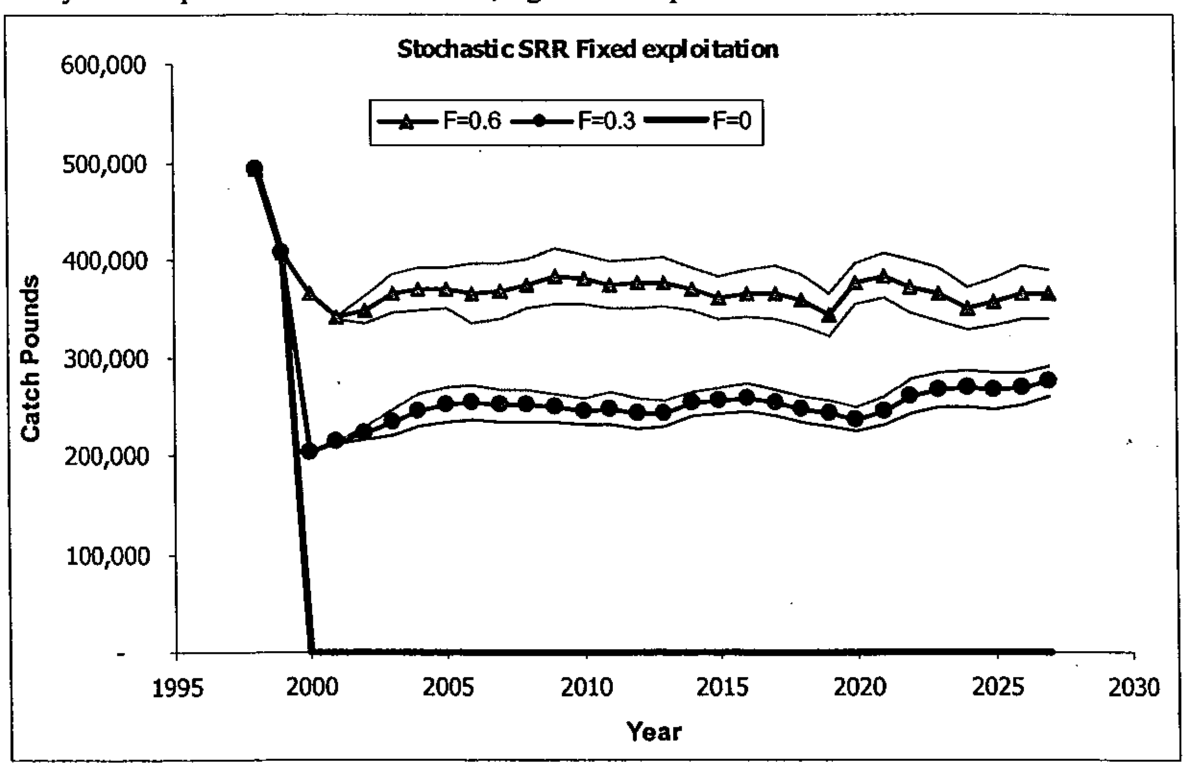


Figure 30. 30 year projection of harvest for fixed exploitation ate scenarios, based on the stochastic recruitment model.

Heavy lines represent mean of 25 runs, light lines represent 95% confidence intervals.



APPENDIX 2

2.1 North Carolina river herring landings by gear, 1887-1971

2.2 North Carolina river herring landings and value, 1880-1961

2.3 River herring landings and value, by county for various years.

Appendix 2.1. North Carolina river herring landings* by gear, 1887-1971 (Chestnut and Davis 1975).

Year	Seine	Gill net	Pound net	Dip net	Fyke net	Wheels	Other
1887	10,487	71	7,185				78
1888	9,383	68	6,827				70
1889	8,177	66	6,073				70
1890	9,152	64	7,189				74
1897	5,864	175	9,554			46	
1902	3,461	56	7,473			42	139
1908	2,491	164	8,085		24		165
1918	1,589	373	12,254	250	6		
1923	1,635	270	4,560		2		54
1927	4,486	777	8,576	135	55	60	
1928	1,871	262	5,369	75	33	12	5
1929	1,761	1,056	7,862	15	72		
1930	2,163	671	6,799	20	59	135	
1931	2,231	784	4,795		47	135	
1932	1,331	377	4,591		21	263	
1934	1,430	1,054	11,850	100	11	450	
1936	1,000	687	9,963	79	129	68	
1937	518	320	4,876	19	53	30	
1938	2,030	158	8,958	10	52	10	
1939	1,046	293	6,361	10	3		
1940	1,343	341	6,992	25	5		
1945	831	1,279	5,875		35		
1950	110	294	5,942		75		
1951	130	1,076	11,276		52		
1952	210	135	6,161		3		
1953	275	314	13,247		5		
1954	365	573	11,825		3		
1955	304	641	11,702		14		
1956	487	607	11,443		11		
1957	380	851	10,529		38		
1958	237	2,483	12,155		4		
1959	592	1,791	11,766		13		
1960	140	1,602	11,058		11		
1961	288	1,374	10,288		1		
1962	151	1,707	12,443		2		
1963	301	1,806	12,941				
1964	532	1,145	5,883				
1965	514	3,233	9,077				
1966	1	103	12,414				
1967	36	52	18,395				
1968	854	999	13,597	73			
1969	1,003	772	17,905	80			
1970	581	31	10,873	34			
1971	979	78	11,657				

* landings X '000 pounds

Appendix 2.2 North Carolina river herring landings and value, 1880-1961 (from Chestnut and Davis 1975).

Year	Landings ('000 pounds)	Value ('000 dollars)
1880	15,520	143
1887	23,747	173
1888	20,451	162
1889	19,316	145
1890	22,112	165
1896	14,356	116
1897	20,839	127
1902	15,173	116
1904	10,492	124
1908	12,530	140
1918	17,356	401
1923	8,989	119
1927	13,911	147
1928	7,808	111
1929	10,768	102
1930	9,839	68
1931	7,994	81
1932	6,584	42
1934	14,897	91
1936	11,929	130
1937	5,818	58
1938	11,219	112
1939	7,714	77
1940	8,708	109
1945	8,022	177
1950	6,422	128
1951	12,534	129
1952	6,511	81
1953	13,842	138
1954	12,758	127
1955	12,648	130
1956	12,554	135
1957	11,773	118
1958	14,914	149
1959	14,154	142
1960	12,815	128
1961	11,951	120

Appendix 2.3. River herring landings and value, by county for various years (from Chestnut and Davis 1975).

	Beaufort		Bertie		Camden		Carteret		Chowan		Craven	
Year	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1889	350,280	4,363	2,601,200	25,851	-	-	-	-	5,665,994	59,206	443,660	4,202
1897	161,867	3,947	2,740,191	22,534	77,733	889	10,000	15	7,807,387	52,019	475,666	7,385
1902	561,620	5,553	1,909,000	19,423	25,000	320	24,500	372	3,950,000	37,938	192,800	3,084
1918	326,865	6,760	427,884	10,115	-	-	75,636	3,774	7,977,543	186,183	22,800	725
1928	499,313	7,956	494,890	7,375	700	13	9,550	370	3,403,200	42,630	19,800	650
1930	391,000	1,964	1,188,000	5,940	16,000	175	37,000	420	3,172,800	28,529	127,500	836
1938	1,000	10	6,030,000	60,300	10,000	100	700	7	3,492,500	34,925	2,800	42
1945	2,600	57	2,700,000	59,400	5,000	110	8,500	187	-	-	3,279,800	72,156
1950	8,600	172	2,030,000	40,600	1,400	28	-	-	3,327,900	66,558	-	-
1960	13,800	138	4,663,500	46,635	12,000	120	15,500	155	7,130,400	71,304	1,000	10
1965	13,400	139	4,444,200	45,950	5,000	57	-	-	7,722,400	79,540	-	-

