NBP-91-56

Winter Flounder (*Pseudopleuronectes americanus*)

Species Profile 68 pp

Gray, C. L. (RIDEM)

Narragansett Bay Estuary Program

Current Report
The Narragansett Bay Project

WINTER FLOUNDER (Pseudopleuronectes americanus) SPECIES PROFILE

Ms. Cynthia L. Gray
Marine Biologist

Rhode Island Department of Environmental Management
Division of Fish & Wildlife
Marine Fisheries Section

#NBP-91-56

Jointly funded by Narragansett Bay Project and National Marine Fisheries Service.

The Narragansett Bay Project is sponsored by
the U.S. Environmental Protection Agency and
the R.I. Department of Environmental Management.

D·E·M

WINTER FLOUNDER (Pseudopleuronectes americanus) SPECIES PROFILE

Ms. Cynthia L. Gray
Marine Biologist

Rhode Island Department of Environmental Management
Division of Fish & Wildlife
Marine Fisheries Section

#NBP-91-56

Jointly funded by Narragansett Bay Project and National Marine Fisheries Service.

EXECUTIVE SUMMARY

This winter flounder profile is the initial document in a series intended to provide background necessary for cooperative management of important finfish species occurring in Rhode Island waters.

Winter flounder support a very important and valuable fishery in Rhode Island, contributing to the bulk of the commercial and recreational fisheries. Catches of winter flounder in statistical area 539, which includes Narragansett Bay, have declined 53% since landings peaked in 1982. Commercial catch per unit effort has also declined 59% since 1982. Abundance indicators remain well below the all time highs reached in 1979.

This review of the biology of winter flounder, Pseudopleuronectes americanus, includes nomenclature, taxonomy, ecology, stock description, range, abundance in Rhode Island waters, life history, habitat requirements, migration and movements. Also included are reproduction, growth and development, food and feeding, predators, disease and parasites. In addition to the commercial and recreational value of the fishery a summary of Rhode Island regulations is also included.

Winter flounder eggs are demersal and adhesive, larvae are non-buoyant and display a mixed planktonic-benthic behavior. After metamorphosis winter flounder are benthic and juveniles spend their first two years in or near shallow natal waters and move seaward with age. Adult winter flounder are demersal and reach sexual maturity in the average of 2.84 years, in Southern New England.

Additional management measures for winter flounder are currently being debated by the Rhode Island Marine Fisheries Council.

TABLE OF CONTENTS

Species Profile: Winter Flounder
Pseudopleuronectes americanus(Walbaum)

Common Name: Winter Flounder
Scientific Name: *Pseudopleuronectes americanus*
Author: Walbaum 1792

Other Common Names - Blackback, Georges Bank Flounder, Lemon Sole, Flounder, Sole, Flatfish, Rough Flounder, Mud Dab, Black Flounder (Bigelow and Schroeder 1953); Dab, Plie rouge and Carrelet (Leim and Scott 1966).

Classification

Phylum: Chordata
Subphylum: Vertebrata
Class: Osteichthyes
Order: Pleuronectiformes(Heterosomata)
Family: Pleuronectidae
Genus: *Pleuronectes*
Species: *americanus*

VALUE

Commercial:

The winter flounder, *Pseudopleuronectes americanus*, is indigenous to the shallow bays and estuaries (including Georges Bank) of the American North Atlantic Coast and is taken in commercial quantities by otter trawl (Figure 1), from Nova Scotia to New Jersey. Winter flounder is also subject to intensive sport fisheries from the Gulf of Maine to Maryland. The fishery in federal waters is managed under the New England Fisheries Management Council's Multispecies Fishery Management Plan (FMP). The winter flounder is one of the most important species in the commercial and recreational fisheries of Narragansett Bay and adjacent waters (Buckley and Caldarone 1988). Winter flounder support a very important and valuable fishery in Rhode Island, and, according to Grove (1982) winter flounder have historically been the most abundant demersal fish in Rhode Island, contributing the bulk of the commercial and recreational fisheries in Narragansett Bay and several of the salt ponds along the state's southern coast.

An assessment of the status of winter flounder stocks off the Northeastern United States compiled by Northeast Fisheries Center (NEFC) has shown that commercial landings from the Southern New England-Mid Atlantic area increased from roughly 4,000 metric tons (mt) in the mid-1970s to nearly 12,000 mt in 1981. Commercial catches have steadily declined from their early 1980's level. Recreational catches increased from 1979-1985, then declined through 1988 (Table 1). The combined recreational and commercial landings declined by 11% in 1988 to about 8,200 mt. Most of this decline was due to decreases in commercial landings

(5,200 mt to 4,300 mt) (United States Department of Commerce (USDC) 1989).

NEFC spring survey indices have shown similar trends as commercial catches since 1975, increasing through 1981. With the exception of 1985, commercial catches have declined from 1981 to 1987. In 1988, the index increased to 0.6 kg/tow, a value double that of 1987 but still low in comparison to earlier years in the time series (Table 1).

Declining survey indices in the most recent years along with the continued decline in landings since 1981 suggest that landings will not increase in the near future (Figure 2). There are uncertainties, however, in the overall stock structure in this region with suggestions of many localized groups. Thus, local fluctuations in catches might be expected since fishing pressure is not applied uniformly throughout the region. The status of the stocks can not be determined with certainty without increasing the level of assessment (USDC 1989).

Winter flounder comprised about 10 % of Rhode Island's annual finfish landings for 1987 (Gibson 1987) with the landed value of winter flounder approximately four million dollars. Commercial landings of winter flounder in Rhode Island have been steadily declining since the 11 inch size limit was implemented on 01 JANUARY 1986 (Figure 3). On 01 JANUARY 1990 an 11 ½ inch was implemented and as of 01 JANUARY 1991 a 12 inch size limit will be in effect.

Increasing the minimum legal size will increase yield per recruit. Gibson (1989c) found that catches of winter flounder in statistical area 539 have declined 53 % since peak landings in 1982 (Figure 4). Commercial catch per unit effort has also declined 59 % since 1982 (Figure 5). Gibson (1989c) found that recent research abundance indicators remain well below the all time highs reached in 1979 (Figures 6-8). The average size of winter flounder landed in southern New England has declined from 380 mm to 310 mm since 1977 (Figure 9). Gibson (1989c) concluded from length frequency data in Narragansett Bay (Figure 10) that increasing the minimum size to 12 inches would elimate 44 % of the catch the first year. Yield recovery would be stimulated in the second year and five years later through their progeny. He found this to be consistant with stock projections made for a number of groundfish species by NEFC, which indicate a 5-10 year rebuilding time for depressed stocks following implementation of large mesh sizes or a reduction in fishing mortality (Gibson 1989c).

Recreational:

Sportfishing trips occur throughout the year from shore, bridges, jetties, and docks, from private boats, and from charter and party boats (McConnell et al. 1981). NMFS initiated a series of surveys in 1979 to obtain estimates of participation, catch and effort by recreational fishermen in the marine waters of the United States. Figure 11 represents the recreational catches of winter flounder in Rhode Island waters (USDC 1987). Results of a tag and release program conducted annually by the R.I. Division of Fish & Wildlife in upper Narragansett Bay showed that 48% of the total recoveries were returned by recreational fishermen (Powell 1988). The highest number of recreational recoveries reported was during the month of May, followed by April and October (Figure 12). Ninety-seven (97)% of all recreational recoveries came from within Narragansett Bay, which may be a function of the distribution of fishing effort. Recovery of females outnumbered that of males by a 3.5:1 ratio as compared to a 1.9:1 female:male sex ratio during tagging. No recreational recoveries were reported from Mt. Hope Bay or the Sakonnet River. The highest number of recoveries (46) came from Area 2 (primary tagging area) in upper Narragansett Bay, the same as the previous two years (Figure 13) (Powell 1988).

Winter flounder length/weight relationship (Figure 14) and yearly average length (Figure 15) were calculated from the data of Rhode Island Marine Recreational Fishery Statistics Survey (Karlsson 1990; unpublished).

