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A Century of Fishing and Fish Fluctuations in Narragansett Bay

Candace Oviatt,[1] Steven Olsen,[1] Mark Andrews,[1] Jeremy Collie,[1] Timothy Lynch,[2] and Kenneth Raposa[1]
[1] *Graduate School of Oceanography, University of Rhode Island, Narragansett, RI 02882 USA;*
[2] *Rhode Island Department of Environmental Management, Jamestown, RI 02835 USA*

ABSTRACT: Fish and shellfish abundance for Narragansett Bay and coastal Rhode Island waters from landing data and surveys were compared over the past century using the originally abundant species. The first quantitative data became available in the late 1800s as conflicts developed between the hook-and-line fishermen and the fish trap fishermen with the hook-and-line fishermen claiming a reduction in the availability of fish. Subsequent data were available from the state of Rhode Island and National Marine Fisheries Service landing data, and from the Graduate School of Oceanography and Rhode Island Department of Environmental Management surveys. In the early records, several anadromous fish species were abundant which are no longer abundant or not reported in recent surveys such as alewife, shad, and smelt. Changes in shellfish include the disappearance of soft-shell clam, cultured oyster, and scallop and a replacement by quahog although the landing of quahog is recently down. Lobster was abundant in the early record and has increased in abundance in the recent records. Several species of fish that once dominated the catch have decreased. Boreal species like winter flounder have decreased with increasing water temperatures over the past 30 years. Migratory fish like menhaden and food fish like scup have decreased to low levels in the late 1900s compared to the 1800s. Predictions of fish yield from primary production indicate that migratory populations sustained the fishery in the late 1800s but in the late 1900s these populations no longer exist to sustain such a fishery. Survey data indicate these waters without fish have become prime habitat for crabs and lobsters.

> *The legislatures of Massachusetts and Rhode Island in 1869–1870 requested a law be passed prohibiting fixed apparatus for catching fish.* (Spencer F. Baird, 1873).

> *The compelling argument is not regulation and terse fact; rather we must accept our responsibilities and obligations, as users and temporary proprietors of the coastal commons, to keep track of what is happening there, to measure changes as they occur both naturally and in response to our presence, and to act responsibly—all this because we, too, are part of nature. It follows, than, that planning, restoration, and overall responsibility can and should become part of our existence. How well we are progressing is the job of monitoring.* (H. Perry Jeffries *et al.*, 1988)

KEY WORDS: Fishing, fluctuations, Narragansett Bay, fish.

INTRODUCTION

In the normal course of events, humans continually improve the procedures by which they accomplish a task. Fishermen provide a convincing example of this statement (Pol and Carr, 2000). Fishermen have changed their methods for catching fish from hand-lines and seines in the early 1800s, to pound and heart traps in the late 1800s, to bottom trawls in the mid-1900s, moving from inshore to offshore as fish inshore succumbed to more efficient methods. With the transition to each new gear, fishermen, mainly those using the older method, express concern that the new gear will catch all the fish. In the 1860s, the use of fish traps caused dismay in the community. The General Assembly of Rhode Island appointed a Joint Special Committee to examine the fisheries of Rhode Island. Based on their findings through interviews that committee recommended, an unsuccessful law to prohibit the trap fishery (Joint Special Committee, 1870). At the same time Spencer F. Baird of the Smithsonian was commissioned by Washington to assess the facts on fish abundance, resulting in the first summary of fishery statistics for the U.S.

The dramatic improvement in fish capture technology in the mid 1800s involved large traps constructed of net, stakes, anchors, and floats (Harkness, 2001). A "leader," several tens of meters in length, extended out from the shore forming a barrier to migrating fish. The fish would follow this leader that ended in a square or heart-shaped holding trap or pound that work boats emptied every day or so. Whole schools of fish were captured in these traps as they migrated along the coast.

Through interviews and accumulations of landing data, Baird (1873) assessed populations of fish in the waters of southeastern New England. A sampling of hook-and-line fishermen interviews suggested an amazing abundance of fish in Narragansett Bay in the early days of traps (Baird, 1873). John D. Swan reported, "There was one place where (scup) run over a point where the waters was 3 m deep and they were so thick as to be crowded out of the water." Nathaniel Smith reported "One man could catch enough scup 40 years ago to load a boat in a short time. I have seen the water all full of them under my boat." George Crabb caught 180 kg of tautog in one day in 1870 and from 45–90 kg of tautog on single days in 1872. Joseph Sherman caught 110 kg of tautog and 18 kg of sea bass and cod in just 3 hours in 1869. Benjamin Nason and his father caught 270 kg of tautog and cod in one day in 1870. Mr. H. G. caught 450 kg of striped bass in 2 hours in 1870. Meanwhile, the traps caught about 500,000 kg per trap over the 25-day spring season (Baird, 1873). Did the traps reduce the fish populations available to hook-and-line fishermen? Some evidence even suggested a decline in trap catch between the earliest records and the late 1800s. In 1857, W. C. H. Whaley set traps off Sakonnet and Watch Hill and recorded catches of roughly 11,000,000 kg of fish. Fourteen years later, in 1871, the catch for these traps declined to about 817,000 kg, a 92% decrease in landings (Baird, 1873). Part of this decline may have been due to an increase in the number of traps (Figure 1). The first trap was set at Sakonnet Point in 1845; by 1871, nine traps were located at Sakonnet Point (Baird, 1873). Baird (1873) argued that a decline was indicated by the increase in the effort required to obtain an equal catch and the lack of fish in areas where they had once been abundant throughout the season.

This analysis and accurate description of the fishery did not result in legislation limiting the trap fishery. In the late 1800s to the 1920s, over 200 fish traps ringed the shores of Narragansett Bay and lined the southern coast of Rhode Island (Figure 1). The Annual Reports (State of Rhode Island and Providence Plantations, Inland Fisheries, 1880s to 1932) indicated 119 traps in 1898, a peak of 267 traps in 1913, and 159 traps in 1920. During this period, hand-lining ceased to be an important method of catching fish.

The trap fishery, in turn, began to decline as a trawl fishery became the more efficient method for catching fish. In 1960, 16 traps were still leased in Rhode Island waters (Power, 1962). These traps caught roughly 170,000 kg of fish per trap during the season (Power, 1962) compared to 1871, the early period in the history of the trap fishery, when 500,000 kg per trap were caught (Baird, 1873). The catch became poorer by the end of the 1960s decade when 23 traps caught roughly 60,000 kg per trap. The trap industry continued to catch fewer fish and was weakened by competition with the trawl fishery. Legislation was introduced with the purpose of increasing fish in Narragansett Bay, and most of the bay was closed to the trap fishery in 1966 (Holmsen, 1973). By 2000, less than 10 traps still fished Rhode Island coastal waters. Recent catch from a Newport trap has been 20,000 kg per season in the 1990s, although an early season catch was double this in one day in 2001 (Harkness, 2001).

The bottom trawl consisted of a large net bag towed behind a fishing boat (Cushing, 1982). With the steam trawler came a double winch that enabled the use of otter boards on separate bridles in the late 1800s in the North Sea, and first used in Rhode Island coastal waters in the 1930s. The mouth of the net, usually a weighted bottom line or chain, and a buoyant head rope was held open by the two otter boards towed to either side. The boards and the bottom chain dragged the bottom, herding fish and invertebrates—usually into the net. A cod end at the back of the bag had a smaller, usually diamond, mesh that held the catch secure until brought aboard (Glass, 2000). Small day boats fished inshore waters but by the 1960s, Narragansett Bay was no longer the site of a large commercial fishery. The fish were being caught out to sea by fleets of long distance trawlers. From the 1960s to early 1970s, offshore foreign fleets harvested everything captured in their large trawls (DeAlteris *et al.*, 2000). With the implementation of the Fishery Conservation and Management Act in 1976, harvesting by foreign fleets ceased but as the capacity of the domestic fleet increased, pressure on ground fish caused declines in offshore stocks beginning in the 1980s. While the domestic fishery was more selective for valuable fish, leaving skates and sharks behind, this strategy caused great changes in the species composition of the offshore community (DeAlteris *et al.*, 2000).