	Currituck		Dare		Gates		Hertford		Hyde		Martin	
Year	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1889	27,804	305	1,523,600	11,679	94,000	1,175	311,462	3,888	94,640	1,142	420,000	4,289
1897	117,000	708	1,620,414	12,520	-	-	677,684	8,895	2,000	30	167,005	1,594
1902	78,300	700	992,200	12,808	-	-	35,100	2,960	34,500	452	195,000	1,935
1918	275,751	6,392	905,991	41,247	73,688	1,179	216,875	5,205	87,706	3,054	55,000	2,700
1928	17,733	474	296,097	7,369	-	-	50,000	562	30,400	605	382,700	8,090
1930	16,900	418	206,400	3,278	40,000	600	103,000	575	58,000	950	214,000	1,220
1938	5,000	56	15,900	159	225,000	2,250	900,000	9,000	52,000	2,600	225,000	2,250
1945	21,500	472	50,000	1,100	35,000	770	115,000	2,530	1,500	330	125,000	2,750
1950	6,500	130	52,200	1,044	55,000	1,100	86,000	1,720	-	-	100,000	2,000
1960	12,000	120	218,100	2,181	50,000	500	134,900	1,349	25,400	254	200	2
1965	1,800	19	132,200	1,367	-	-	-	-	3,200	33	-	-

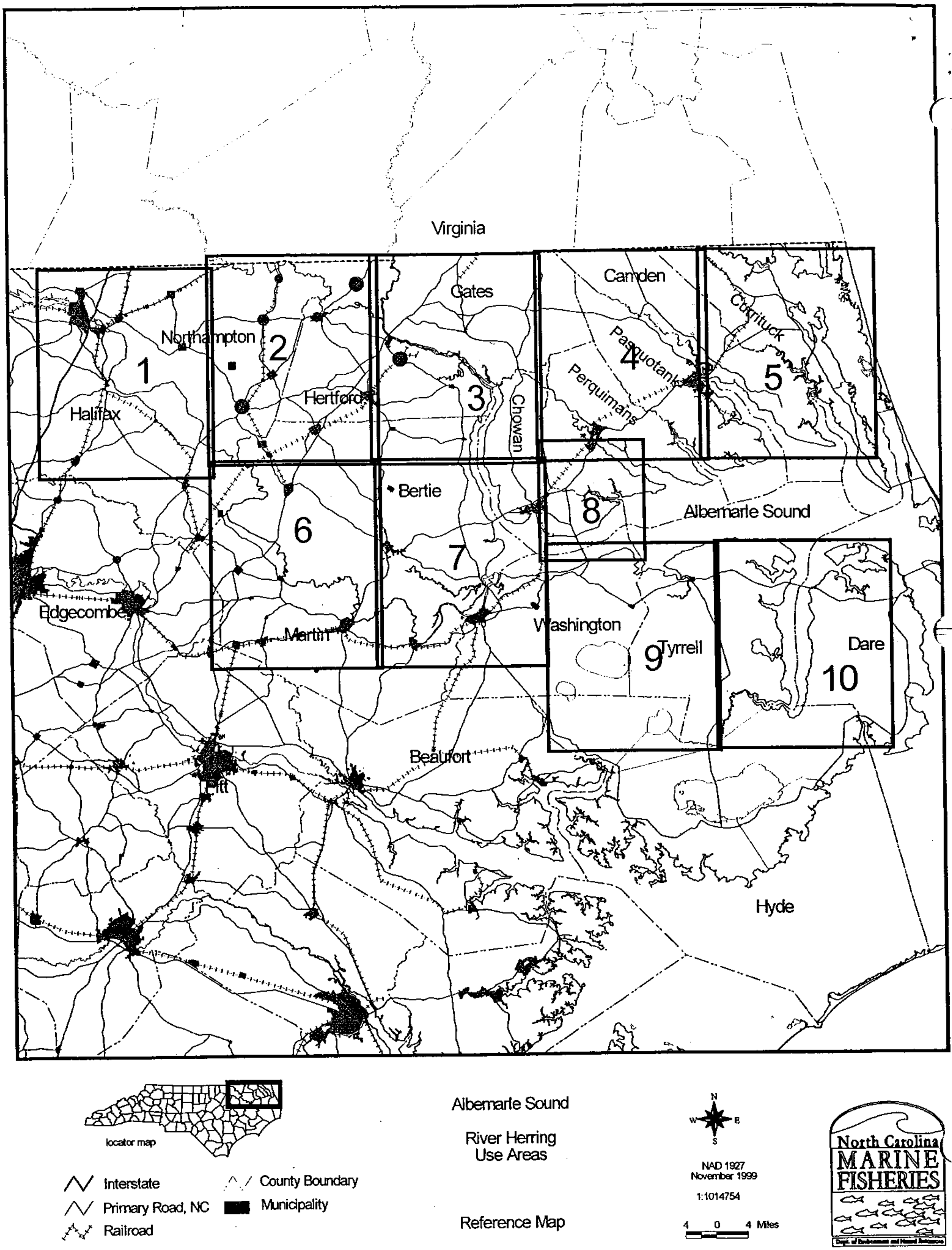
Appendix 2.3 (Continued)

Year	New Hanover Pounds	New Hanover Value	Onslow Pounds	Onslow Value	Pamlico Pounds	Pamlico Value	Pasquotank Pounds	Pasquotank Value	Pender Pounds	Pender Value	Perquimans Pounds	Perquimans Value
1889	-	-	-	-	-	-	136,760	1,882	-	-	755,800	7,513
1897	-	-	50,000	600	26,666	400	236,181	2,076	1,660	20	216,445	2,238
1902	-	-	19,400	228	93,350	1,100	192,000	2,370	4,500	54	377,500	6,807
1918	15,000	1,200	177,507	6,250	3,750	125	89,000	1,300	-	-	100,000	2,090
1928	-	-	84,500	1,690	55,835	800	82,360	2,246	-	-	72,758	1,260
1930	-	-	-	-	75,000	668	101,500	1,580	-	-	180,000	1,600
1938	-	-	-	-	2,500	25	700	7	-	-	700	7
1945	-	-	-	-	-	-	19,300	425	-	-	28,900	636
1950	-	-	-	-	300	15	11,400	228	-	-	13,200	264
1960	-	-	-	-	1,500	15	26,600	266	100	1	100,000	1,000
1965	1,800	126	-	-	-	-	6,000	57	300	3	406,500	4,497

Year	Pitt Pounds	Pitt Value	Sampson Pounds	Sampson Value	Tyrrell Pounds	Tyrrell Value	Washington Pounds	Washington Value
1889	7,480	94	-	-	1,221,920	12,168	718,800	7,459
1897	7,596	227	13,330	160	636,814	5,164	738,668	5,429
1902	16,340	312	9,240	138	819,000	8,222	1,317,000	12,204
1918	-	-	-	-	1,913,733	38,040	1,739,091	84,880
1928	10,000	455	-	-	776,000	8,580	1,522,095	19,597
1930	70,000	350	-	-	1,798,400	8,992	2,043,227	10,213
1938	-	-	-	-	130,400	1,304	176,900	1,769
1945	-	-	-	-	80,000	1,760	1,550,000	34,100
1950	-	-	-	-	105,000	2,100	625,000	12,500
1960	-	-	-	-	51,200	512	358,800	3,588
1965	-	-	-	-	23,800	246	67,000	693