ECOLOGY

The winter flounder is a demersal, euryphagous marine species which preys on a diverse assemblage of invertebrates and its feeding is influenced by size and availability of food species (Pearcy 1962). Winter flounder "appear to adapt" to a benthic existence after the midpoint of their first year, when their food preference shifts from plankton to benthic invertebrates (Frame 1974).

Casterlin and Reynolds (1982) found that flounder of different ages and sizes exhibit different depth distributions because of their different responses to temperature and light, resulting in intraspecific niche differentiation which may minimize intraspecific competition.

STOCK DESCRIPTION

There is considererable evidence that winter flounder are organized into many small stocks that are reproductively isolated (Lobell 1939; Perlmutter 1947; Saila 1961b, 1962; Howe and Coates 1975; Scarlett 1986; NUSCO 1987; Gibson 1989a). Saila (1961b) inferred discrete subpopulations in Narragansett Bay and subsequently demonstrated discrete spawning populations in the Sakonnet River, Mt. Hope Bay and the West Passage. According to Gibson (1989a), this tendency, coupled with the considerable environmental differences across the species range, often leading to stock specific growth rates.

RANGE

Overall:

The winter flounder is distributed along the Atlantic coast of North America (Figure 16) from the inshore to the offshore fishing grounds, 20 fathoms and less (Leim and Scott 1966); common from the Strait of Belle Isle; on the north shore of the Gulf of St. Lawrence where it has been characterized as "all along the coast," (Bigelow and Schroeder 1953) and in southern and southeastern Newfoundland to Chesapeake Bay. The winter flounder tolerates a wide range of salinities, however, in general the species is limited to the tidal part of estuaries (Bigelow and Schroeder 1953).

Within Narragansett Bay :

Winter Flounder are present throughout the year in Narragansett Bay, but are most abundant during the late fall, winter and spring months, and least abundant during the summer and autumn when water temperatures are at their yearly maximum (Oviatt and Nixon 1973). Winter flounder caught in Narragansett Bay and the sounds off the Rhode Island shore complete nearly all of their life cycle in Rhode Island waters (Olsen and Stevenson 1975). Winter flounder generally account for 36-90% of the fish species in Rhode Island waters (Richards 1963; Oviatt and Nixon 1973; Jeffries and Johnson 1974) and are plentiful in estuaries and salt ponds.

ABUNDANCE IN RHODE ISLAND WATERS

In Narragansett Bay, winter flounder abundance is dependent upon successful reproduction and survival of early life stages (Buckley and Caldarone 1988). Winter flounder larvae are found throughout Narragansett Bay with centers of abundance in the upper Narragansett/Mt. Hope systems and peak abundance occurring during April (Durbin and Durbin 1988).

Juvenile winter flounder abundance and distribution in Narragansett Bay have been monitored annually since 1986 by the R.I. Division Fish & Wildlife at 15 stations (Figure 17). Juvenile winter flounder were most abundant in the shallow areas of the upper Bay and in the Sakonnet River (Powell 1986, 1987). Highest monthly abundance of juveniles occurred in August between Patience Island and the mouth of the Kickamuit River. All stations in the Sakonnet River had high mean numbers of flounder per seine haul (Powell 1989a).

Monthly samples of demersal fish were collected by Oviatt and Nixon starting in June 1971 continuing through May 1972. Nine regular and 13 occassional stations in Narragansett Bay, Rhode Island were sampled for abundance and composition or distribution of populations for the Bay as a whole. They found that winter flounder was the most abundant species, accounting for 36 % of the total catch by number and 39 % by weight. Weights ranged from 8 % in July to 70 % in January. Despite their numerical dominance in catch, winter flounder populations have been characterized by periodic large fluctuations in abundance. According to Jeffries and Johnson (1974) and Jeffries and Terceiro (1985) the mean annual abundance (derived from weekly tows at Whale Rock and Fox Island) during a 17 year period from 1966 to 1982, indicates that winter flounder, the chief year round resident, reached peak abundances in 1968 and then plummetted and remained at depressed levels for 11 years. A recovery in 1979 was followed by a decline in the early 1980's which still persists (Saila et al. 1988).

The pattern of annual winter flounder landings during the last 33 years supports the population cycle theory described by Jeffries and Terceiro (1985) which asserts that winter flounder abundances were statistically associated with annual variations in winter temperature, i.e. colder winters are associated with greater numbers of winter flounder. Data on landings demonstrate that the population decline has continued since the 1979 peak, with 1987 values approximately the lowest levels since the 1968 crash. Indices of abundance (stratified mean weight per tow and stratified mean number per tow) declined from 1987 (Lynch and Karlsson 1989). According to Lynch and Karlsson (1989) these declines are also the result of seasonal fluctuations in abundance occurring in Narragansett Bay, Rhode Island Sound, and Block Island Sound (Figure 18). According to Powell (1989c) the months of greatest winter flounder movement in Narragansett Bay are March, April, May and October. This is based on numbers of fish caught during the tagging effort, combined with tag return data.

The lowest abundance of adult winter flounder in the middle (Fox Island) and upper estuary (Mt. Hope Bay) occurs in July and August (Figures 19 & 20), while Whale Rock, at the mouth of the Bay, showed the highest abundance during these months (Figure 21) (Powell 1989a). This trend is reversed for other months of the year in these areas (Powell 1989a). Oviatt and Nixon (1973) found the highest biomass of winter flounder in Narragansett Bay to occur in January and June with the minimum in August and September. Data from Powell (1989a) winter flounder tag recoveries show this same seasonal movement. A study by Saila (1961a) showed similar seasonal onshore-offshore migration from Rhode Island coastal ponds.

LIFE HISTORY

Eggs are demersal and adhesive, and are localized in the vicinity of the spawning grounds. The larvae are nonbuoyant and display a mixed planktonic-benthic behavior (Pearcy 1962) unlike the larvae of other flatfish species which are more pelagic (Buckley 1989). After metamorphosis, winter flounder are benthic. According to Buckley (1989) juveniles spend their first two years in or near shallow natal waters, where movement is in response to extreme heat or cold. Juveniles in estuaries gradually move seaward as they grow larger. Adult winter flounder are demersal. Winter flounder do not school (Klein-MacPhee 1978), but display small scale seasonal migrations.

HABITAT REQUIREMENTS

Type/Substrate:

Eggs and larvae:

Throughout the range of the species, spawning usually occurs inshore over sandy bottoms or algal mats at depths of 1.8 to 3.6 meters (Martin and Drewry 1978). According to Klein-MacPhee (1990 pers. comm.) eggs are found in assocation with filamentous diatoms called algal mats. Newly hatched larvae are found within a few centimeters of the bottom, in depths less than 37 m, with concentrations within 25 km of the shore, near mouths of estuaries (Martin and Drewry 1978). They exhibit intermittent swimming alternating with resting on the bottom (Klein-MacPhee 1978).

Juveniles:

After metamorphosis, juveniles prefer a substrate of sand and silt (Buckley 1989). The preferred habitat type for juvenile winter flounder in Narragansett Bay is of a sandy mud consistency mixed with detrital matter (Powell 1990 pers. comm.) with the predominant species being Ulva and Codium.

Adults:

Adult winter flounder are an inshore, shallow-water bottom species residing on soft mud to moderately hard bottoms, usually in depths of 1.8 to 60 meters (Scott and Scott 1988). Although adults prefer mud or grassy bottoms, they are also found on sand, clay, or gravel (Martin and Drewry 1978). Populations on offshore banks are found on hard bottom of one type or another (Bigelow and Schroeder 1953).

Temperature/Salinity:

Eggs/Larvae:

Eggs and larvae are eurythermal (Klein-MacPhee; pers. comm. 1990). Williams (1975) investigated the survival and duration of development of winter flounder eggs at a number of constant temperatures ranging from -1.8° C to 18.0°C. Many specimens were able to develop at the lowest temperatures used (-1.5°C and -1.8°C); however, the highest viable hatch occurred at temperatures between 0-10° C. At temperatures above 10°C, many hatched individuals were inviable or exhibited structural abnormalities. An upper lethal temperature of 15°C was determined.