The decrease of fish has become a familiar pattern for all major fishing grounds. The decline in many regions began after the 1950s with improved technology and increased effort (Ojaveer and Lehtonen, 2001). The ecosystem impacts, caused by the loss of large marine vertebrates due to fishing, has become an important topic (Jackson *et al.*, 2001). This article traces the changes with fishing pressure over the past 100 years in one northeast estuary but what can be observed in this small portion of coastal waters reflects the changes that have happened or are in progress in coastal waters worldwide. The question for this article was the same one Baird addressed. Are fish and shellfish less abundant in Narragansett Bay and the region now than in the past? Are fish abundance trends a function of fishing pressure or some other factor(s)? Although many surveys routinely collect information on fish, it is humbling to realize that we still face the same lack of quantitative information that Baird (1873) faced 100 years ago. Populations of fish are known relative to the method of capture and not as a census value or area abundance. Has fish abundance really decreased or is this perception clouded by limited assessment abilities? By gathering survey and fishery landing data and estimating area of capture, we assessed change in species composition and biomass. We considered such factor as fishing activity, climate trends, habitat loss, pollution, or combinations of these factors operating in the northeast regional fishery.

METHODS

Survey and landings data have been compiled from state, university, and federal sources. For the late 1800s and early 1900s, the Baird and Goode Reports (Baird, 1873; Baird and Goode, 1881; Goode and Associates, 1887) provided early comprehensive information based on interviews of fishermen. From the early 1900s to the late 1920s—prior to the Depression—annual reports by the state of Rhode Island (1900–1928) consistently reported fish and shellfish catch for localities in Rhode Island. These data were not comprehensive for the state and were presented by town in Rhode Island, and by species. For recent information, the National Marine Fisheries Services (NMFS) has reported Rhode Island landings data (Power, 1962; National Marine Fisheries Services, 1985; NMFS website: http://www.st.nmfs.gov/st1). The federal annual landings weight data are compiled by species and sometimes by gear, near shore/offshore, and by location, but not separated to the Narragansett Bay yield. Since the 1950s, otter trawl survey data (30 min tows; 2.5 cm stretch mesh in the cod end) have been collected weekly from a Fox Island station off Wickford in Narragansett Bay by Charles J. Fish, H. P. Jeffries, and currently by J. Collie at the Graduate School of Oceanography (GSO) at the University of Rhode Island. Data from the Fox Island station represents fish populations in the mid to lower West Passage in 6–7 m of water over a silty-sand sediment (Figure 1). These data are available upon request (jcollie@gso.uri.edu). From 1979 to 2000, the Rhode Island Department of Environmental Management (RIDEM) has conducted spring and fall trawl surveys (20 min tows at 2.5 kts) at about 26 stations in Rhode Island coastal waters (Lynch, 2000). Distribution of sampling stations employed both random and fixed allocation. Fixed stations have been established to sample discharge features and distinctive areas. Since 1990, monthly surveys have been conducted at 13 fixed stations in Narragansett Bay during the summer months (Lynch, 2000). The 3/4 scale high-rise bottom trawl had a head rope length of 13.7 m, a foot rope length of 18.3 m, and a cod end liner mesh of 0.95 cm, *i.e.*, the trawl was designed to catch all but the smallest sizes. For consistency, we have only used the spring and fall data. Trawl survey fish and invertebrate data are presented by number per tow, and in addition, by the state surveys, biomass per tow. For some analyses, the data have been compiled by 5- or 10-year time intervals and reported as wet weight or as percentage of the total for the species or species group.

For some comparisons, number or biomass per area have been estimated using the speed of the tow, the duration of the tow, and the width of the net. The 1800s and 1900s data were compared by making assumptions on the size of the habitat

TABLE 1

Metric Conversions for Historical Fish and Shellfish Catch, for Standing Crop, and For Habitat Area Comparisons of Fish and Shellfish Biomass

Fish and Shellfish Wet Weights
- 1 barrel = 200 lbs = 91 kg (RI Annual Reports, Inland Fisheries; Baird (1873) indicates 1 barrel = 150 lbs = 68 kg; 25% error possible)
- 1 bushel scallops ≈ 7 lbs wet weight ≈ 7 lbs gallon l^{-1} ≈ 0.8 kg l^{-1}
- 1 bushel clams ≈ 10 lbs wet weight ≈ 4.5 kg
- 1 bushel oyster ≈ 8 lbs wet weight ≈ 3.6 kg
- g wet weight m^{-2} = lbs $acre^{-1}$ * 454 g lb^{-1} 4047 m^{-2} $acre^{1}$

Net tows (Assume 100% efficiency): Number or biomass, kg w w m^{-2}
- RIDEM: fish m^{-2} = tow speed (2.5 kts) * tow time (20 min) * net width (8 m)[1] * fish tow^{-1}

Rhode Island Landings:
- Areas of Narragansett Bay including Mt. Hope and Sakonnet River, (Chinman and Nixon, 1985): 342 × 10^6 m^2 (NB)
- Area of Coastal waters to 3 nautical miles: 452 × 10^6 m^2 (CW)
- Shellfish area (Chinman and Nixon, 1985):

Oysters	0–1 m, 30 × 10^6 m^2
Soft clam	1–2 m, 21 × 10^6 m^2
Quahog	0–4 m, to 1971, 67 × 10^6 m^2 upper bay; 0–8 m, after 1971, 145 × 10^6 m^2 upper bay (Pratt, 1987)
Scallop	1–2 m, 21 × 10^6 m^2

- Fish and Lobster Area
- Lobster, Menhaden, Scup, Mackerel, total fish-NB and CW
- Alewife, Shad, Smelt, Eel, Flounder, Striped Bass, Bluefish, Tautog, Weakfish-NB
- Cod-CW

[1]net width = mean of bottom and headline lengths (Dealteris, personal communication). For the RIDEM net, this value was 8 m.

area. We calculated fish and shellfish abundance for the estimated area of the habitat (Table 1). An implied assumption of these estimations was that catch approximated abundance. For each shellfish species, a depth for the habitat was estimated: 0 to 1 m for oyster, 1 to 2 m for softshell clam, and 0 to 8 m for quahog depending on depth of exploitation. For lobsters and some fish, we estimated the area of Narragansett Bay and coastal waters to 3 nautical miles off shore (Table 1). For other fish species, we estimated the area of Narragansett Bay; for cod we estimated the area of coastal waters (Table 1). Areas for these designations were available in Chinman and Nixon (1985) or state coastal waters were estimated as a rectangular area 44 nautical miles (length of Rhode Island coastline) by 3 nautical miles offshore.