APPENDIX 3

RIVER HERRING USE AREAS



Virginia
Northampton
Halifax
Hertford
Gates
Chowan
Camden
Pasquotank
Perquimans
Currituck
Bertie
Albemarle Sound
Edgecombe
Martin
Washington
Tyrrell
Dare
Beaufort
Pitt
Hyde
1
2
3
4
5
6
7
8
9
10
locator map
Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Albemarle Sound
River Herring
Use Areas
Reference Map
N
W
E
S
NAD 1927
November 1999
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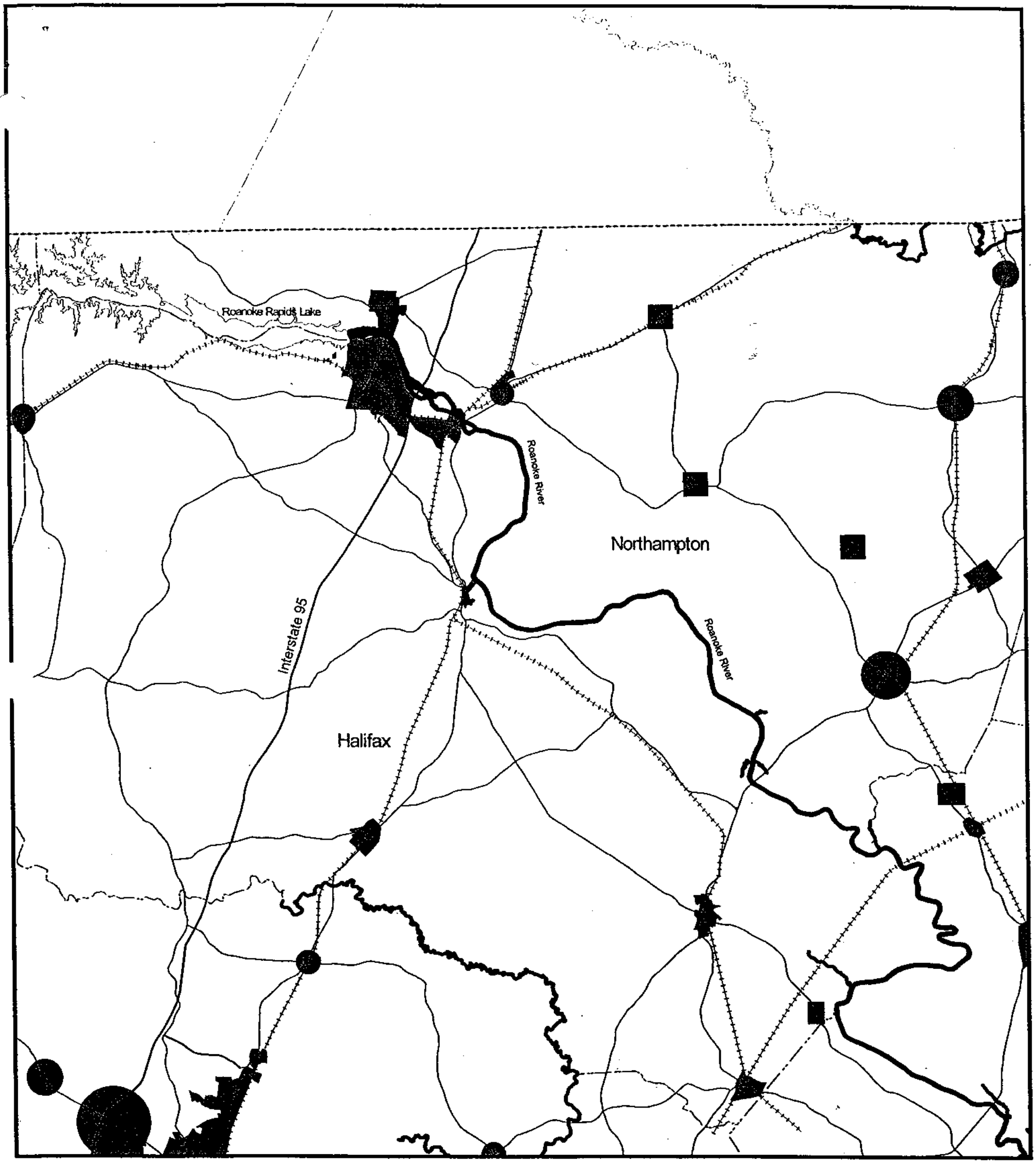
4 0 4 Miles
North Carolina
MARINE
FISHERIES