According to Laurence (1975), specific growth of winter flounder increased with temperature and it did not increase with age at the given experimental temperatures (Table 2). He found that the laboratory tested larvae did not survive to metamorphosis at 2°C (a temperature which the early spawned larvae encountered), indicating that 2°C is less than optimal for winter flounder growth. Prolonged exposure to periods of low temperature may adversely affect survival, by disrupting the timing of several events in their early life history (Jeffries and Johnson 1974; Laurence 1975). Laurence (1975) also found that higher temperatures induced higher oxygen consumption and metabolic rates in winter flounder.

Rogers (1976) determined that both salinity and temperature are important to the incubation of winter flounder eggs. The highest viable hatch occurred over a salinity range of 15-35 o/oo at 3°C. At temperatures above 3°C the optimal salinity range was approximately 15 to 25 o/oo. The major effect of increased temperature is to decrease the incubation period. Whereas, salinity is the factor having more effect on successful hatching and survival on embryos and larvae of winter flounder (Rogers 1976).

Juveniles:

Pearcy (1962) showed that juveniles are euryhaline and eurythermal; they were found throughout the Mystic River (Conn.) estuary in all seasons, in water ranging from 4-30 o/oo and 0-25°C. He also found that laboratory experiments indicated that the extremes of these factors may be close to lethal limits and that minimum salinity tolerance (LD 50) varied between 1 and 5 o/oo after acclimation, even for small individuals of 7-10mm. The minimum lethal temperature in the winter was usually between -1.0°C and -1.5°C, when the freezing of tissues was noted (Pearcy 1961). Casterlin and Reynolds (1982) found juveniles entering shallow estuarine and cove nursery areas, which during the summer may reach temperatures exceeding 25°C. Between 20°C and 29°C, sublethal effects such as inhibition of feeding occur with avoidance responses initiating at or below 27°C. Furthermore, they found that if the young fish do not reach the deeper, cooler water (or bury themselves in cooler bottom sediments), they will "succumb to heat death" at 29°C.

Adults:

McCracken (1963) concluded that P. americanus has a preferred temperature range of 12-15°C; Huntsman and Sparks (1924) found interference with vital activities in P. americanus begining at 27.3°C; Pearcy (1962) reported a maximum temperature tolerance of about 30°C. Adult winter flounder commonly live in salinities of 5 to 35 o/oo (Buckley 1989).

The winter flounder is capable of surviving in ice-laden, subzero waters during the winter by synthesizing plasma antifreeze polypeptides (AFP) (Chakrabartty, Ananthanarayanan and Hew 1989) or antifreeze glycoproteins (AFGP) (Chakrabartty, Yang and Hew 1989).

COLORATION AND PIGMENTATION

Color and pigmentation patterns in winter flounder vary to mirror the bottom substrate (Bigelow and Schroeder 1953), however, winter flounder have less control over shade and pattern than the summer flounder.

MIGRATION AND MOVEMENTS

Depths occupied by winter flounder in any particular locality, at any particular time, depend largely on local temperature conditions (Bigelow and Schroeder 1953). Aside from local onshore-offshore migration, results of tagging experiments have shown that the winter flounder is a relatively stationary fish (Bigelow and Schroeder 1953; Howe and Coates 1975; Klein-MacPhee 1978). Perlmutter (1947) stated that the winter flounder population is comprised of many relatively independent, localized stocks inhabiting the bays and estuaries along the coast and that any movement of fish away from these areas, other than seasonal, is not a directed migration but rather a gradual dispersion from population centers which is considered a characteristic phenomenon with non-migratory animals.

The distribution of winter flounder eggs and larvae is minimally affected by wind and tide, because eggs are adhesive and demersal, and the early pelagic larval stages are commonly found in the protected backwaters of bays and inlets (Perlmutter 1947).

Newly hatched larvae ascend to the surface waters where they drift in the plankton for 4 to 7 weeks (Grove 1982; Frank and Legget 1983) and during this time they are symmetrical in the vertical plane.

Juveniles appear in the near shore zone during the spring and summer (Pearcy 1962) and unlike adults, they can tolerate water temperatures as high as 29° C, although an avoidance response is initiated at around 27° C (Casterlin and Reynolds 1982). Powell (1989a) concluded that during this "summer period" while juveniles are in the estuaries, adult flounder (3+ and older) have moved offshore to cooler deeper waters. Age classes I and II are primarily found at depths of less than 18 meters, except in colder weather when they are at depths of 18 to 37 meters (Martin and Drewry 1978). Seasonal abundance data for 1975-1985 summarized by Jeffries (1988) supports this seasonal movement. According to Powell (1989a) the following spring, as water temperatures begin to rise, young winter flounder (1+) begin moving back into the shallower shore zones of the estuary. Powell (1989a) further states that these older fish move into the intertidal areas during the night, as they are less tolerant of light and warmer water temperatures than are 0+ individuals.

Powell (1986) concluded that winter flounder, tagged in upper Narragansett Bay, begin moving into the Bay in early fall, primarily by way of the East Passage (Figure 22). Data from the tag returns indicated no migration of fish that he tagged in the upper West Passage, through the West Passage or Sakonnet River. By late fall and early winter the in-shore migration had intensified and many fish moved into the Upper Bay (Figure 23). By late spring and early summer, as water temperature begins to rise, flounder begin to move down and out of the Bay (Figure 24). Tag return data through this time indicates that a seaward migration occurs principally by the way of the East Passage with some fish "holding out" in the deeper, colder waters of the lower East Passage (Powell 1986).

REPRODUCTION

Mode:

Studies by Breder (1922) conducted at Woods Hole showed that spawning occurred at night, between 2200 and 0330 hours. Prior to spawning, winter flounder (especially females) exhibited a large amount of swimming activity. He found that fish of both sexes swam rapidly in a circle about one foot in diameter, counter-clockwise with vent outwards.

As they swam, eggs were extruded from the females and fertilized simultaneously by the males. This continued for ten seconds, then the fish sank motionless to the bottom

Spawning Factors:
Throughout the range of this species (excluding Georges Bank), spawning usually occurs inshore over sandy bottoms or algal mats (which produce highest survival) at depths of 1.8 to 3.6 meters with bottom temperatures ranging between 1-10° C (optimum at 3-4°C) (Martin and Drewery 1978). Ovulation does not occur above 6°C, and requires salinity between 11.4 o/oo and 33 o/oo (Martin and Drewery 1978). Field observations in two estuaries of Narragansett Bay, and Narragansett Bay in general, indicate that spawning occurs at salinities ranging from 11 to 32 o/oo (Rogers 1976).

Winter flounder spawn once a year from November to May when water temperature is near the annual minimum (Foster 1987). Spawning seems to be temperature related so that the onset and peak of spawning occur at temperatures of 2-5°C with no extensive release of eggs occurring above 6°C (Bigelow and Schroeder 1953). Spawning times vary, begining earlier in the southern part of the fish's range and progressively later as one proceeds northward (Klein-MacPhee 1978). Table 3 summarizes spawning dates at different geographic locations from north to south.

Reproductive Capacity: Topp (1968; cited in Klein-MacPhee 1978) measured ova density and found it ranged from 6,082 to 18,963 eggs/g of ovary with a mean of 10,595 eggs/g of ovary. Egg diameter ranged from 0.33 to 1.00 mm with a mean of 0.61 mm. There was no significant correlation between mean egg size and fish size, but egg size differed among age groups, age group three having the smallest eggs. The average fecundity for winter flounder females is about 500,000 eggs/female (Scott and Scott 1988). Fecundity studies are summarized in Table 4.

Rhode Island Spawning Season:
Results of the first three years of a mark and recapture study by Powell (1989a) indicate that flounder in upper Narragansett Bay spawn from late December into April based on reproductive condition. He also found that the presence of large number of ripe and spent females indicated peak spawning occurs during February and March. This is the same period described by Crawford (1990) for Rhode Island coastal ponds.