These habitat area estimations have an unknown associated error. For example, for oyster habitat, all oysters were not intertidal, but grown in extensive subtidal beds; the original natural habitat was probably intertidal to subtidal in the upper bay and coastal ponds (Table 1). Some species of fish were caught in traps along the coast and ringing the bay. They may not have ranged to 3 nautical miles offshore. Some fish, winter flounder, for example, may have been largely caught in winter in the bay but when offshore in the summer, not caught by early hand-liners. Lobsters have always been caught in the bay and offshore to 3 nautical miles or further (Table 1). Several of the original fish species such as scup, cod, mackerel, and swordfish were caught at increasing distances offshore or along the continental shelf and not within

TABLE 2

The 1880 Annual Fishery (Good and Associates, 1887) Catch of Fresh Fish, Processed Fish, and Shellfish, kg w w. The Listed Name, Current Common Name, and Scientific Name are Provided (American Fisheries Society, 1991; Collette and Klein-MacPhee, 2002; Gosner, 1978)

List Name	1880 Catch	Common Name	Scientific Name
Fresh Fish			
Alewife	64,000	alewife	*Alosa pseudoharengus*
Sea bass	89,000	black sea bass	*Centropristis striata*
Striped bass	133,000	striped bass	*Morone saxatilis*
Tautog	212,000	tautog	*Tautoga onitis*
Bluefish	335,000	bluefish	*Pomatomus saltrix*
Cod	310,000	atlantic cod	*Gadus morhua*
Eel	124,000	American eel	*Anguilla rostrata*
Flounder & flatfish	160,000	winter flounder	*Pseudopleuronectes americanus*
		summer flounder	*Paralichthys dentatus*
Mackerel	40,000	atlantic mackerel	*Scomber scombrus*
White & yellow perch	14,000	white perch	*Morone americana*
		yellow perch	*Perca flavescens*
Salmon	180	atlantic salmon	*Salmo salar*
Scup	3,038,000	scup	*Stenotomus chrysops*
Shad	22,000	american shad	*Alosa sapidissima*
Smelt	43,000	rainbow smelt	*Osmerus mordax*
Squeteague	148,000	weakfish	*Cynoscion regalis*
Swordfish	41,000	swordfish	*Xiphias gladius*
Mixed fish	162,000		
Food Fish Total	5,921,000		
Processed/Industrial Fish			
Dry Cod (fresh wt.)	877,000		
Alewives (fresh wt.) (pickled and smoked)	1,059,000		
Menhaden (for oil and scrap)	31,187,000	Atlantic menhaden	*Brevootia tyrannus*
Mixed Fish	615,000		
Shellfish			
Lobster	192,000	northern lobster	*Homarus americanus*
Clams	245,000	soft shell clam	*Mya arenaria*
Scallop	57,000	bay scallop	*Aequipecten irradians*
Oyster	593,000	common oyster	*Crassostrea virginica*

state territorial waters (Table 2). For the sum of all errors, estimates were likely only within 50%.

Weight units have been converted from barrels, bushels, and pounds to kilograms wet weight. A barrel has been indicated as 68 or 91 kg by two different sources (Table 1). A value of 91 kg per barrel was adopted, assuming the more local source was correct. A barrel was probably not a constant weight in any case; up to +25% error may be associated with these values. A weight for a bushel of shellfish changes according to species but also with the condition and size of the individuals. Up to a 25% error may be associated with these values.

Net efficiency was conservatively estimated at 100%. In general, trawls are very efficient and this efficiency has been improved for over 100 years (Pol and Carr, 2000). For example, the 1995 bristle sweep that was developed in New Bedford, was considered so efficient that it was quickly banned (Pol and Carr, 2000). Unlike the selectivity of true fishing gear, assessment trawl surveys have been conducted to sample everything except the smallest sizes. The actual catch efficiency may be variable from 15–100% depending on species, condition of the bottom, net configuration, tide, weather, etc. (Dealteris, personal communication; Glass, 2000; Pol and Carr, 2000). The variability in efficiency makes any estimate questionable; thus the most conservative approach has been used. The catch values may be up to 85% too low compared with true abundance. While these estimates may be conservative by a factor of three, the assumptions are the same as those made for a "standard tow." A "standard tow," that is often used for statistical within and between station/time comparisons, assumes an implied, unreal, constant catch efficiency.

RESULTS

FISHERY OF THE LATE 1800s

In 1880, several fisheries, including the trap fishery, were well established in the upper and lower bay, with fish and shellfish showing high yields in both areas (Table 3). Enormous quantities of menhaden were processed by a factory located in Portsmouth, Rhode Island (Figure 1). Tiverton, Newport, Wickford, and Saunderstown had the highest food fish catches. Pawtucket, Apponaug, and East Greenwich had the highest shellfish catches. High numbers of lobster were landed in Newport, Bristol, and Wickford. Earlier records for shellfish in 1865 indicated that oysters had the highest yield in the Providence River area (Table 4). By 1879, most

TABLE 3

1880 General Fisheries of Rhode Island by Town (Goode and Associates, 1887) Ordered from the Northern Part of Narragansett Bay to the Southern Part in kg w w or MT (Wet Weight in Metric Tons) as noted

Town	Fish, kg	Shellfish, kg	Lobster, kg	Comment
Pawtucket	17,000	220,000		mainly clams
Warren		432		some shad
Bristol	75,000		10,000	swordfish abundant
Warwick Cove	1800			eels
Apponaug	17,000	26,000		scallops, clams
East Greenwich	60,000	37,000		scallops, clams
Tiverton	559,300	4358		alewife, menhaden, & freshfish
Portsmouth	454–817 MT			menhaden
Wickford	172,000		7000	freshfish, eels, refuse fish
Saunderstown	520,000			freshfish
Newport	245,000 + 190 MT scup		72,000	freshfish, swordfish scup
Little Compton	32,000			scup

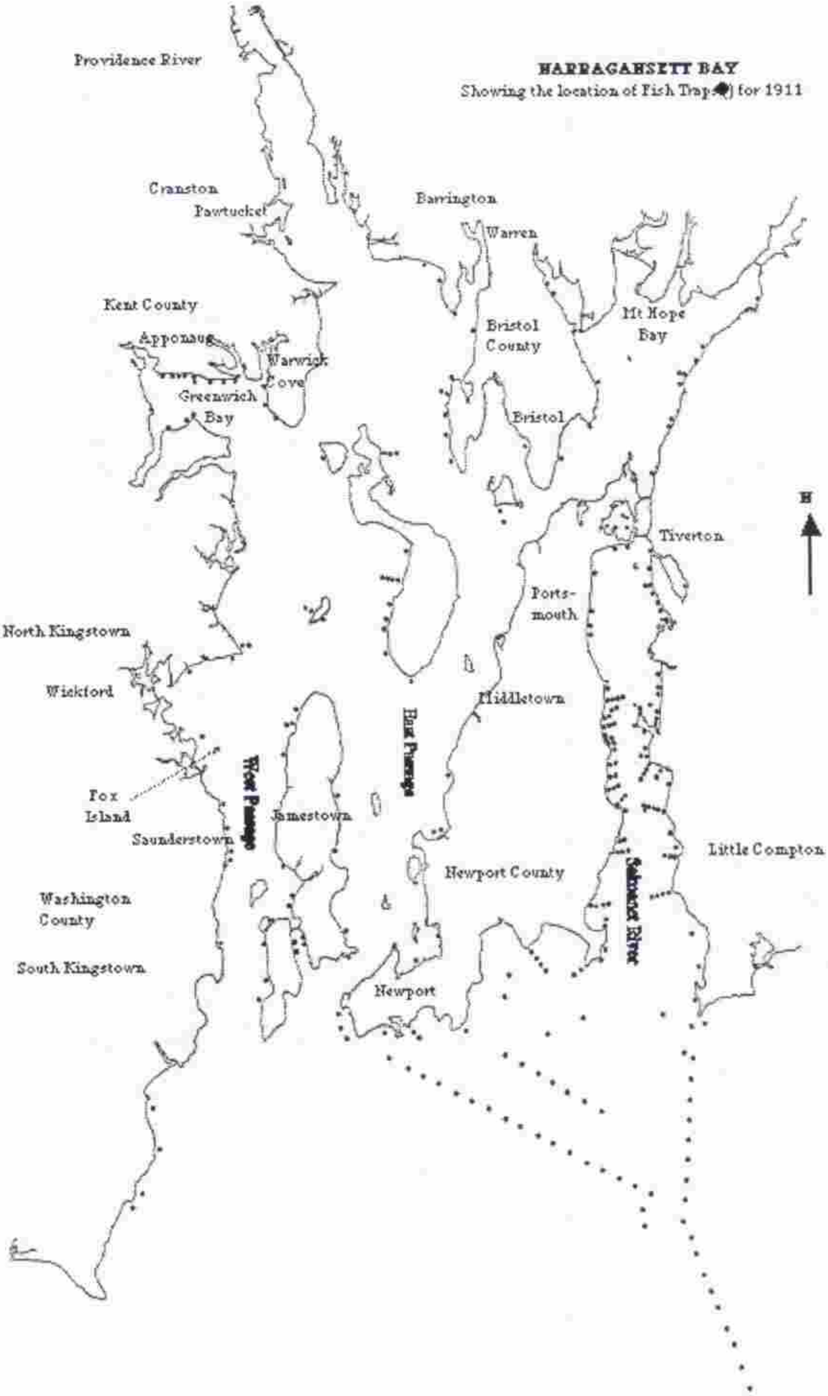

FIGURE 1. A map of Narragansett Bay indicating the location of floating fish traps in 1911 and place locations referred to in text (modified from State of Rhode Island and Providence Plantations, Inland Fisheries Report, 1911).