locator map

Albemarle Sound

River Herring
Use Areas

Map 1

Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish
Spawning Area

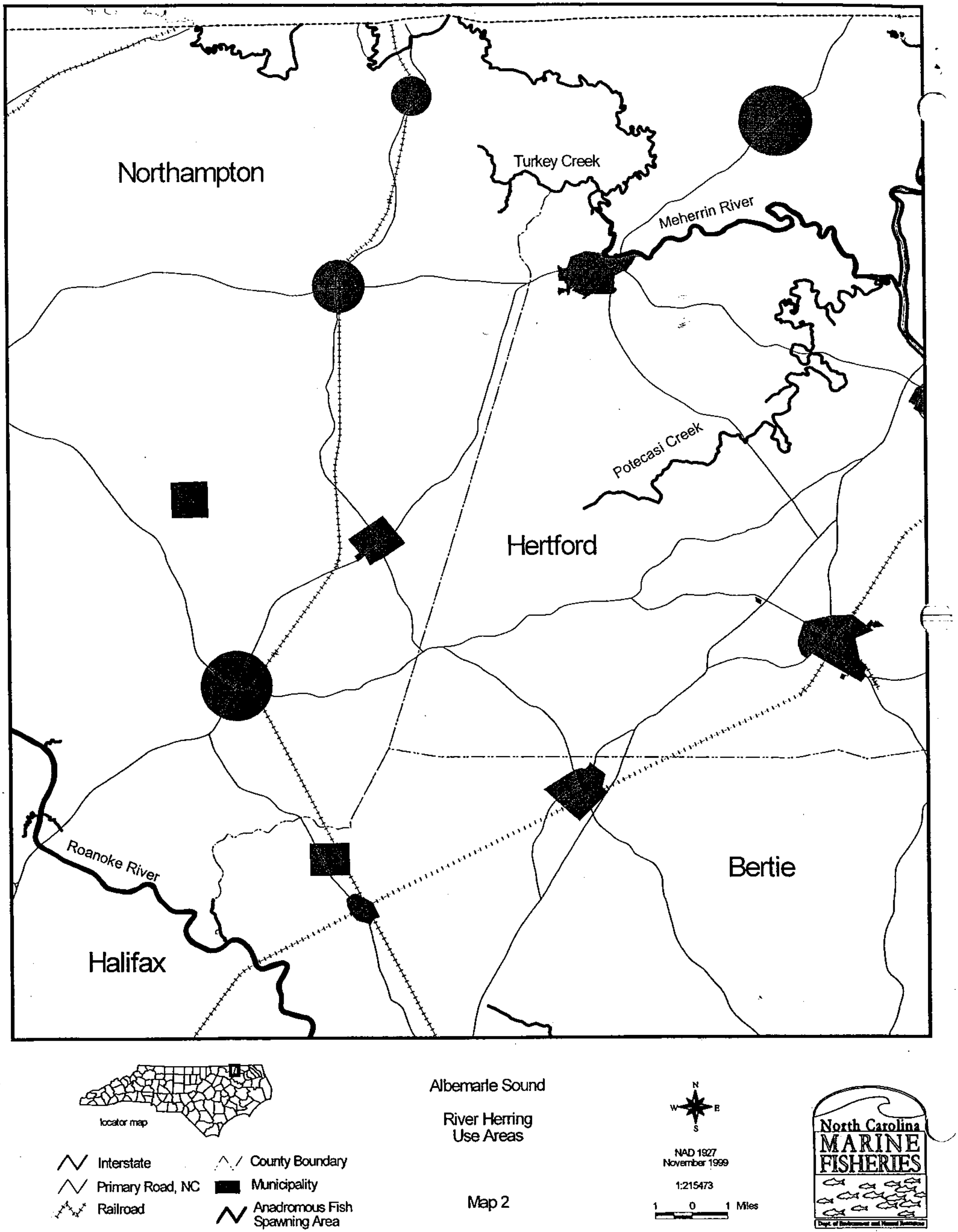
N
W E
S

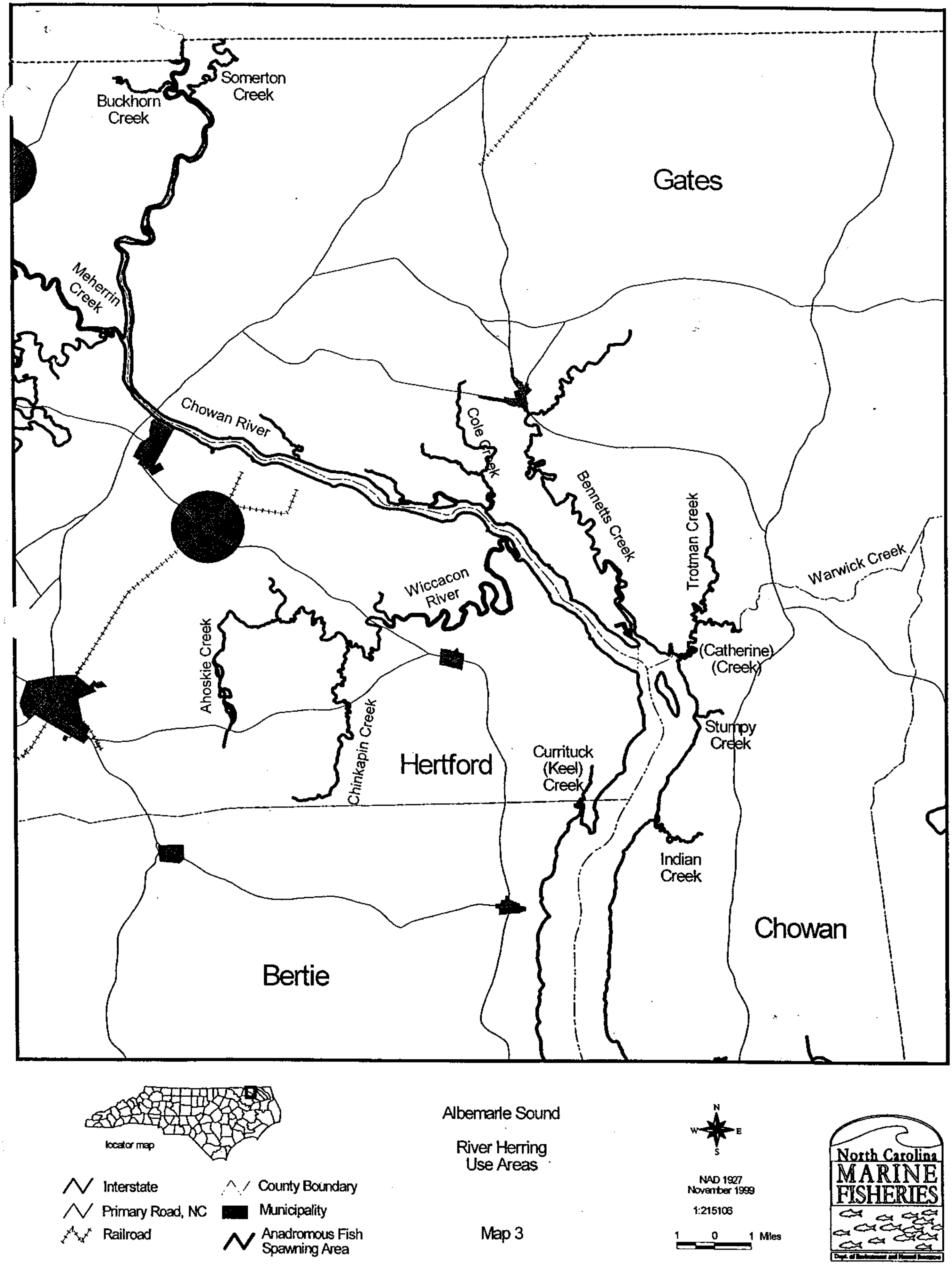
NAD 1927
November 1999

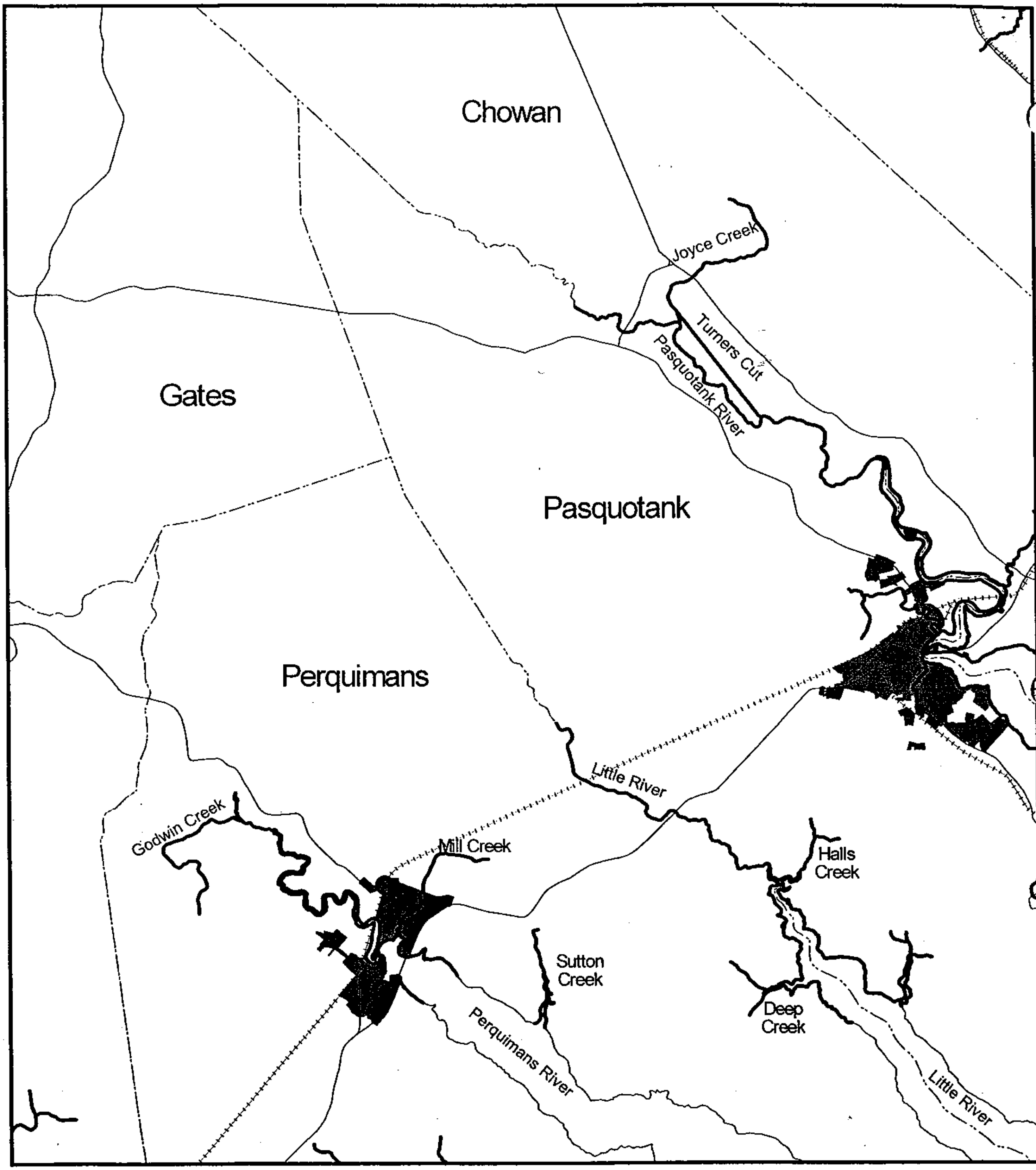
1:350748

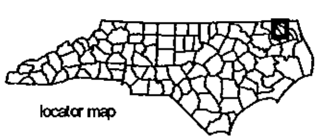
1 0 1 2 Miles

North Carolina
MARINE
FISHERIES


Northampton
Turkey Creek
Meherrin River
Potecasi Creek
Hertford
Roanoke River
Halifax
Bertie
locator map
Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area
Albemarle Sound
River Herring Use Areas
Map 2
N
W
E
S
NAD 1927
November 1999
1:215473
1 0 1 Miles
North Carolina
MARINE FISHERIES