Rhode Island Spawning Locations:
The most important spawning areas in Narragansett Bay are thought to be upper Narragansett Bay(north of Prudence Island), Mt. Hope Bay, and the Sakonnet River (Cooper 1964). According to Powell (1989a) Greenwich Bay, Wickford Cove and other shallow coves around Narragansett Bay are also thought to be important spawning areas, although this has not been fully documented. A tag and recapture study conducted by Black et al. (1988) found that Gaspee Point and

Fox Island support distinct groups of winter flounder which return to their respective spawning grounds in subsequent years. Spawning also occurs in the Pawcatuck River, Brightman's Pond and Quonochontaug Pond (Sisson and Satchwill; unpublished data 1990), Green Hill Pond (Saila 1961a), and Pt. Judith Pond (Grove 1982).

GROWTH AND DEVELOPMENT

Egg:

Breder (1924) found the eggs of P. americanus to be minute, demersal, and adhesive, resulting in eggs that tend to be more or less distorted, sometimes ovid in shape. He also found the eggs to have a modal diameter of 0.81mm, varying from 0.71mm to 0.86mm. Klein-MacPhee (1990; pers. comm.) found fertilized winter flounder eggs ranging from 0.74mm to 0.85mm and unfertilized eggs that ranged from 0.62mm to 0.87mm. In Rhode Island coastal salt ponds, Stolgitis et al. (1976) found winter flounder eggs that ranged in size from 0.80 - 0.98mm. Newly shed eggs have no oil globule (Klein-MacPhee 1978; Grove 1982). The specific gravity of individual fertilized eggs found by Pearcy (1962) as determined with gum arabic and seawater technique, was 1.085 - 1.095, and when compared with **in situ** estuarine water of was 1.010 - 1.024. The spermatozoons average about 0.030mm to 0.035mm in total length (Breder 1924).

Embryonic Stages:

Breder (1924) described the embryonic development of winter flounder eggs. He collected the eggs from ponds in the Woods Hole Region during February when the water temperature was 1°C to 2°C. Although the eggs were collected in water temperatures of 1°C to 2°C, he states the eggs were incubated at 69°F/20.6°C, which is lethal. Klein-MacPhee (1990; pers. comm.) and Buckley (1990; pers. comm.) agree that this discrepancy in the original data probably is the result of a printing error. Klein-MacPhee (1978) also states that the timetable described by Breder (1924) best corresponds to temperatures of 6°C - 8°C. Klein-MacPhee (1983; unpubl. data) characterized the embryonic stages of eggs taken from adult winter flounder in Narragansett Bay, Rhode Island:

Temperature 5°C
1) 04 hrs - first cell division

Temperature range 3.5°C-5.6°C
2) 08 hrs - four cell division
3) 12 hrs - 16 cell division
4) 16 hrs - Blastula
5) 2nd Day - Gastrulation complete
6) 3rd Day - Embryonic axis
7) 4th Day - Optic Cups
8) 7th Day - Myotomes
9) 8th Day - Otolith first seen; tail reaches nose
10) 12th Day - Tail passes nose, makes bend

11) 14th Day - Hatch

Rogers (1976) reported that the embryonic period lasts 5-31 days depending on water temperature.

Larval Development:

Laroche (1981) decribed the development of winter flounder from hatching to metamorphosis (Figure 25-26). He found that newly hatched larvae are about 2.4 mm long; have myomeres numbering from 38-40; dorsal fin rays and anal fin rays numbering 60-76 and 44-58 respectively; have an undifferentiated fin fold extending along the body midline from the head around the notochord tip to the anus, and undifferentiated pectoral fin folds, neither having pigmentation; eyes lacking pigmentation.

External melanophores are scattered over the head and abdominal region with the greatest concentration along the dorsal surface of the body and on the ventrolateral surface of the yolk sac. A vertical band of concentrated melanophores of various sizes is present across the center of the postanal region. Irregular rows of aligned external melanophores are present on both sides of the ventral mid-line between the anus and postanal band, with a single irregular row of melanophores extending along the ventral surface from the vertical band nearly to the notochord tip.

An irregular row of melanophores is present along the dorsal midline, extending posteriorly nearly to the notochord tip. Additionally, a few scattered melanophores appear laterally. Internal melanophores are present in a patch over the posterior hindgut near the anus and over the middle of the gut. Larvae >2.6 mm have one to several internal melanophores present along the anterior edge of the cleithrum, often appearing under the operculum. Pigmentation begins to appear in the eyes at about 2.9 mm.

At about 3.2 mm a row of internal melanophores are present over the notochord. In larvae >3.4 mm, one or two melanophores are present at the articulation of the lower jaw. By 3.5 mm eye pigmentation is complete; melanophores disappear from dorsolateral surfaces of the head; a few small melanophores appear along the margin of the pectoral fin fold. At 3.6 mm pigmentation disappears from the dorsolateral surface of the abdominal region and melanophores previously scattered over the yolk-sac are on the ventrolateral surfaces of the body, with some of these forming a row, often expanded and appearing as a solid line between the anus and cleithrum, with some on each side of the line. Scattered melanophores appear on the anal fin fold. At 3.7 mm yolk-sac absorption is complete.

At about 4.2 mm a few melanophores appear at the center of the dorsal fin fold and the gut loops. At >4.4 mm internal melanophores are present over the notochord in the vicinity of the pectoral fin base posterior to the cleithrum. The number of melanophores on the fin fold at the notochord flexion point increases in number with development and are visible on the caudal fin during and after development of caudal fin rays.

At about 5.0 mm the notochord begins to flex. At >5.0 mm the postanal band becomes less distinct, and is usually represented by only a few large stellate melanophores. At 5.3 mm the pectoral fin rays first begin to develop. At about 5.6 mm the dorsal, anal and caudal fin rays begin development in preflexion (prior to notochord flexion) larvae. At >5.6 mm scattered external melanophores begin appearing over the lateral surfaces of preflexion larvae. At >5.8 mm transforming larvae rapidly acquire a covering of external melanophores, and concentrated pigment spots develop along the dorsal and ventral body surfaces.

Preflexion larvae >6.2 mm have external melanophores beginning to appear scattered over the abdominal region, and as metamorphosis begins, the juvenile pattern of dense melanophore covering develops. At about 6.4 mm melanophores disappear along the margin of the pectoral fin fold. When the fish is about 6.6 mm the notochord flexion is complete and the pelvic fin bud appears in postflexion. Transition from pelagic to benthic habit usually occurs between 6.0 and 7.0 mm.

At about 7.0 mm adult complements of dorsal, anal and principal caudal fin rays are present. Migration of the left eye to the right side of the head and loss of pigmentation on the blind left side (onset of metamorphosis) occurs from 7 to 13 mm standard length in natural and laboratory populations and from 6 to 14 wk after the first feeding in laboratory, field enclosure and natural populations (Bigelow and Schroeder 1953; Laurence 1975; Laurence et al. 1979). Chambers and Leggett (1987) compared size and age at metamorphosis in laboratory-reared winter flounder. They found that the overall correlation between growth and developmental rates at metamorphosis was larger than that between length and age at metamorphosis (Table 5). Their data shows a positive correlation between growth and developmental rates and between length and age at metamorphosis. This indicates that fish with lower daily growth rates during the larval period metamorphosed later than fish with higher growth rates, even though these later fish were larger at metamorphosis. Conversely, fish with rapid growth rates metamorphosed early (i.e. had a shorter larval period) but at a smaller size. The timing of metamorphosis may also quantitatively change the intra- and interspecific interactions due to their size specificity and the correlation of age and size at metamorphosis. At 7.3 mm there is complete development of the pelvic fin bud and the free tip the of notochord disappears. In individuals >7.3 mm pigment bars (characteristic of juveniles) begin to develop on the dorsal and anal fins in flexion and postflexion larvae.