TABLE 4

Rhode Island Shellfish Catch Ordered From the Northern Part of Narragansett Bay to the Southern Part for 1865 (Goode and Associates, 1887), in Bushels with Comment From the Interviews[1]

Town	Clams	Quahogs	Scallops	Oysters
Providence	404	2966	3	50,450
East Providence	3405	830	—	12,100
Cranston	200	—	—	—
Barrington	962	457	—	—
Warren	1215	10	—	—
Bristol	200	—	—	—
Warwick	9125	2953	1627	242
East Greenwich	1415	339	6635	13
Tiverton	576	55	—	—
Portsmouth	7715	145	500	—
Middletown	119	—	—	—
North Kingstown	5740	1480	870	
South Kingstown	257	—	18	3070
Jamestown	162	6	—	—
Newport				

[1]Based on opinions of owners of shore farms.
Amounts should be doubled to estimate the truth.

of the oyster harvest was not native; the oysters were transplanted from Connecticut and other southern estuaries; 42% of the beds were owned by out-of-state companies (Goode and Associates, 1887). Bay scallops were mainly landed from the Greenwich Bay area; quahogs were mainly landed in upper bay areas; soft shell clams were abundant everywhere (Table 4).

The biomass of fish landings for the state of Rhode Island was first listed by species in 1880 (Table 2). The most important fresh food fish by far was scup, caught mainly in the trap fishery. Tautog, bluefish, and cod were the second-tier big three, followed by sea bass, striped bass, eel, flounder, and weakfish. For dried, pickled, and smoked fish, cod and alewives ranked the highest. The industrial menhaden had a factor of 10 greater yield than the second most abundant species, scup. Oyster meats were the second largest biomass of fresh food landed and worth more in dollars than any other species at $.54 per kg (Table 2). Lobsters, by contrast, were worth about $.08 per kg. Two anadromous species, sturgeon and salmon, were already disappearing (Goode and Associates, 1887). Other anadromous fish—alewife, shad, and smelt—were still abundant where dams had not yet obstructed their freshwater passage, but overall abundance of these species had declined greatly from historical levels (Buckley and Nixon, 2001).

FISHERY OF THE LATE 1900s

By the latter half of the 20th century, fishery-yield for the dominant species of the late 1800s had shifted to down bay and offshore locations. In 1960, the lower bay and

TABLE 5

The 1960 Rhode Island Landings are Shown for Fish and Shellfish by County (Power, 1962) (kg). This List Contains the Same Species List Except for Those no Longer Caught as the 1880 List of Table 2. The Difference Between This Total and the Total for All Species Caught in 1960 is 6 × 10^6 kg Shown at the Bottom

	Bristol	Kent	Newport	Washington	Total
Fish					
Alewife	—	—	—	—	—
Sea bass	—	—	—	—	—
Striped bass	—	—	32,000	3000	35,000
Tautog	—	—	22,000	8000	31,000
White perch	—	—	—	2000	2000
Bluefish	—	—	14,000	1000	16,000
Cod	—	—	160,000	213,000	373,000
Eel	8600	8000	—	3000	20,000
Flounders	—	—	182,000	914,000	1,676,000
Fluke	—	—	246,000	335,000	—
Mackerel	—	—	38,000	18,000	56,000
Scup	—	—	2,060,000	898,000	2,958,000
Squeteague	—	—	300	700	1000
Swordfish	—	—	13,000	83,000	96,000
Mixed fish	—	—	20,000	6,848,000	6,868,000
Menhaden	—	—	17,000	11,128,000	11,145,000
					23 × 10^6 Total
					12 × 10^6 w/o
Shellfish					
Clam					
hard	505,000	753,000	63,000	136,000	1,457,000
soft	2000	—	—	—	—
Scallop	—	—	—	—	—
Oyster	—	—	—	211,000	11,000
Lobster	36,000	1000	136,000	110,000	289,000
Total (all species)	568,000	816,000	5,312,000	24,775,000	25 × 10^6 list
					31 × 10^6 all

w/o = menhaden.

coastal landings were higher than the upper bay for all species except eel and quahog (Figure 1, Table 5). By far, the largest biomass of fish landed was still menhaden, but many of these fish, while still caught in Rhode Island waters, were beginning to be landed by purse seiners to more southern states such as New Jersey. The apparent decrease in Rhode Island menhaden landings from 31 × 10^6 kg in 1880 (Table 2) to 11 × 10^6 kg in 1960 (Table 5) may or may not be real.

Rhode Island landings for 1960 represent total Rhode Island fish, a portion of which may be from outside Rhode Island territorial waters. Trawlers were now fishing far outside of state territorial waters. However, the source of error in estimating 1960 biomass from Rhode Island territorial waters was reduced compared to most years. Landings of otter trawl mixed fish from offshore fell by 78% in 1960 due to high supply the previous year and subsequent sluggish demand from hog and

TABLE 6
Rhode Island Fishery Effort for Different Types of Gear in 1880 and 1960, kg man^{-1} season^{-1}

	1880[1]	1960[2]
Heart pounds - 3 men	284	17,000
Traps - 6 men and a cook	13,670 (scup) 8694 25,970	9300
Handline from vessel	4700 (includes swordfish) 3200	450–4500 (bluefish and striped bass, Oviatt, 1977).
Shore seine	6800 (Alewives) 1400 4000 (Perch)	22,000 (assuming 2 men)
Lobster - vessel & traps	1600 1400 (27 kg pot^{-1} 1906[3])	7300 (16 kg pot^{-1} in 1960 and 9–12 kg pot^{-1} in 1994, NMFS)
Digging soft shell clam	360 950 1100	no data
Dredging scallop	530 190 290	no bay scallop
Spearing eel (winter)	900	55 kg pot^{-1}
Otter trawl	—	126,000 (assuming 3 men) (60,000 in 1997, assuming 3 men)

[1]Goode and Associates, 1887.
[2]Power, 1962 (New England).
[3]Rhode Island Fisheries, 1907.

poultry farmers (Power, 1962). The mixed fish (681 MT), cod (136 MT), yellowtail flounder (90 MT), and whiting (136 MT) were likely caught in offshore waters, like Nantucket shoals and not included here in the totals for Rhode Island waters (Table 5). The remainder (1044 MT), including menhaden, have been assumed to be from state waters. Scup from floating traps held second place as the highest biomass of fish after menhaden from purse seine gear, followed by flounder, swordfish, and mackerel. No anadromous fish had significant landings (Table 5). With the exception of quahogs and lobsters, shellfish had disappeared (bay scallops) or become unimportant (softshell clam, oyster) (Table 5).