Somerton Creek
Buckhorn Creek
Gates
Meherrin Creek
Chowan River
Cole Creek
Bennetts Creek
Trotman Creek
Warwick Creek
Wiccacon River
Ahoskie Creek
(Catherine) (Creek)
Stumpy Creek
Chinkapin Creek
Hertford
Currituck (Keel) Creek
Indian Creek
Chowan
Bertie
locator map
Albemarle Sound
River Herring Use Areas
Map 3
Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area
N
W
E
S
NAD 1927
November 1999
1:215108
1 0 1 Miles
North Carolina MARINE FISHERIES





Albemarle Sound

River Herring Use Areas

Map 4

Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area

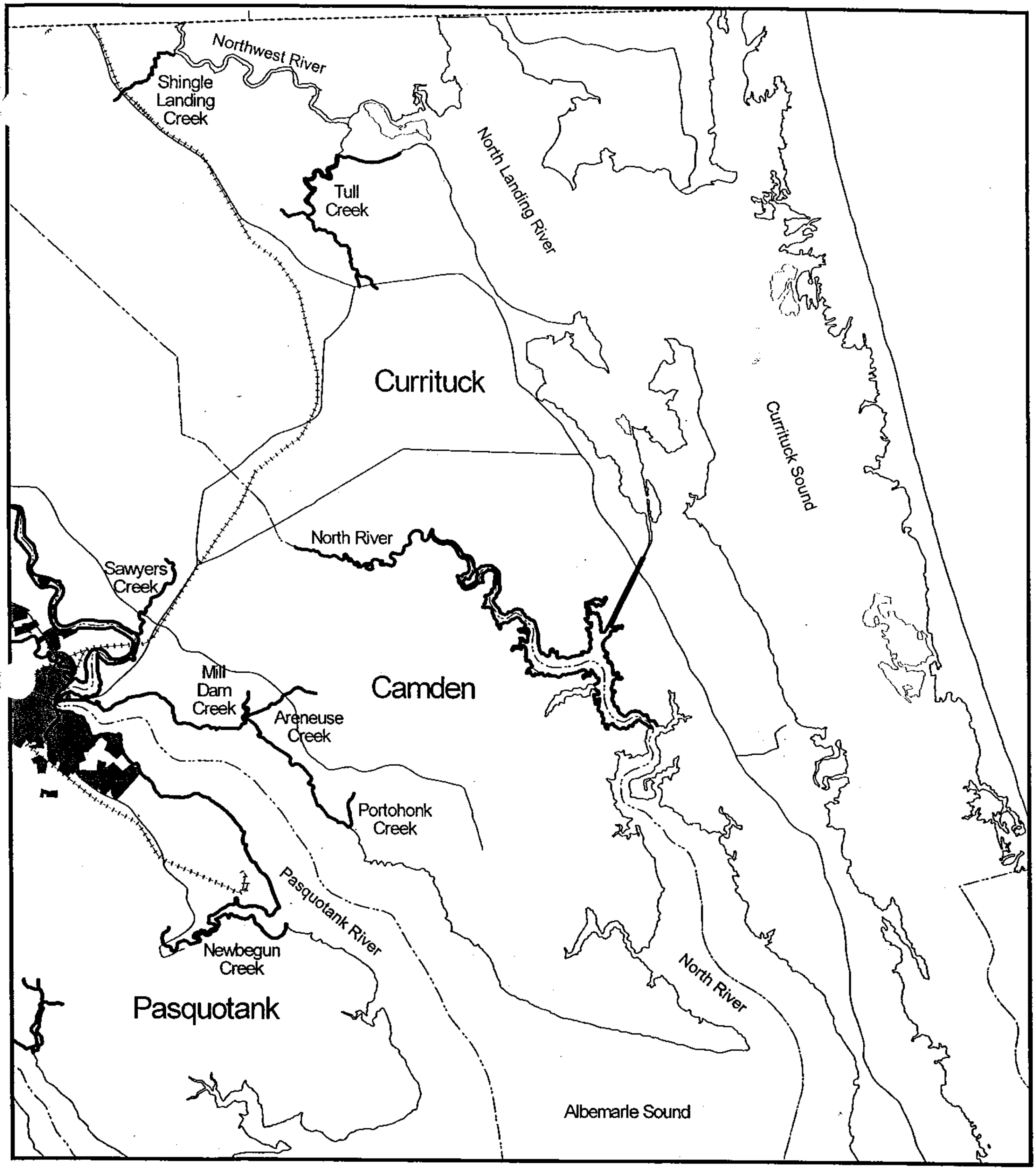
N
W E
S

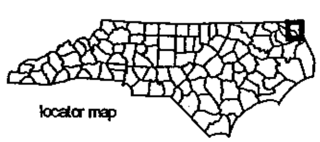
NAD 1927
November 1999

1:217305

1 0 1 Miles

North Carolina MARINE FISHERIES





Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area

Albemarle Sound

River Herring Use Areas

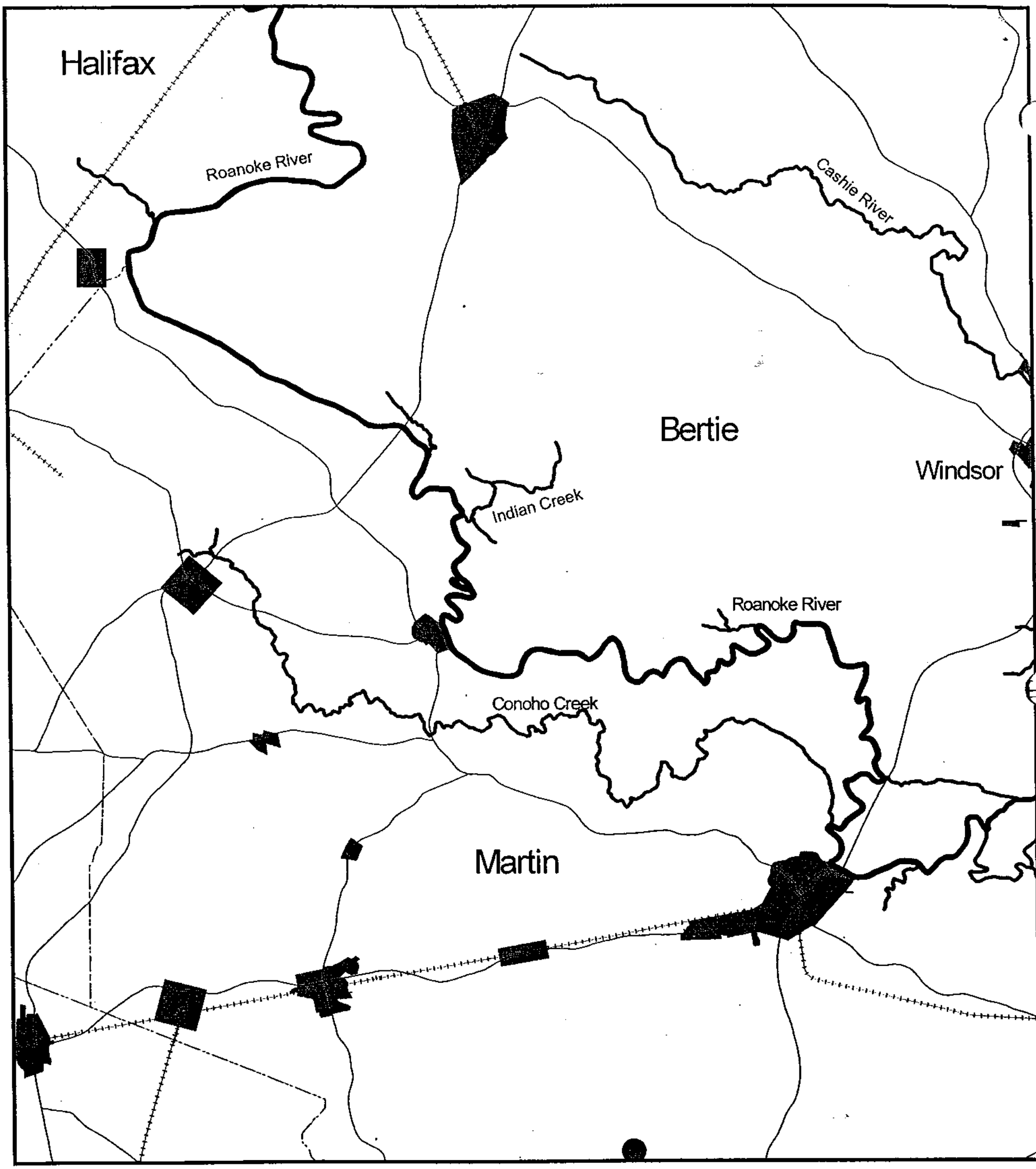
Map 5

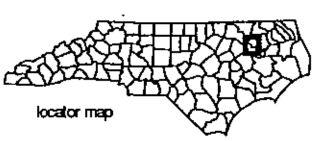
NAD 1927
November 1999

1:217305

1 0 1 Miles

North Carolina MARINE FISHERIES




locator map

Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area

Albemarle Sound

River Herring Use Areas

Map 6

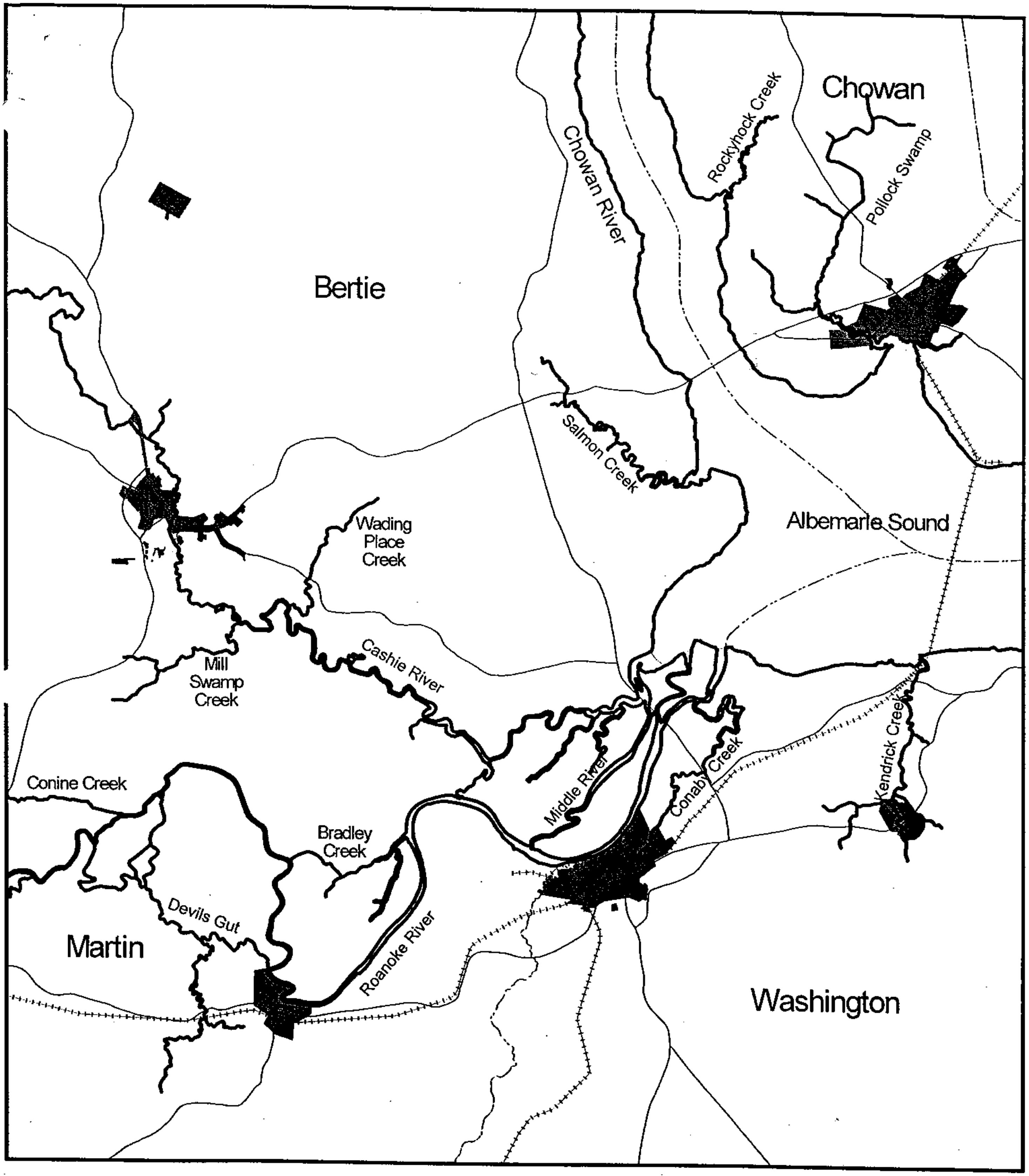
N W E S

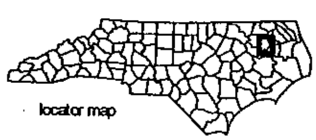
NAD 1927
November 1999

1:199812

0.8 0 0.8 Miles

North Carolina MARINE FISHERIES





Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area

Albemarle Sound

River Herring Use Areas

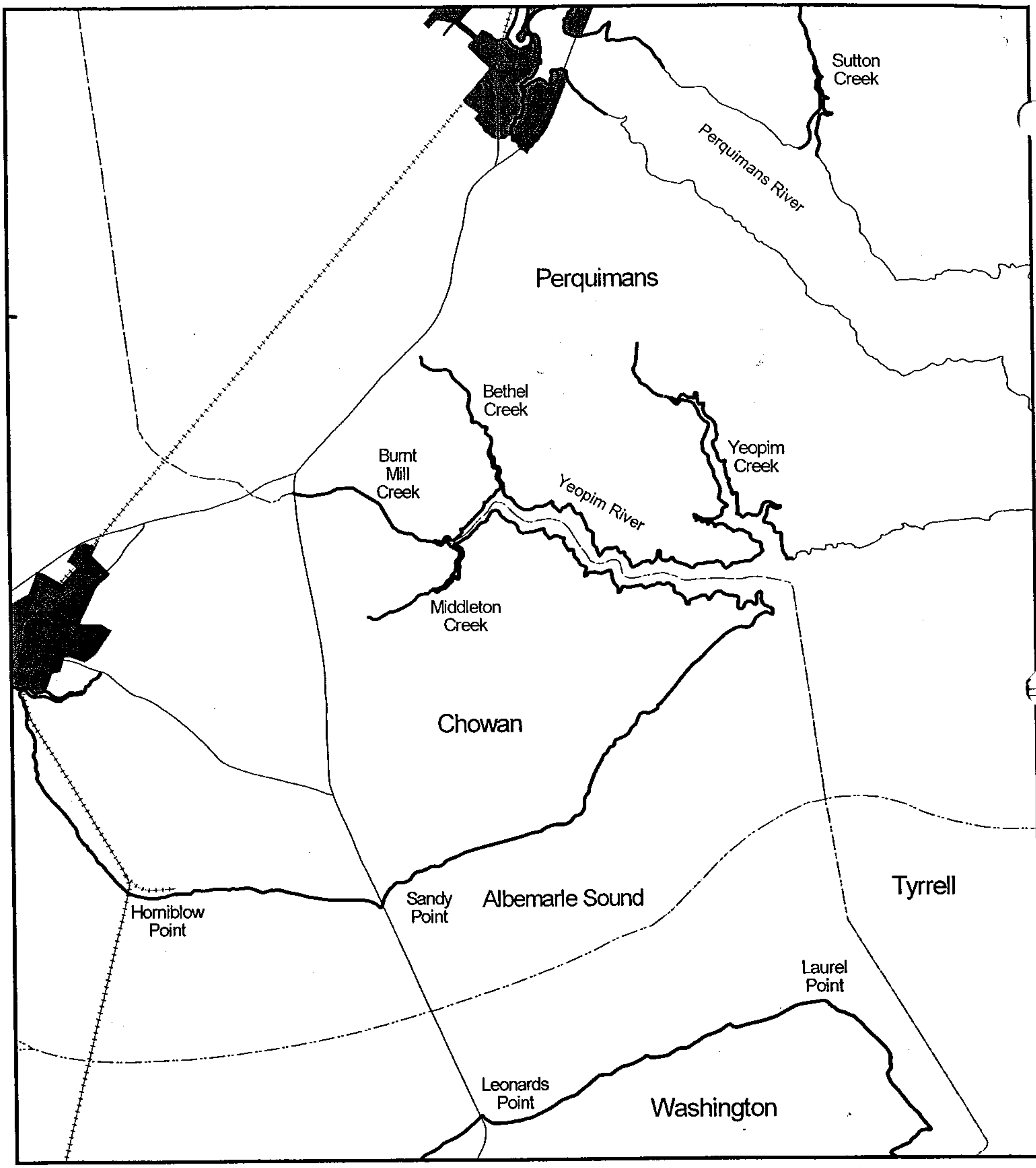
Map 7

N W E S

NAD 1927
November 1999
1:202831

1 0 1 Miles

North Carolina MARINE FISHERIES
Dept. of Environment and Natural Resources



locator map

Albemarle Sound

River Herring Use Areas

Map 8

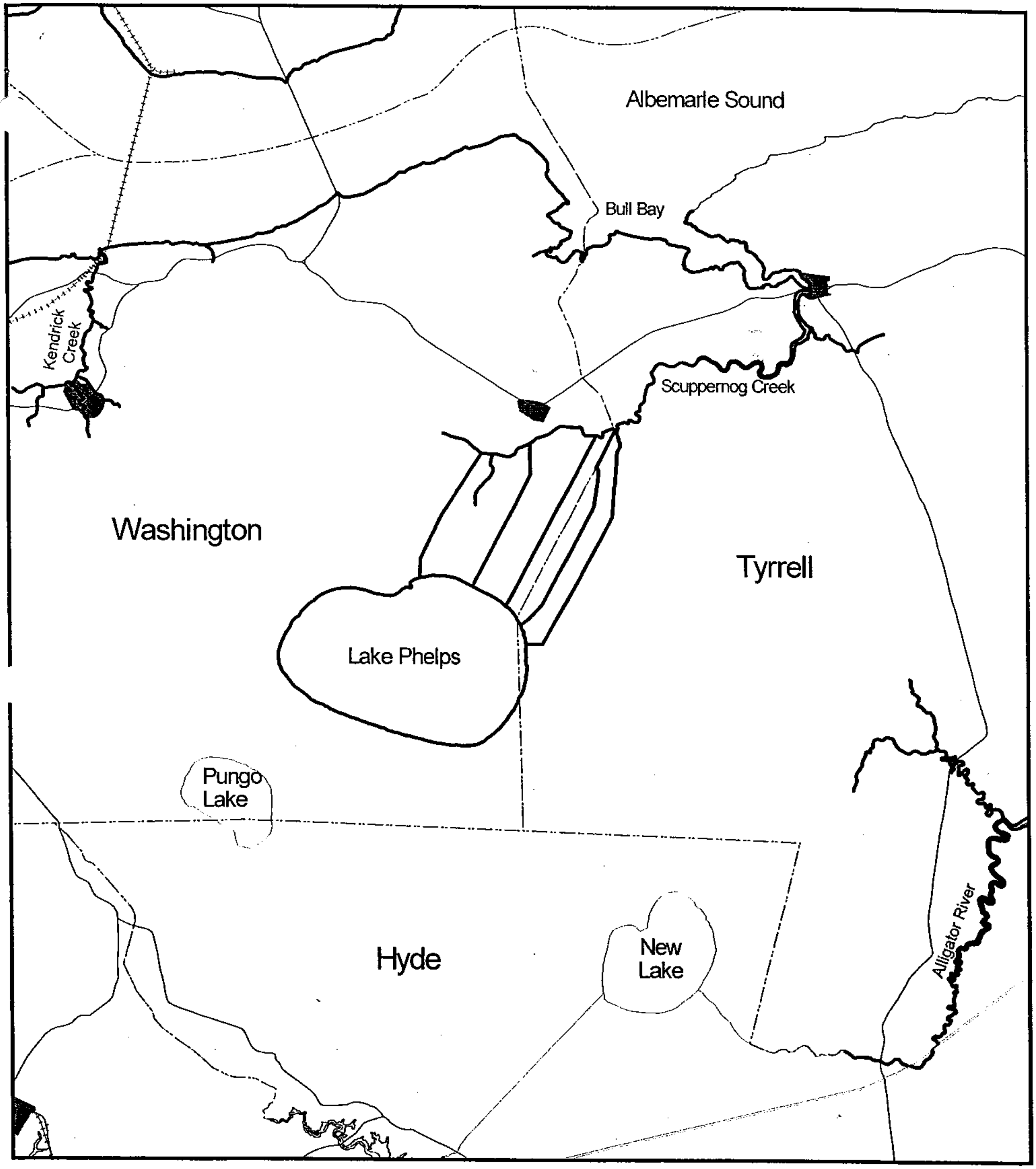
NAD 1927
November 1999

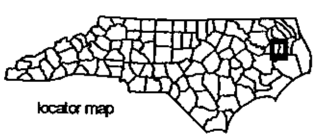
1:126547

0.5 0 0.5 Miles

Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area

North Carolina MARINE FISHERIES





Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area

Albemarle Sound

River Herring Use Areas

Map 9

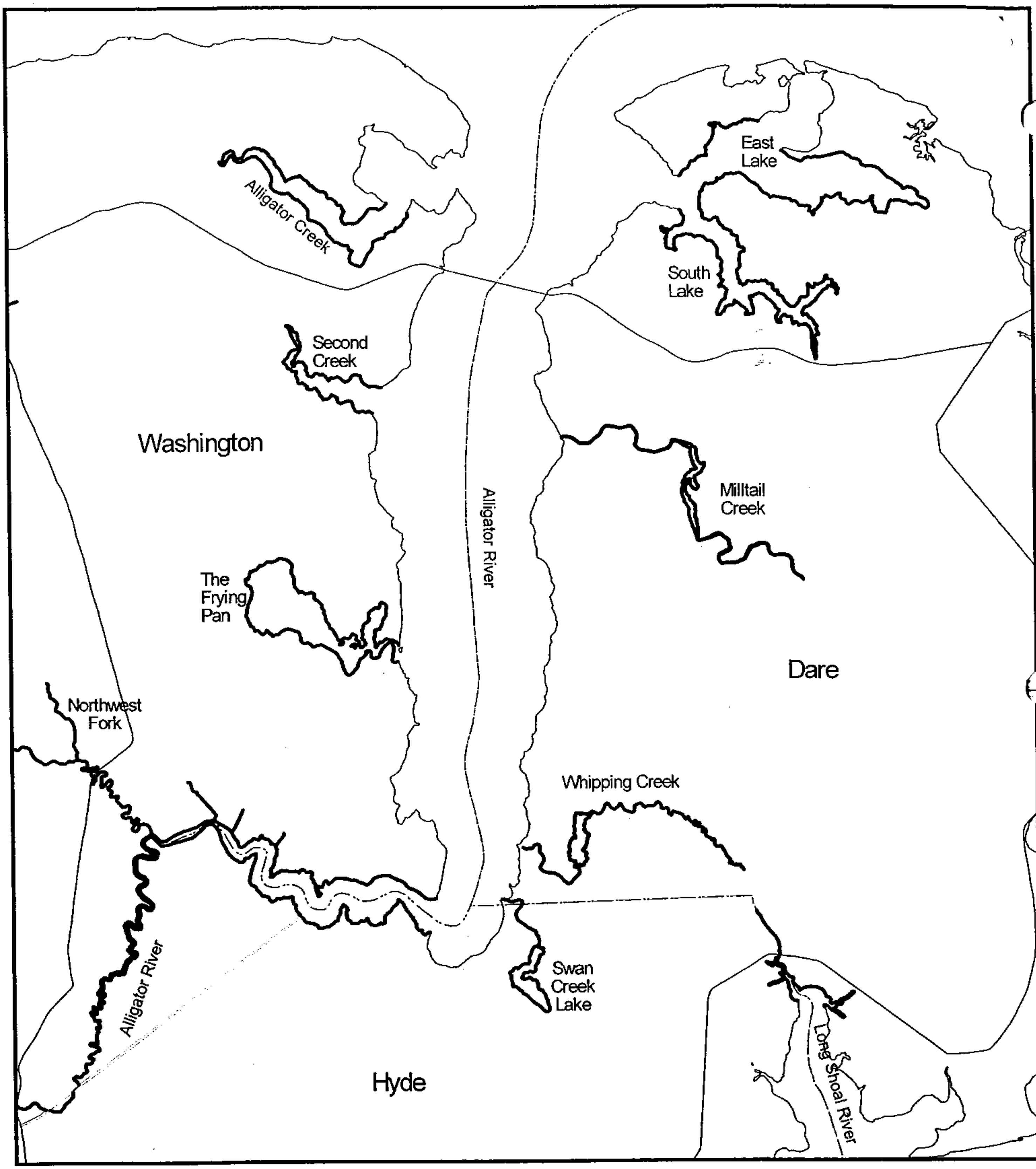
N W E S

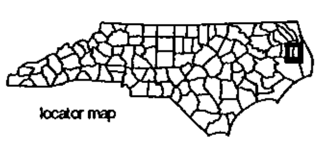
NAD 1927
November 1999

1:239438

1 0 1 Miles

North Carolina MARINE FISHERIES





Interstate
Primary Road, NC
Railroad
County Boundary