At 9.8 mm melanophore numbers on the caudal fin membrane increase through flexion and postflexion periods, with the entire fin becoming covered with melanophores, including an intense pigment patch near the fin base.

At 13 mm formation of pelvic fins is complete, with the pectoral fin rays being the last to complete development and marking the end of the transformation and the beginning of the juvenile period. Various body parts were measured on larvae by Laroche (1981) to examine developmental morphology and the body proportions are summarized in Table 6.

Juvenile Development:

Buckley and Caldarone (1988) examined the growth and condition of young-of-year (YOY) winter flounder in Narragansett Bay over a four month period. They found that YOY are primarily responsive to local conditions such as food availability. Furthermore, the observed differences in size and composition of YOY winter flounder among sites are not great and tend to diminish with time over the first year of life. They also found that the mean size of YOY winter flounder in Narragansett Bay was larger than those reported for the Mystic River Estuary (Pearcy 1962) or the Niantic River (Northeast Utilities 1987). Growth of juvenile winter flounder was highest in Narragansett Bay during warm months and decreased in October with falling temperatures (Buckley and Caldarone 1988). Data were broken down by each site making it possible to estimate a maximum length for YOY winter flounder for each month: 100 mm for July, 107 mm for August, 109 mm for September and 115 mm for October. The monthly mean length for each site is given in Figure 27. Generally, Greenwich Bay fish were the largest and Conimicut Point fish were the smallest of nine stations sampled in October, Greenwich Bay, Mill Cove, and Spectacle Cove produced the largest YOY winter flounder. Bissel Cove produced the smallest.

Adult Development:

Growth of winter flounder varies with geographic locality. According to Gibson (1989a) for the inshore stocks, there was a tendency for flounder south of southern New England (Eastern Long Island Sound to Narragansett Bay) to be larger at early ages than flounder north of southern New England which conversely were larger at older ages. The offshore population on Georges Bank was larger at all ages than all the inshore stocks. He assumed that the observed differences in growth were the results of variation in the spatio-temporal overlap of preferred temperatures with regions of high food availability i.e. high temperatures in the southern portion of the range drive adult winter flounder away from productive inshore waters resulting in a shorter growing season. Conversely, to the north, colder temperatures may reduce the degree-days available for efficient growth despite food availability. Applying the von Bertalanffy growth parameters, Gibson (1989a) found that winter flounder populations in southern New England, near the central portion of the range examined, had the largest growth parameter. These fish reached a large size and approached their maximum lengths at rapid rates (Table 7). In southern New England estimates of L50, the length where 50% of the females are mature, was 10.19 in. (Gibson 1989b). He then converted these lengths to ages using the growth models presented in Gibson (1989a) to give ages at 50% maturity (A50). He found that winter flounder in southern

New England mature in the average of 2.84 years, and concluded that size is more important in controlling flounder maturation than is age.

FOOD AND FEEDING

The diet of winter flounder consists of food items belonging to five major taxa: crustaceans, polychaetes, molluscs, macroalgae and tunicates (Mulkana 1966; Olla et al. 1969; Frame 1971, 1973, 1974; Oviatt and Nixon 1973; Wells et al. 1973; Levings 1974; Worobec 1982; Bharadwaj 1988). Winter flounder are omnivorous (Frame 1973; Oviatt and Nixon 1973; Wells et al. 1973; Worobec 1982) and may be functional omnivores (Wells et al. 1973). Foods items consumed by winter flounder are summarized in Tables 8-10. Winter flounder are visual feeders (Olla et al. 1969; Bharadwaj 1988) requiring minimal light penetration to seek prey (Pearcy 1962; Frame 1971; Olla et al. 1969; Worobec 1982). Factors influencing prey selection are likely to be visual, since prey organisms of similar weight (size) are differentially selected (Levings 1974). Feeding occurs in all seasons of the year following a daily cycle (Mulkana 1966; Olla et al. 1969; Frame 1971; Laurence 1977). Other feeding periodicity patterns have been described with feeding periods occurring: (1) 2-3 hrs. prior to sunrise, in early afternoon and evening (Bharadwaj 1988) and (2) from sunrise continuing through the mid-morning hours (Frame 1971), although the quantity of food consumed daily is variable i.e. on cloudy days during the summer, feeding commences well after sunrise, so that stomach contents on a cloudy day weigh less than might be expected on a clear day and fish also consume less food and stomachs remain empty longer during the winter.

The volume of food consumed by winter flounder are lowest during cold periods (December-April) (Levings 1974), and highest during warm periods (June-September) (Worobec 1982; Bharadwaj 1988). Gastric evacuation is influenced by food type, temperature, frequency of feeding, meal size, and fish size (Worobec 1982), with larger meals causing a lag in the start of digestion, leading to longer evacuation times and lower evacuation rates. Higher evacuation rates generally occur in fish feeding on small prey (Bharadwaj 1988). The intertidal zone is a major feeding area for inshore winter flounder populations (Tyler 1972). Feeding behavior in winter flounder does not appear to be linked with the state of the tide (Bharadwaj 1988), although winter flounder do enter the intertidal zone to feed, occupying this area for 6-8 hrs. of the 12-hr. tidal cycle (Tyler 1972).

Yolk-sac larvae spend the first 4-14 days of life without exogenous feeding (Rogers 1976). Larvae begin to feed at or shortly after the absorption of their yolk (Buckley 1982), and the immediate availability of suitable food after yolk sac absorption is the "critical period" in the organisms life . The diet of larval (<1.5cm total length(TL)) winter flounder (stages 1-3) consists of phytoplankton (diatoms and dinoflagellates), ciliates (tintinnids), and small zooplankton. A high proportion of early stage (stage 1) larvae contain phytoplankton and ciliates; major prey groups of older stage (stages 2-3) larvae are tintinnids, copepod eggs and nauplii, copepodites, and polychaete larvae; stage 3 larvae feed primarily on copepod, nauplii and copepodites (Klein-MacPhee 1987). Larval winter flounder consume plankton (copepods) as a function of their size and copepod size; smaller flounder larvae initiate feeding on small prey (nauplii) and gradually eat increasingly greater percentages of larger (older stage) copepods as larval flounder size increases, showing a linear increase in food consumption with increasing size (Laurence 1977). In general, winter flounder larvae consume the same organisms, but percent composition of these prey in the diet changes with location and various other physical and biological factors (Frame 1971; Klein-MacPhee 1987). The amount of food consumed during the day depends on the size of the fish and the density of prey organisms available; percent body weight consumed per day by larval winter flounder ranges from 300% at the smallest larval sizes to 27-31% at the largest larval sizes (Laurence 1977).

Juvenile winter flounder (1.5-25cm TL) feed on crustaceans, polychaetes, molluscs, tunicates and macroalgae (Frame 1971, 1973, 1974; Worobec 1982; Bharadwaj 1988). Food preference shifts after the midpoint of the first year from planktonic to benthic. Planktonic copepods are more numerous in juvenile winter flounder in the spring, and amphipods, polychaetes, and bivalves are more numerous in the summer and fall, which suggests the benthic community is not an important food source in the spring for juvenile winter flounder (< age 1.5) (Frame 1974). Planktonic crustaceans in the diet of young (age 1+) flounder are replaced by polychaetes as the flounder grows older (Pearcy 1962). Polychaetes, amphipods and molluscs are the most preferred food types of juvenile (11-26 cm TL) winter flounder, with tunicates being eaten only by fish greater than or equal to 20 cm TL (Worobec 1982; Bharadwaj 1988). Juvenile winter flounder consume amounts of food ranging from 1-5% of their body weight (Bharadwaj 1988). Smaller fish tend to select smaller prey species and there is a preference for larger food organisms with increasing fish size (Mulkana 1966). Temperatures above 20°C cause cessation of feeding in juvenile winter flounder (Frame 1973).