FISHERY EFFORT 1880 AND 1960

As Baird noted, an increased effort to catch an equal amount of fish suggests less abundant fish. Sufficient information from Goode and Associates (1887) and Power (1962) permits various gear—effort comparisons for the two periods of 1880 and 1960 (Table 6). Comparisons on the basis of kg per man per season did not indicate detectable differences for the trap fishery, or the hook-and-line fishery. Shore seines appeared to catch a higher biomass in 1960 than in 1880, but this may be the result of sparse data or inexact comparison of gear or area covered. While the overall catch of lobsters increased four-fold, the catch per pot declined by 50%. This indication of reduced catch per effort, combined with the lack of recent comparable information for soft shell clam and bay scallop, provides a sense of more fishermen catching less shellfish in 1960 compared to 1880. The big change is the bottom trawl fish catch where one man catches eight times what can be attributed to a trap fisherman (Table 6).

CHANGES IN SPECIES COMPOSITION 1960 TO 2000

Three trends in species composition appeared in the last 40 years of trawl survey data which may be related to climate, pressure of the bottom trawl fishery, or both. One trend was that northern species have decreased. Abundance from the Narragansett Bay, Fox Island station, indicate reduced numbers of the northern sea robin and winter flounder (Figure 2). A second trend was that as bottom fish species decreased, several species of decapods increased including blue crabs, cancer crabs, lady crabs, and lobsters. The two species of cancer crabs and lobsters from the Fox Island station have increased by factors of 400 and 200, respectively, in the 1990s compared to the 1960s (Figure 3). The latter has increased despite a large increase in fishing effort and lobster landings (Table 6). A third trend was all bottom fish—commercial, noncommercial, northern and not—appeared to have decreased as some pelagic species, with the exception of scup, have increased (Figure 4). In the RIDEM trawl survey in Narragansett Bay, sea robins, skates, tautog, and flounders have decreased, while bluefish and butterfish have increased (Figure 4). Bluefish, which feed on schools of pelagic fish, may be an indirect indicator of this trend since they have risen from 1%

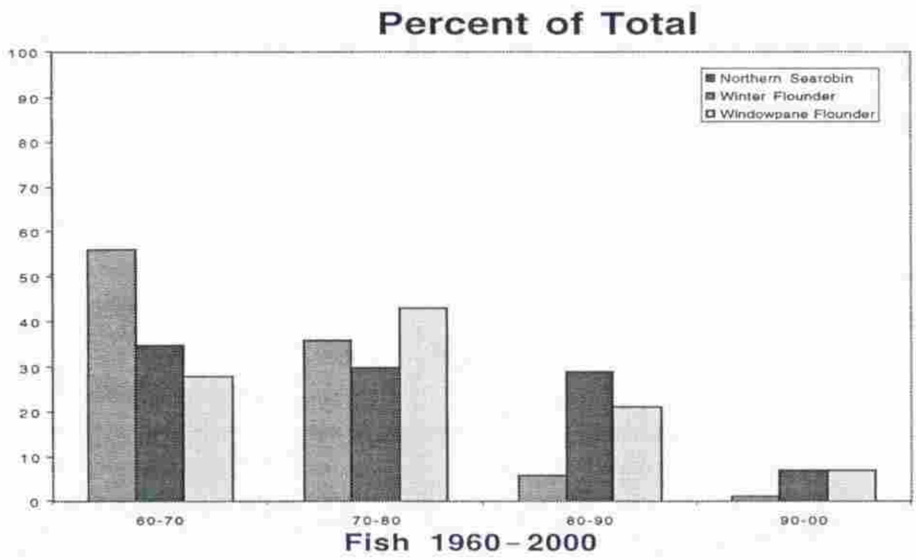

FIGURE 2. Graduate School of Oceanography Fox Island weekly trawl data with percentage of total by species summarized by decade for the period 1960 to 2000 for northern sea robin, winter flounder, and windowpane flounder (data from an electronic data base in 2001 from jcollie@gso.uri.edu).

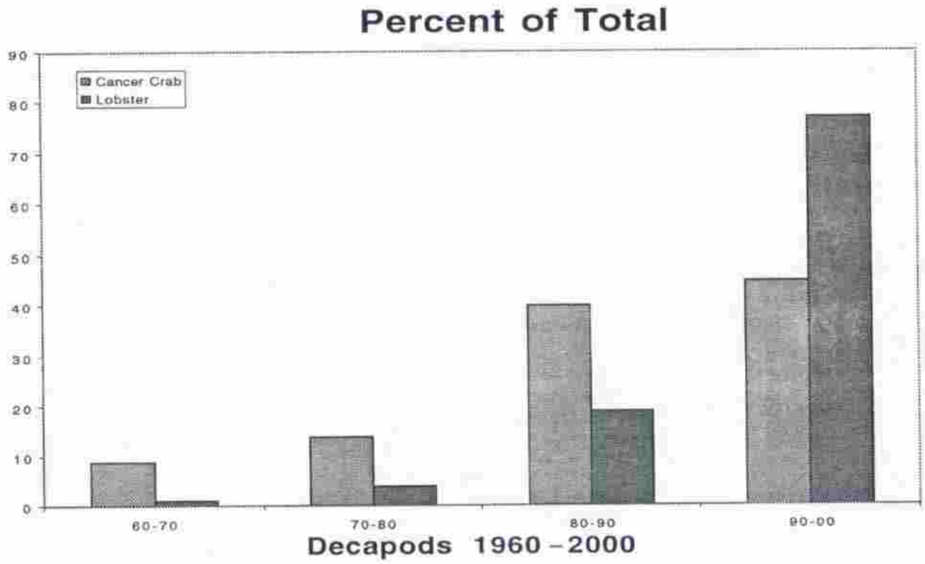

FIGURE 3. Graduate School of Oceanography Fox Island weekly trawl data with percentage of total by species or species group summarized by decade for the period of the survey for two species of cancer crabs and lobster (data from an electronic data base in 2002 from jcollie@gso.uri.edu).

of the catch in 1980 to 15–20% of the catch in the late 1990s. Other piscivorous predators support this trend for some pelagic fish, in spite of the evident variability and other factors such as DDT toxicity for birds and hunting for marine mammals. The RIDEM bird survey indicates that counts of cormorants have rebounded from 1 or 2 in the mid 1960s to over 200 in the late 1990s (Figure 5) (Myers, RIDEM, 2002). Counts of harbor seals indicated large increases in Narragansett Bay (Schroeder, 2000). The number of seals at Rome Point, south of Wickford, have increased from 15 or so in the mid-1960s to 100—140 in the late 1990s (Schroeder, 2000). While some pelagic fish species—noted above and including bluefish, butterfish, and anchovy—have increased, total biomass of pelagic species has changed little from 1865 to 1980 kg w w over the 20 years of the baywide survey (Figure 4). In the 5 year period at the beginning of the survey, compared to the last 5 years of the survey, the big change has been the decline in biomass of demersal fish. The demersal species that have decreased included northern sea robin, red hake, sea raven, skate, dogfish, tautog, windowpane flounder, and winter flounder (Figure 4). The biomass of demersal fish decreased by over a factor of four during this period from 1675 to 7212 kg w w, respectively.