Municipality
Anadromous Fish Spawning Area

Albemarle Sound

River Herring Use Areas

Map 10

N
W E
S

NAD 1927
November 1999

1:216938

1 0 1 Miles

North Carolina MARINE FISHERIES

Appendix 4

HISTORICAL REGULATIONS PERTAINING TO RIVER HERRING IN NORTH CAROLINA

Historical Regulations Pertaining To River Herring

The following rules are quoted from the referenced rule books:

North Carolina Fishing Laws - Consolidated Statutes 1923- Fisheries Commission Board

If any person fishes on Sunday with a seine, drag-net, or other kind of net, except such as is fastened to stakes, he shall be guilty of a misdemeanor, and fined not less than two hundred nor more than five hundred dollars, or imprisoned not more than twelve months.

It is unlawful to set, fish or use any gill nets of any description, either stake, anchor or drift, for commercial purposes in the Albemarle Sound west of a line drawn straight from Batt's Island on the northern side of Albemarle Sound to mouth of Scuppernong River on the south side of said sound, except between the hours of four o'clock and eleven o'clock p.m., and then said nets or combinations of such nets shall not be more than six hundred yards in length, and there shall not be allowed to any boat more than six hundred yards. Any person, firm or corporation violating the provisions of this section shall be guilty of a misdemeanor and, upon conviction, shall be fined not less than two hundred dollars (one half to go to the informant and the other half to the school fund), or imprisoned in the discretion of the court.

If any person shall drift or fish any drift nets between the first day of February and the first day of May of any year, within two miles of the mouth of any river emptying into Albemarle Sound, or within three miles of any seine-beach on the Albemarle or Croatan sounds while being fished, or within ten miles of Ocracoke, Hatteras, Oregon or New inlets, or within ten miles of the Roanoke Marshes, he shall be guilty of a misdemeanor, and be fined not less than fifty dollars or imprisoned not less than thirty days: Provided, the people of Dare County shall be allowed to use drift nets for herring.