Adult winter flounder (>25 cm TL) feed on the same classes of invertebrates as age 1+ juvenile flounder (>11 cm TL), but seasonal preferences for given taxa differ (Frame 1974). Amphipods, crustaceans, polychaetes, bivalves, gastropods, tunicates, macroalgae and detritus are consumed by adult winter flounder (Oviatt and Nixon 1973; Levings 1974). Scott (1982) found that winter flounder concentrated largely on softer fish, small crustaceans, and polychaetes. In adult winter flounder larger than 27 cm TL, tunicates may be a major food source and have been found to comprise more than 95% of the dry weight eaten (Worobec 1982). During spring feeding (April/May), food particles are small, but many are eaten; during summer (June/July), food particles are larger and fewer are eaten (Levings 1974). Ouellette and Feng (1979) found that winter flounder constantly consumed a significant quantity of polychaetes and the importance of polychaetes in the diet of winter flounder increased with age. General feeding trends of adult winter flounder are similar to juvenile feeding trends in that daily rations are lowest during cold periods (December - April), highest during warm periods (June-September) (Levings 1974; Worobec 1982). Ripe adult winter flounder stop feeding during the spawning season (November-May) (Perlmutter 1947; Tyler 1973; Grove 1982) and resume feeding after spawning. Life history events may be related to seasonal changes in prey selection; heavy feeding during April-July may represent recovery of stored energy after loss of gonadal tissue during spawning (Levings 1974).

Winter flounder migrations may be temperature-dependent and may also depend on food and feeding limitations in a discrete area, in particular, the inability to capture enough prey within a feeding period to meet metabolic demands as opposed to feeding migrations induced by low absolute abundance of prey organisms (Worobec 1982).

PREDATORS

Sarsia tubulosa medusae prey on winter flounder larvae, and their distribution in time and space was similar to that of the larvae (Pearcy 1962). He suggests the possibility of a classical predator-prey lag oscillation, since peaks of flounder abundance were followed by peaks of Sarsia. Grove (1982) suspected that jellyfish, Aurelia aurelia and sand launce, Ammodytes americanus might prey on larvae (prolarvae winter flounder were later found in sand launce stomachs). She observed that larvae were not found when jellyfish were present in large numbers (6480/m3) in the upper pond area of Point Judith Pond, R.I..

While in deep water during winter, this flounder is probable prey for monkfish, dogfish, and sea raven (Dickie and McCracken 1955). Winter flounder are also important food for harbour, harp, and grey seals (Fisher and MacKenzie 1955; Mansfield 1967). Tyler (1971) stated, "I have seen both great blue heron and osprey take fish in the intertidal areas of Passamaquoddy Bay." but he did not say whether they prey on juveniles or adults.

DISEASE

Bottom dwelling fishes, especially those which are minimally migratory, and occupy the same area after metamorphosis, may be expected to exhibit environmentally induced diseases (Ziskowski et al. 1987) and this behavioral aspect of its life history increases the chance that condition at capture is reflective of environmental conditions in the capture area.

Black et al. (1988) examined the exposure of adult winter flounder to contaminated natural environments (Figure 28) prior to spawning, and the possible impact of this exposure upon their progeny. These investigators found that flounder eggs from New Bedford Harbor, Massachusetts contained significantly higher levels of polychlorinated biphenyls (PCB's) (39.6 µg/g dry weight). Larvae which hatched from these eggs, under clean laboratory conditions, were significantly smaller in length (2.96 mm) and weight (0.018 mg) than fish from Fox Island, Rhode Island (1.08 µg PCB/g dry weight), (3.22 mm, 0.022 mg). They attributed the retarded growth to either contaminants covarying with PCB's and/or the influence of inherited PCB residue.

Lee et al. (1988) conducted a study on the probable effects of pollution on stocks of winter flounder in Narragansett Bay and vicinity. They chose three sites (Warwick Neck, Whale Rock and Quonochontaug Pond), which were presumed to represent a pollution gradient. Sampling was done during the winter and late spring. These investigators found that of the contaminants examined (PCB's, lead, cadmium, mercury and arsenic) none were found in "unacceptably" high amounts in the muscle tissues. However, the amounts found in the livers were consistently higher than muscle tissue levels (Tables 12-15). Additionally, they found that concentrations of some metals were highly correlated, and that the presence of neoplasms and macrophage aggregates are associated with high levels of PCB's in the liver. They concluded that anthropogenic pollution is adversely affecting the "health" of winter flounder in Narragansett Bay.

Ziskowski et al. (1987) examined approximately 85,000 individuals of 10 economically important fish species, for gross external lesions and anomalies. They found that the prevalence of fin rot, fin erosion and lymphocystis from winter flounder in Southern New England (Block Island to the northern tip of Cape Cod, to the 27m isobath) was significantly lower when compared with the eight geographic areas tested (Figure 29). They also found that externally evident axial skeletal anomalies (bent fin) as well as ulcers were uncommon and showed no geographic trend in their occurrence and distribution.

PARASITES

The winter flounder is host to a great variety of parasites, and these are summarized in Table 11.

RHODE ISLAND MINIMUM SIZE REGULATIONS:

No person, firm, or corporation shall take, possess, sell, possess for sale, or offer for sale any winter flounder measuring less than eleven and one-half (11-1/2) inches total length whether caught within the jurisdiction of this State or otherwise. Effective January 1, 1991 the winter flounder size will be increased to twelve (12) inches total length. (RIMFC REGULATION) (Penalty 20-3-3 - Part 3.03).

WINTER MESH SIZE REGULATIONS IN RHODE ISLAND:

This area is defined as all Rhode Island State waters which are north of the following lines: north of a line running from the easternmost extension of Carrier Pier to

Conanicut Pt. to the tips of the T Pier on Prudence Island to Carr's Point; and north of a line from Sachuest Pt. to Sakonnet Point; and all waters north of Quonochontaug and Charlestown Breachways. In that portion of the area described above which is open to trawling, it is illegal to utilize an otter trawl during the period November 1 to Febuary 28, (inclusive) which has a cod end which measures less than 5" stretched mesh (measured inside knot to inside knot). For the purposes of this regulation the cod end of an otter trawl shall be defined as the last 20 meshes on the terminal end of the net. (RIMFC REGULATIONS) (Penalty 20-3-3-Part 3.03).

RHODE ISLAND MARINE FISHERIES COUNCIL--Part 3.03 Penalties: Unless another penalty is specified in this Title, any person who shall violate a rule or regulation of the Marine Fisheries Council shall, upon conviction, be punished by a fine of not more than five hundred dollars ($500.00) or imprisonment for not more than thirty (30) days, or both. (REFER TO RHODE ISLAND GENERAL LAW 20-3-3).

LICENSES: **Season:** Year-round.	**FEE:**
Non-commercial	
(resident or non-resident)	None
Commercial Fishing	
Fish Traps *	
License	$100.00
Plus $10.00/trap	$ 10.00
Gill Nets	$100.00
Rod and Reel (and diving)	$100.00
Individual (without boat)	$100.00
Commercial Vessels (finfish only)	
Commercial resident vessels *	
Up to 50' LOA	$100.00
50' to 99' LOA	$125.00
Over 99' LOA	$ 10.00/ft.
Mult. purpose (good for all above)*	$150.00
Plus $10.00 for a gill net license	$ 10.00
Non-resident otter trawler	$ 5.00/ft.

* RESIDENTS ONLY

<u>Expiration of licenses</u>:
Commercial licenses expire annually on December 31. (R.I.G.L. 20-2-14).

<u>Obtaining licenses</u>:
All marine licenses are issued by the licensing section of the Department of Environmental Management, 22 Hayes St., Providence, R.I. 02908. Tel. No. 401-277-3576.

RHODE ISLAND GAME FISH AWARD PROGRAM:

On 21 APRIL 1989 the state record for winter flounder was set by Cynthia Raso of Wakefield, R.I. The official weight and size of this winter flounder was 3 lbs. 6 oz. at 19 in.