The methods of capture have not changed for shellfish, but only the quahog and lobster have remained commercially important. No bay scallops have been taken from Narragansett Bay in several decades. The eelgrass habitat of bay scallop that used to extend from Greenwich Bay south no longer exists (Doherty, 1995). As the *Providence Journal* newspaper reports daily, the shallow sandy habitat of soft shell clams lies mainly behind coliform bacteria pollution boundaries where no shellfishing is permitted. Oysters have been absent from the bay in commercial quantities for 50 years; a natural repopulation of the bay in the 1990s has succumbed to disease and exploitation (Figure 6). Quahogs rose to peak yields in the 1950s and declined

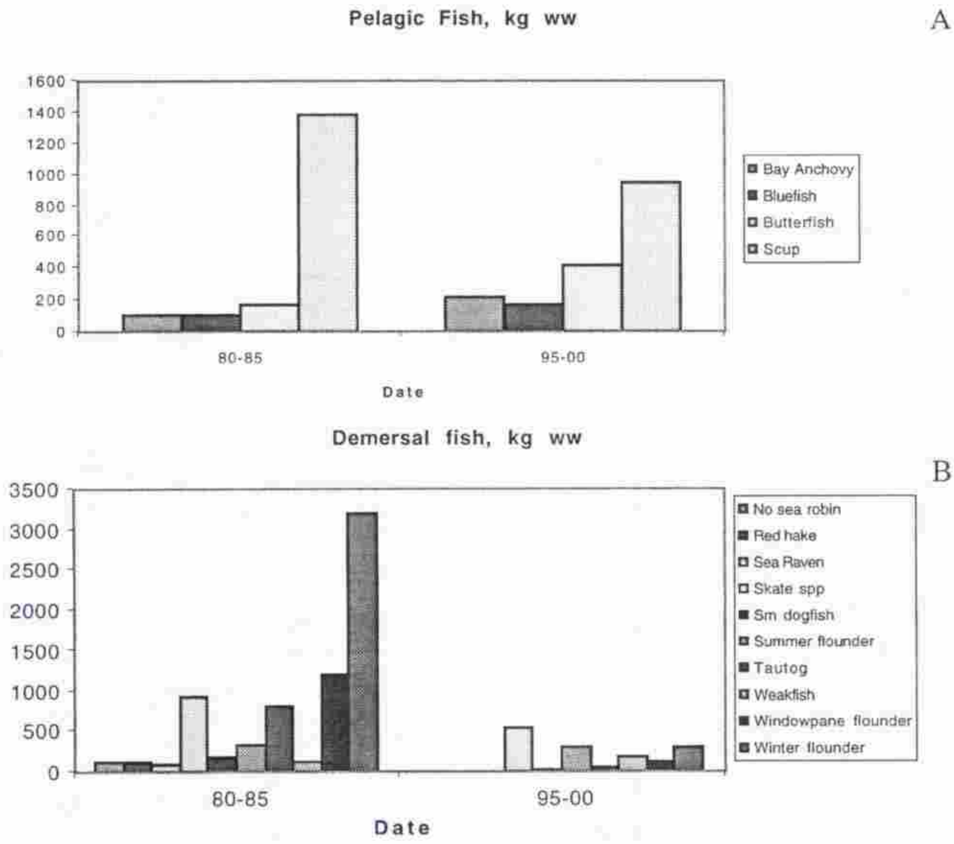

FIGURE 4. Biomass of dominant pelagic fish (A) and demersal (B) fish (over 100 kg w w) over 6-year periods in the early 1980s and late 1990s from the RIDEM spring and fall trawl survey over 26 stations in Rhode Island coastal waters (Lynch, 2000).

in the early 1970s when the bullrake replaced tongs so that depths to 8 m could be exploited (Pratt, 1987). In response, yield increased to the mid-1980s and then declined to present values around 500 MT (Figure 7). While the area fished has not changed, the landings of lobsters have increased dramatically even while lobsters have faced an exploitation rate close to 100% for legal size animals. Landings from historical levels have risen from roughly 500 MT to about 2500 MT (Figure 8). While yield has increased, catch per unit effort has declined by 50% (Table 6).

AREA ESTIMATES

Fish landings from Narragansett Bay from the late 1800s have been compared to landings from the late 1900s to examine trends in yields per unit area (Table 1). Total commercial fish yield, excluding menhaden, attained about 12 g wet weight m^{-2} by the beginning of the century (Figure 9). By 1960, this level had been sustained; thereafter, biomass of fish yield declined to present day levels of about

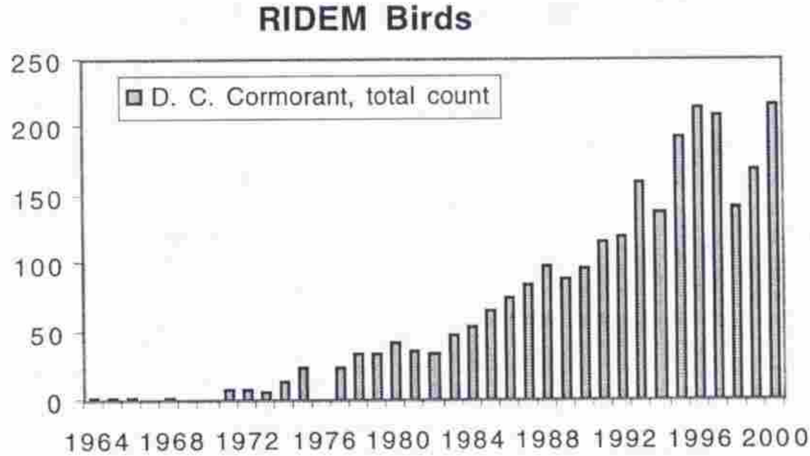

FIGURE 5. RIDEM total cormorant counts in Narragansett Bay (Myers, RIDEM electronic data base in 2001).

2 g wet weight m^{-2} (Figure 9). Rhode Island Department of Environmental Management fish trawl surveys indicate an average standing crop weight of 2.3 g wet weight and 0.09 individuals m^{-2} for 1980 to 2000 (Table 1) (Lynch, 2000). Fish landings with relatively high biomass in 1900 included weakfish (4.1 gww m^{-2}, scup (3.7 gww m^{-2}), winter flounder (2.3 gww m^{-2}), cod (1.4 gww m^{-2}), and American eel (0.6 gww m^{-2}). Fish landings with relatively large biomass in 1999 included mackerel (1.8 gww m^{-2}), which may be mostly caught outside of Rhode Island coastal waters, bluefish (0.5 gww m^{-2}), winter flounder (0.4 gww m^{-2}), and scup (0.3 gww m^{-2}) (NMFS Rhode Island Landings, 1999). With the exception of mackerel, bluefish, and striped bass, all species have less biomass in 1999 compared to historical levels (Figure 9).

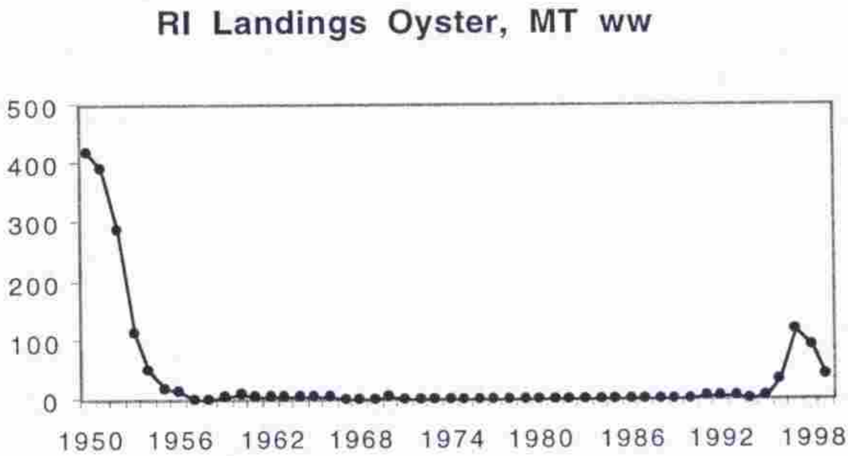

FIGURE 6. Rhode Island landings of oysters to 1999 from NMFS (http://www.st.nmfs.gov/st1).