It is the duty of the Fisheries Commissioner or other persons entrusted with the enforcement of the fishery laws of the State to seize and remove any gill net of any description being set, setting or being used in violation of this article, or which is more than six hundred yards in length, and to dispose of the same as provided by law.

Rules and Regulations of the Department of Conservation and Development Relative to the Commercial Fisheries of North Carolina 1947

It shall be unlawful for any person, firm or corporation to fish nets of any kind in Albemarle Sound and its tributaries above a line drawn from Laurel's Point Lighthouse to Batts Island between sunset and sunrise during the shad and herring fishing seasons.

It shall be unlawful to fish with gill nets in Croatan Sound south of Fleetwood Point.

It shall be unlawful to set gill nets for shad in the Albemarle Sound or its tributaries above the new Highway bridge across Albemarle Sound at or near Pea Ridge; or to set nets of any kind within three hundred yards of said bridge.

It shall be unlawful to set anchor gill nets or to set any stake gill nets of any kind of more than twenty yards in length in that part of Croatan Sound between Roanoke Marshes lighthouse and a straight line from Caroon's Point to Rhodom's Point, or to set them in any water of the State within a distance of four hundred yards from the limits allowed for pound net fishing.

North Carolina Fisheries Rules and Regulations 1955. Laws Subchapter IV of Chapter 113 of the General Statutes of North Carolina. Department of Conservation and Development.

It shall be unlawful to set nets of any kind within 1000 yards on either side of a line drawn from Albemarle Sound through the center of Croatan Sound.

It shall ne unlawful to fish with gill nets of any kind in Croatan Sound south of Fleetwood Point. It shall be unlawful to set peg nets, anchor gill nets, stake gill nets or gill nets of any other kind in that portion of Croatan Sound north of Fleetwood Point in a length in excess of 20 yards, and such nets shall be fastened to stakes by the top line.

It shall be unlawful for any person, firm or corporation to fish drift gill nets in Roanoke River over 40 yards in length, or to drift any net within 200 yards of another net.