ACKNOWLEDGEMENTS

I would like to thank the following individuals who have given me valauble assistance by providing information; Grace Klein-MacPhee, Mark R. Gibson, Timothy R. Lynch, J. Christopher Powell, Richard J. Satchwill and Richard T. Sisson. John D. Karlsson and Richard J. Satchwill for generation of graphs. David Borden, John D. Karlsson, Richard J. Satchwill and Richard T. Sisson for a review of the manuscript and valuable suggestions. Thomas Angell for literary searches allowing me to complete this work uninterrupted. Janice Sieburth, Head Librarian at the University of Rhode Island, Graduate School of Oceanography Narragansett, Rhode Island, for her untiring assistance. Mrs. Hazel Sirr for editing the bibliography.

BIBLIOGRAPHY

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildlife Serv., Fish. Bull. 53, 577 p.

Bharadwaj, A. S. 1988. The feeding ecology of the winter flounder in Narragansett Bay, Rhode Island. MS Thesis, Univ. Rhode Island, Kingston, R.I., 129 p.

Black, D.E., D.K. Phelps and R.L. Lapan. 1988. The effect of inherited contamination on egg and larval winter flounder, Pseudopleuronectes americanus. Marine Env. Res. 25(1):45-62.

Breder, C. M., Jr.
1922. Description of the spawning habits of Pseudopleuronectes americanus in captivity. Copeia 102:34.
1924. Some embryonic and larval stages of the winter flounder. Bull. U.S. Bur. Fish. 38:311-315.

Buckley, J. 1989. Species profile: life histories and environmental requirements of coastal fishes and invertebrates(North Atlantic)--Winter flounder. U.S. Fish and Wildlife Service Biol. Rep. 82(11.87):12p.

Buckley, L. J.
1982. Effects of temperature on growth and biochemical composition of larval winter flounder, Pseudopleuronectes americanus. Mar. Ecol. Prog. Ser. 8:181-186.
1990. Personal Communication.

Buckley, L.J. and E.M. Caldarone. 1988. Recent growth and biochemical composition of juvenile, Young-of-Year winter flounder from different areas of Narragansett Bay. Current Report Narragansett Bay Project: Report #NBP-89-14.

Casterlin, M. E. and W. W. Reynolds. 1982. Thermoregulatory behavior and diel activity of yearling winter flounder, Pseudopleuronectes americanus (Walbaum). Env. Biol. Fish. 7(2):177-180.

Chakrabartty, A., V.S. Ananthanarayanan and C.L. Hew. 1989. Structure-function relationship in a winter flounder antifreeze polypeptide. I. Stabilization of an α-helical antifreeze polypeptide by charged-group and hydrophobic interactions. J. Biol. Chem. 264(19): 11307-11312

Chakrabartty, A., D.S.C. Yang and C.L. Hew. 1989. Structure-function relationship in a winter flounder antifreeze polypeptide. II. Alteration of the component growth rates of ice by synthetic antifreeze polypeptides. J. Biol. Chem. 264(19): 11313-11316.

Chambers, R. C. and W. C. Leggett. 1987. Size and age at metamorphosis in marine fishes: an analysis of laboratory-reared winter flounder (Pseudopleuronectes americanus) with a review of variation in other species. Can. J. Fish. Aquat. Sci. 44:1936-1947.

Cooper, R. A. 1964. Some vital statistics of the tautog, Tautog onitis (L.), from Rhode Island. University of Rhode Island PhD Thesis. 152p.

Crawford, R. E. 1990. Winter flounder in Rhode Island coastal ponds. Rhode Island Sea Grant, University of Rhode Island, Narragansett, RI. RIV-G-90-001. 24p.

Dickie, L. M., and F. D. McCracken. 1955. Isopleth diagrams to predict equilibrium yields of a small flounder fishery. J. Fish Res. Bd. Can. 12: 187-209.

Durbin, A. G. and E. G. Durbin 1988. Zooplankton and Ichthyoplankton in Narragansett Bay: status and trends. Part 2: Ichthyoplankton.

Fisher, H. D., and B. A. Mackenzie. 1955. Food habits of seals in the Maritimes. Prog. Rep. (Atl.) Fish. Res. Bd. Can. 61: 5-9.

Foster, K. L. 1986. Estuarine winter flounder, p. 41-44. In report on the third NEFC stock assessment workshop. Ref. Doc. 86-14, Woods Hole Lab., NMFS, NOAA, Woods Hole, MA 02543, 98p.

Frame, D.W.
- 1971. Biology of young winter flounder:feeding habits, metabolism and food utilization. Dissertation University of Mass.
- 1973. Conversion efficiency and survival of young winter flounder (Pseudopleuronectes americanus) under experimental conditions. Trans. Amer. Fish Soc. 102:614-616.
- 1974. Feeding habits of young winter flounder: prey availability and diversity. Trans. Fish. Soc. 103(2):261-269.

Frank, K. T. and W. C. Leggett. 1983. Multispecies larval larval fish associations: accident or adaptation? Can. J. Fish. Aquat. Sci. 40: 754-762.

Gibson, M. R.
- 1989a. A study and comparison of winter flounder growth rates in several Northwest Atlantic populations from New Jersey to Newfoundland with emphasis on Rhode Island. Res. Ref. Doc. 89-5. Rhode Island Division of Fish and Wildlife. 31p. A.
- 1989b. Variation in size at maturity in winter flounder: implications for fishing effects on spawning stock biomass levels. Res. Ref. Doc. 89-6. Rhode Island

Division of Fish and Wildlife. 30p.
1989c. Size limits with special reference to winter flounder in Rhode Island. Res. Ref. Doc. 89-2. Rhode Island Division of Fishand Wildlife. 32p.

Grove, C. A. 1982. Population biology of the winter flounder, Pseudopleuronectes americanus, in a New England estuary. MS Thesis, Univ. Rhode Island, Kingston, R.I., 81p.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Bull. U.S. Bur. Fish., 43: 388p.

Howe, A. B. and G. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. Trans. Amer. Fish. Soc., 104:13-29.

Huntsman, A. G. and M. I. Sparks. 1924. Limiting factors for marine animals. Contri. Can. Biol. New Serv. 2:97-114.

Jeffries, H.P. and W.C. Johnson. 1974. Seasonal distributions of bottom fishes in the Narragansett Bay area: seven-year variations in the abundance of winter flounder (Pseudopleuronectes americanus). J. Fish. Res. Bd. Can. 31:1057-1066.

Jeffries, H.P. and M. Terceiro. 1985. Cycle of changing abundances in the fishes of the Narragansett Bay area. Mar. Ecol. Prog. Ser. 25:239-244.

Jeffries, P., S. Hale, and A. Keller. 1988. Historical data assessment of finfishes of the Narragansett Bay area. Current Report the Narragansett Bay Project: #NBP-89-15.

Karlsson, J. D. 1990. Marine Recreational Fish Survey; Unpublished data.

Klein-MacPhee, G.
1978. Synopsis of biological data for the winter flounder, Pseudopleuonectes americanus(Walbaum). NOAA Technical Report NMFS Circular 414. FAO Fisheries Synopsis No.117.
1983. Unpublished data.
1987. Food of larval winter flounder in three areas of Narragansett Bay. Narragansett Bay Symposium pp. 163-164.
1990. Personal Communication.

Klein-MacPhee, G., J. A. Cardin and W. J. Berry. 1984. Effects of silver on eggs and larvae of the winter flounder. Trans. Amer. Fish. Soc. 113:247-251.

Laroche, W. A. 1981. Development of larval smooth flounder, Liopsetta putnami, with a redescription of development of winter flounder, Pseudopleuronectes americanus (Family Pleuronectidae). Fish. Bull. 78(4):897-909.

Laurence, G. C.

1975. Laboratory growth and metabolism of the winter flounder Pseudopleuronectes americanus from hatching through metamorphosis at three temperatures. Marine Biology 32:223-229.

1977. A bioenergetic model for the analysis of feeding and survival potential of winter flounder, Pseudopleuronectes americanus, larvae during the period from hatching to metamorphosis. Fish. Bull. 75(3): 529-546.