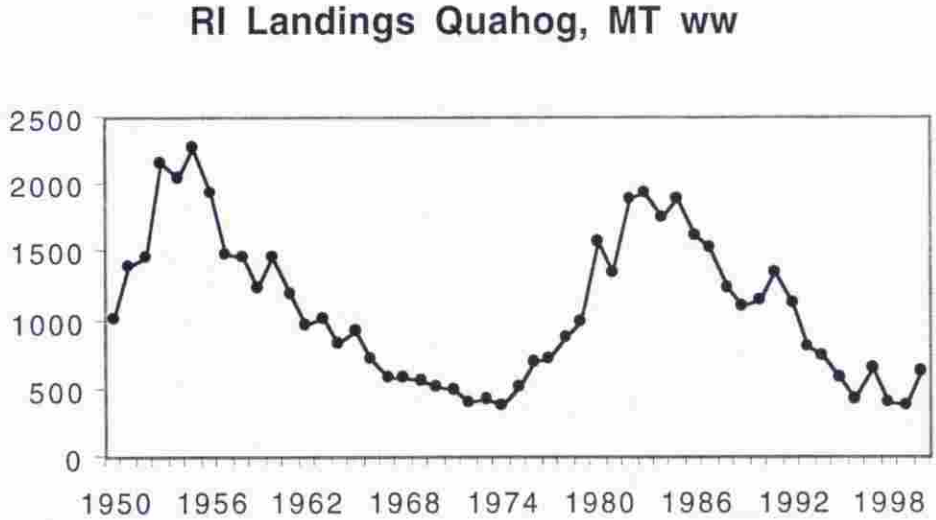

FIGURE 7. Rhode Island landings of quahog to 1999 from NMFS (http://www.st.nmfs.gov/st1).

Shellfish landings were higher for the Rhode Island area at the beginning of the century than at present and major species have changed (Figure 10). Oyster yield, actually a relay aquaculture based on growing out juveniles obtained from southern estuaries, attained values close to 50 gww m^{-2} in 1900 and before disappearing in the middle of the century (Figure 6). Soft shell clam attained yields of 11.6 gww m^{-2} in 1880 compared to about 0.6 gww m^{-2} in 1999. Bay scallops had values of 2.6 gww m^{-2} in 1880 before disappearing by 1960. In 1880, the quahog landings were estimated at 0.6 gww m^{-2}. Over the past 40 years, quahogs have

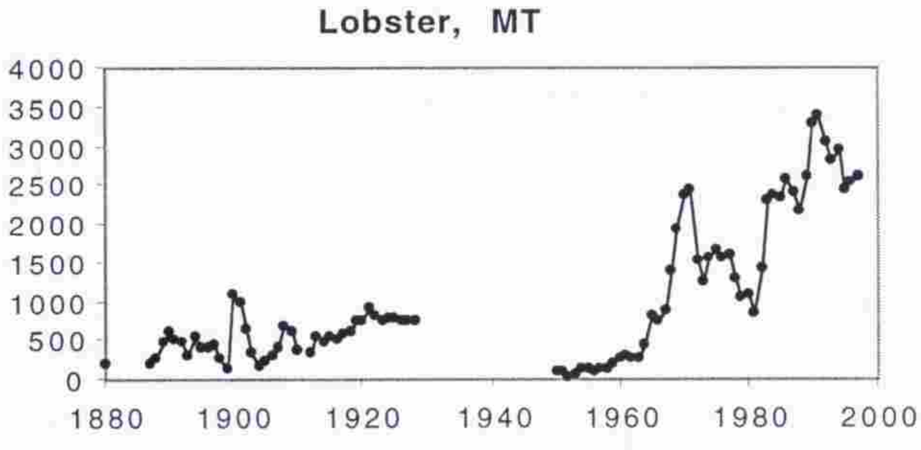

FIGURE 8. Lobster landings from state of Rhode Island to 1930 (16–21 kg per pot per season) and after (1990s 9–12 kg per pot per season) from NMFS. Data from state of Rhode Island and Providence Plantations, Inland Fisheries Reports 1800s to 1930 and NMFS Rhode Island landings (http://www.st.nmfs.gov/st1) in 2001.

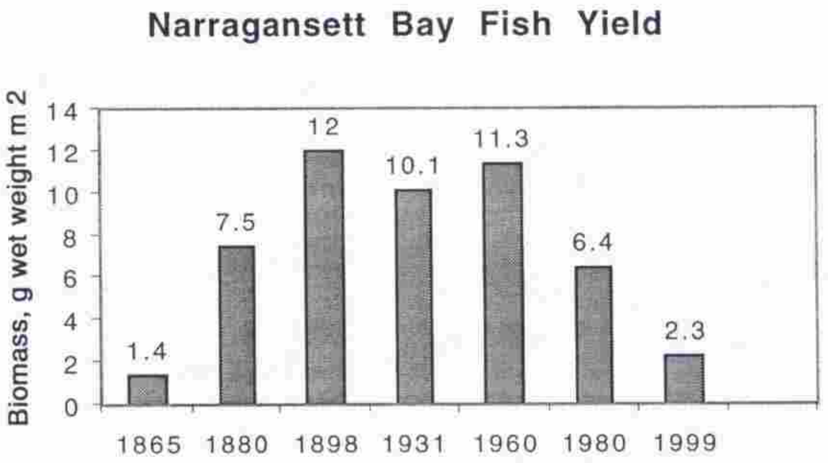

FIGURE 9. Rhode Island landings of the same fish species in late 1800s and late 1900s to 3 miles offshore. Biomass was estimated according to area of habitat (see Table 1).

dominated the shellfish catch with 21.6 gww m^{-2} in 1960, but now constitute only 2.7 gww m^{-2} (NMFS, 1985). Lobsters, which were estimated to be caught over the area of Narragansett Bay and coastal waters, attained 0.2 gww m^{-2} in 1880, and 0.4 gww m^{-2} in 1960 compared to 1.7 gww m^{-2} in 1999. In the 1990s, the re-population of oysters yielded 1.4 gww m^{-2} indicating the immediate response of fishermen to their presence (Table 1). If oysters are excluded, total shellfish catch in 1900 yielded 7.7 g wet weight m^{-2} and in 1960 22.6 gww m^{-2} of mainly quahogs compared to 5.0 g wet weight m^{-2} in 2000. This amounts to an increase of nearly a factor of three to the 1960s but a decrease of 39% of natural stocks over the century.

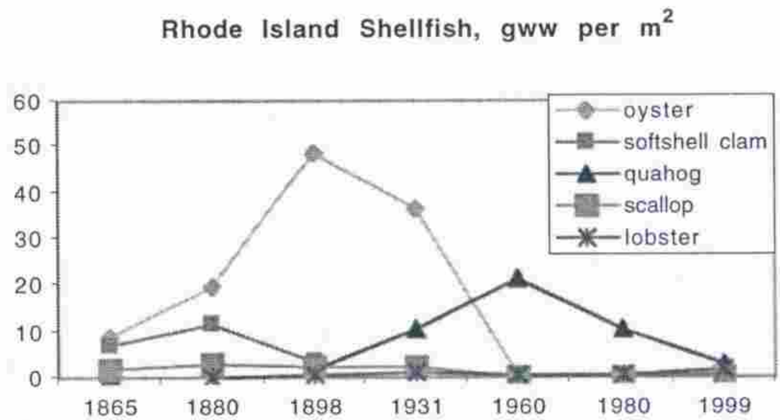

FIGURE 10. Rhode Island landings of shellfish to 3 miles offshore. Biomass was estimated according to area of habitat (see Table 1).