In order to protect and conserve the shad and herring during the spawning season, the Board of Conservation and Development hereby declares all waters of the state closed to taking shad and herring by any method from May 1 to June 1 of each year.

North Carolina Commercial Fisheries Rules and Regulations 1961. Department of Conservation and Development.

No net of any type may be used between sunset and sunrise during the shad and herring fishing seasons in Albemarle Sound or its tributaries west of the line between Laurel Point Lighthouse and Batt's Island.

No pound net, gill net, or seine may be used between April 25 and July 1 of any year in the Albemarle Sound between NC Highway 32 Bridge at Pea Ridge and Norfolk Southern Railroad Bridge. In the area between the Norfolk Southern Railroad Bridge and a line drawn 180° from the western end of US Highway 17 Bridge at Edenhouse, no pound net may be used between April 25 and July 1, and no gill net may be used between March 1 and July 1 of any year.

In Chowan River, no pound net or seine may be used between April 25 and July 1 of any year, no pound net may be used within 400 yards of the mouth of any tributary creek or within 100 yards of another pound net set.

No gill net may be used in the Chowan River below the northern tip of Holiday Island from March 1 to September 1 of any year; in the area above the northern tip of Holiday Island no gill net may be used from April 25 to September 1.

No gill net may be used in the Chowan River within 400 yards of any pound net set; gill nets which are not marked by visible corks or floats, or which are not set parallel to the shoreline, or which have a stretched mesh length of less than 3½ inches may not be used.

North Carolina Commercial Fisheries Rules and Regulations 1965. Department of Conservation and Development

Closed shad and herring season from May 5 through June 30.

No gill nets or seines may be used between May 5 and July 1 of any year in the Albemarle Sound between the Hwy 17 Bridge at Edenhouse and Hwy 32 Bridge at Pea Ridge.

After 1965 fisheries rules were re-written and no specific rules relative to river herring existed until 1995.