DISCUSSION

Historically, the fish community has changed seasonally and annually according to fine environmental, predation, and competitive pressures (Jeffries and Johnson, 1974). Large schools of spring migrants—menhaden, scup, mackerel—spawned just offshore and in the food-rich estuaries producing large summer populations of juveniles providing food for predators—striped bass, bluefish (Oviatt and Nixon, 1973; Oviatt, 1977). Anadromous fish—salmon, shad, alewife, smelt—crowed into streams and rivers in spring to spawn avoiding predation in an alternative habitat (Buckley and Nixon, 2001). During summer, clams, mussels, lobsters, shrimp, and crabs provided abundant prey for cod, sea robin, summer flounder, tautog, scup, squeteague, and bass. This summer community avoided the cold of winter by migrating to warmer habitats offshore and south (Jeffries and Johnson, 1974). During winter, a smaller assemblage of species dominated by winter flounder avoided predation by spawning in winter and avoided competition by migrating offshore in summer (Jeffries and Tercerio, 1985). Clams and scallops protected from predation by sediments and eelgrass reached high population levels. Dominance switched among competitive species with small temperature trends (Jeffries, 1994). When winter flounder decreased after warm winters, scup increased (Jeffries and Terceiro, 1985). Oyster achieved estuary-wide sets equivalent to mussel abundance infrequently and only in warmer-than-normal years. These oyster sets have repopulated Narragansett Bay in 1890, 1908, and 1991 (Kochiss, 1964; Pilson, 1989; Oviatt, unpublished data), whereas mussel apparently repopulate annually. High historical population abundance of oyster and other species must have reflected habitat quality, adaptation to competition and predation, and low disease and exploitation.

Most of the change in yield of fish and shellfish can be attributed to fishing pressure, but other factors have been important for individual species. Pollution boundaries have made large stocks of soft shell clam and quahogs unavailable; however, many observers do not view this as a detriment to the fishery. Many observers believe that these animals form the seed stock for a fishery that would otherwise have disappeared as the oyster and scallop fisheries have. The loss of the scallop fishery may be attributable to the loss of eelgrass habitat. Eutrophication and excessive phytoplankton blooms often cause a loss of eelgrass, but nutrient loads to Narragansett Bay do not appear to have increased dramatically in the last century (Nixon, 1997). The eelgrass may have succumbed to wasting disease of the 1930s and to the scallop trawls that constantly dragged up the beds of eelgrass, until they were replaced by floating macroalgae.

A warming climate trend has increased average winter temperatures of 2°C in winter and 1°C in summer (Oviatt *et al.*, 2002). This temperature change may have decreased the abundance of more boreal fish species including the commercially important winter flounder and the less commercially important northern sea robin (Figure 2). The decrease in winter flounder abundance has been attributed to the predator sand shrimp, *Crangon semptemspinosus* (Jeffries, 2001). With warmer winter temperatures, this predator remains active, preying on winter flounder eggs and larvae once protected by colder winter temperatures. Climate warming may have led to the large increase in lobster landings, despite intensive fishing pressure (Dow, 1969; Mann and Lazier, 1996). Other observers claim that the lobster fishery has become a form of aquaculture, with the baited pots feeding the juvenile lobsters until they become legal size (Saila *et al.*, 2002). The pot method of capture and release of small size lobsters has not changed over time; the number of pots, amount of bait, and its potential to feed a large number of juveniles has increased (Saila *et al.*, 2002). This argument cannot be the whole story, as large numbers of other bottom decapod species have also increased according to the GSO trawl survey (Figure 3). The absence or decrease in fish predation by cod, tautog, and scup, among others, may be as important as other factors in the decapod, including lobster, increase (Jackson *et al.*, 2001).

The change in major species that are no longer harvested, is most evident for shellfish, but many fish species have dropped to insignificant levels as well. No anadromous fish are currently important, including alewife, shad, and smelt (NMFS Rhode Island Landings, 1999). The once, amazingly abundant menhaden may no longer be important; cod have disappeared (NMFS Rhode Island Landings, 1999). Major species of shellfish have been lost, such as bay scallop, or have become insignificant; current shellfish biomass has dropped by 17% since 1960 when quahogs dominated the yield, and by 88% and since 1898 when oysters dominated.

Both fish and shellfish yield have decreased according to estimates of area abundance. Fish, at present, have decreased 81% from 1898 (Figure 9). Remarkably, the trap fishery did not cause a detectable decline in biomass of fish, but the trawl fishery apparently has, and this decrease has occurred over the past 40 years. Fish yield has been related to levels of primary production for many estuarine and marine areas (Nixon *et al.*, 1988). The most recent estimate of synoptic primary production for Narragansett Bay is about 300 $gCm^{-2}y^{-1}$ (Oviatt *et al.*, 2002). A historical reconstruction of the data indicated that nutrient levels may not have changed much in Narragansett Bay since the Industrial Revolution over 100 years ago (Nixon, 1997). Using the fish yield relationship and 300 g $Cm^{-2}y^{-1}$ primary production for 1898 and 1999 suggests 9 gww m^{-2}. Fish yields were 55% greater than predicted by primary production in the last century and 78% less than predicted, at present (Figure 11). This comparison provides an indication that fish sustained great pressure in 1900 but this exploitation level did not lead to a decreased catch (Baird, 1873); 60 years later, the landings equaled the catch of 1898 (Figure 9).

During both of these periods, much of the fishery could not have been sustained by the primary productivity of the bay and the fish must have been constantly repopulated to the fishery by the abundant fish populations migrating from offshore. Fish often aggregate to preferred locations from wide geographic areas (*e.g.*, Rose, 1993). As the inshore fish were removed by fishing, offshore fish moved into coastal waters to take advantage of abundant prey and lack of competitors for the prey. At present, fishing pressure has decreased the fish stock to well below what primary production should support (Figure 11). The RIDEM trawl survey supports this decrease in landings with an estimated standing stock of 2.3 g w w m^{-2} compared to the 2 g w w m^{-2} yield form NMFS Rhode Island landings (Figure 11) (Lynch, 2000). In a survey in the early 1970s, a higher value of 6 g w w m^{-2} was obtained using the same method of calculation (Oviatt and Nixon, 1973). In 2000, there is less migration into the bay by offshore stocks because both the inshore and the offshore stocks have been removed by efficient fishing practices. The evidence suggests that inshore stocks were overexploited in the late 1800s trap fishery. However, as fast

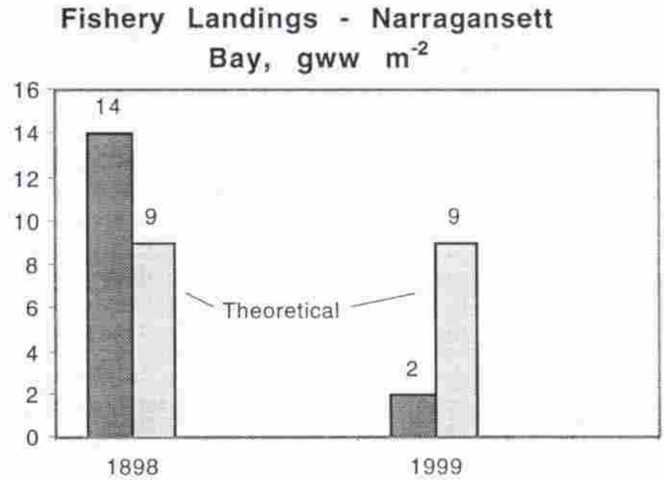

FIGURE 11. Fishery landings for the same species in 1898 and 1999, including menhaden in Rhode Island to 3 miles offshore (see Table 1). The theoretical fish yield is shown for an estimated primary productivity of 300 g C m^{-2} y^{-1} in Narragansett Bay (Oviatt *et al.*, 2002), according to the relationship in Nixon (1988) assuming primary productivity has not changed greatly over the 100-year period.

as the inshore fish were caught, they were replaced by migrating offshore stocks. A hundred years later the fishery has removed stocks once available to migrate into and repopulate the inshore waters. In apparent response, decapods now dominate the demersal community (Figure 3) with lobsters alone accounting for 1.7 g w w yield to the fishery (Figure 10).

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