Laurence G. C., T. A. Halavik, B. R. Burns, and A. S. Smigielski. 1979. An environmental chamber for monitoring "In Situ" growth and survival of larval fishes. Trnas. Amer. Fish. Sec. 108: 197-203.

Lee, T. C., S. B. Saila and R. E. Wolke. 1988. Winter flounder contaminant and pathological Survey - Narragansett Bay and vicinity. Draft Report, Narragansett Bay Project.

Leim, A. H. and W.B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Fis. Res. Bd. Can. No. 155.

Levings, C. D. 1974. Seasonal changes in feeding and particle selection by winter flounder (Pseudopleuronectes americanus). Trans. Amer. Fish. Soc. 103:828-832.

Lobell, M. J. 1939. A biological survey of the salt waters of Long Island, 1938. Report on certain fishes. Winter flounder (Pseudopleuronectes americanus) 28th Annu. Rep. N.Y. Can. Dep., Part I. Suppl. 14: 63-96.

Lynch, T. R. and J. D. Karlsson. 1989. Coastal fishery resource assessment-trawl survey, 1988. Rhode Island Division of Fish and Wildlife 89:31p.

Mansfield, A. W. 1967. Seals of arctic and eastern Canada. Bull. Fish. Res. Bd. Can. 137: 35p. (Second edition, revised.)

Martin, F.D. and G. E. Drewry. 1978. Development of fishes of the Mid Atlantic Bight, an atlas of eggs, larval and juvenile stages. Vol. VI. Stramateidae through Ogcocephalidae. U.S. Dept. Interior, Fish and Wildl. Serv., Biol. Serv. Prog. FWS/OBS. 78-12. 416p.

McConnell, K. E., T. P. Smith and J. F. Farrell. 1981. Marine sportfishing in Rhode Island, 1978. NOAA/Sea Grant, Univ. Rhode Island Tech. Rep. 83.

McCracken, F.D. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum), on the Atlantic Coast. J. Fish. Res. Bd. Can. 20:551-586.

Mulkana, M.S. 1966. The growth and feeding habits of juvenile fishes in two Rhode Island estuaries. Gulf Res. Rep. 2(2):97-168.

NUSCo.(Northeast Utilities Service Company). 1987. Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station, Waterford, CT. Annual Report 1987.

Olla, B.L., R. Wicklund and S. Wilk. 1969. Behavior of winter flounder in a natural habitat. Trans. Amer. Fish. Soc. 98(4):717-720.

Olsen, S. B., and D. K. Stevenson. 1975. Commercial Marine Fish and Fisheries of Rhode Island. CRMC. Univ. Rhode Island Marine Tech. Rep. 34.

Ouellette, T. R. and S.Y. Feng. 1979. Rationale for using the polychaete worm, Nepthys incisa and the winter flounder Pseudopleuronectes americanus as biological monitors for trace in the environment. Marine Sciences Institute, Univ. of Connecticut, Groton, CT.

Oviatt, C.A. and S.W. Nixon. 1973. The demersal fish of Narragansett Bay:an analysis of community structure, distribution and abundance. Estuarine and Coastal Mar. Sci. 1973(I):361-378.

Pearcy, W.G.
1961. Seasonal changes in osmotic pressure of flounder sera. Sci. 134:193-194.
1962. Ecology of an estuarine population of winter flounder, Pseudopleuronectes americanus(Walbaum) Parts I-IV. Bull. Bing. Ocean. Coll. 18(1):5-78.

Pellegrino, P. E. 1973. The ecology of the parasites of the winter flounder, Pseudopleuronectes americanus (Walbaum). PhD Thesis, Univ. Connecticut, 145p.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bull. Bingham Oceanog. Collect., Yale Univ. 11(2). 92p.

Powell, J. C.
1986. Winter flounder population assessment. Performance Report. Rhode Island Division of Fish and Wildlife. F-26-R-21. 14p.
1987. Winter flounder population assessment. Performance Report. Rhode Island Division of Fish and Wildlife. F-26-R-22. 21p.
1988. Winter flounder population assessment. Performance Report. Rhode Island Division of Fish and Wildlife. F-26-R-23. 26p.
1989a. Winter flounder spawning characteristics and habitat requirements. Res. Ref. Doc. 89-4. Rhode Island Division of Fish and Wildlife.

1989b. Winter flounder tagging study, 1986-1988 with comments on movements.

1989c. Winter flounder population assessment. Performance Report. Rhode Island Division of Fish and Wildlife. F-26-R-24. 25 p.

1990. Juvenile winter flounder habitat in Narragansett Bay. Personal Communication.

Richards, S. W. 1963. The demersal fish population of Long Island Sound. Bull. Bingham Oceanogr. Collect., Yale Univ. 18(2), 101p.

Rogers, C. A. 1976. Effects of temperature and salinity on the survival of winter flounder embryos. Fish. Bull. 74(1):52-58.

Saila, S.B.

1961a. The contribution of estuaries to the offshore winter flounder fishery in Rhode Island. Proc. Gulf and Carribean Fisheries Inst. 14th Annual Session pp. 95-109.

1961b. A study of winter flounder movements. Limnology and Oceanography 6(3):292-298.

1962. Proposed hurricane barriers related to winter flounder movements in Narragansett Bay. Trans. Amer. Fish. Soc. 91(2):189-195.

Saila, S., T.M. Bradley and S.G. Ayvazian. 1988. An analysis of mitochondrial DNA from the winter flounder Pseudopleuronectes americanus(Walbaum) in Narragansett Bay. Proposal.

Scarlett, P. G. 1986. Life history investigations of marine fish. Occurrence, movements, food habits and age structure of winter flounder from selected New Jersey Dept. Envir. Prot., Div. Fish, Game and Wildl., Bur. Mar. Fish. Tech. Ser. 86-20. 57p.

Scott, J. S. 1982. Digenean parasite communities in flatfishes of the Scotian Shelf and southern Gulf of St. Lawrence. Can. J. Zool. 60:2804-2811.

Scott, W. B., and M. G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731p.

Sisson, R. T. and R. J. Satchwill. 1990. Unpublished data.

Stolgitis, J. A., J. F. O'Brien and M. J. Fogarty. 1976. Rhode Island salt ponds fisheries inventory. Rhode Island Div. Fish and Wildl., fisheries report No. 2.

Topp, R.W. 1968. An estimate of the fecundity of the winter flounder, Pseudopleuronectes americanus. J. Fish. Res. Bd. Can. 25:1299-1302.

Tyler, A.V.
1971. Periodic and resident components in communities of Atlantic fishes. J. Fish. Res. Bd. Can. 28(7): 935-946.
1972. Surges of winter flounder, Pseudopleuronectes americanus, into the intertidal zone. J. Fish. Res. Bd. Can. 28:1727-1732.
1973. Alimentary tract morphology of selected North Atlantic fishes in relation to food habits. Fish. Res. Bd. Can., Tech. Rep. 361. 23p.

United States Department of Commerece (USDC).
1989. Status of the fishery resources off the North eastern U.S. for 1989. NOAA, NMFS-F/NEC-72.
1987. Marine recreational fishery statistics survey, Atlantic and Gulf Coasts 1986. NOAA, NMFS, Current Fishery Statistics Number 8392.

Wells, B., D.H. Steele and A.V. Tyler. 1973. Intertidal feeding of winter flounder in the Bay of Fundy. J. Fish Res. Bd. Can. 30:1374-1378.

Williams, G. C. 1975. Viable embryogensis of the winter flounder Pseudopleuronectes americanus from -1.8 to 15°C. Marine Biology 33:71-74.

Worobec, M. N. 1982. Field Analysis of winter flounder, Pseudopleuronectes americanus, in a coastal salt pond: abundance, daily ration, and annual consumption. PhD Thesis, Univ. Rhode Island, Kingston, R.I., 115p.

Ziskowski, J.J., L. Despres-Patanjo, R.A. Murchelano, A.B. Howe, D. Ralph and S. Atran. 1987. Disease in commercially valuable fish stocks in the Northwest Atlantic. Marine Pollution Bull. 18(9):496-504.

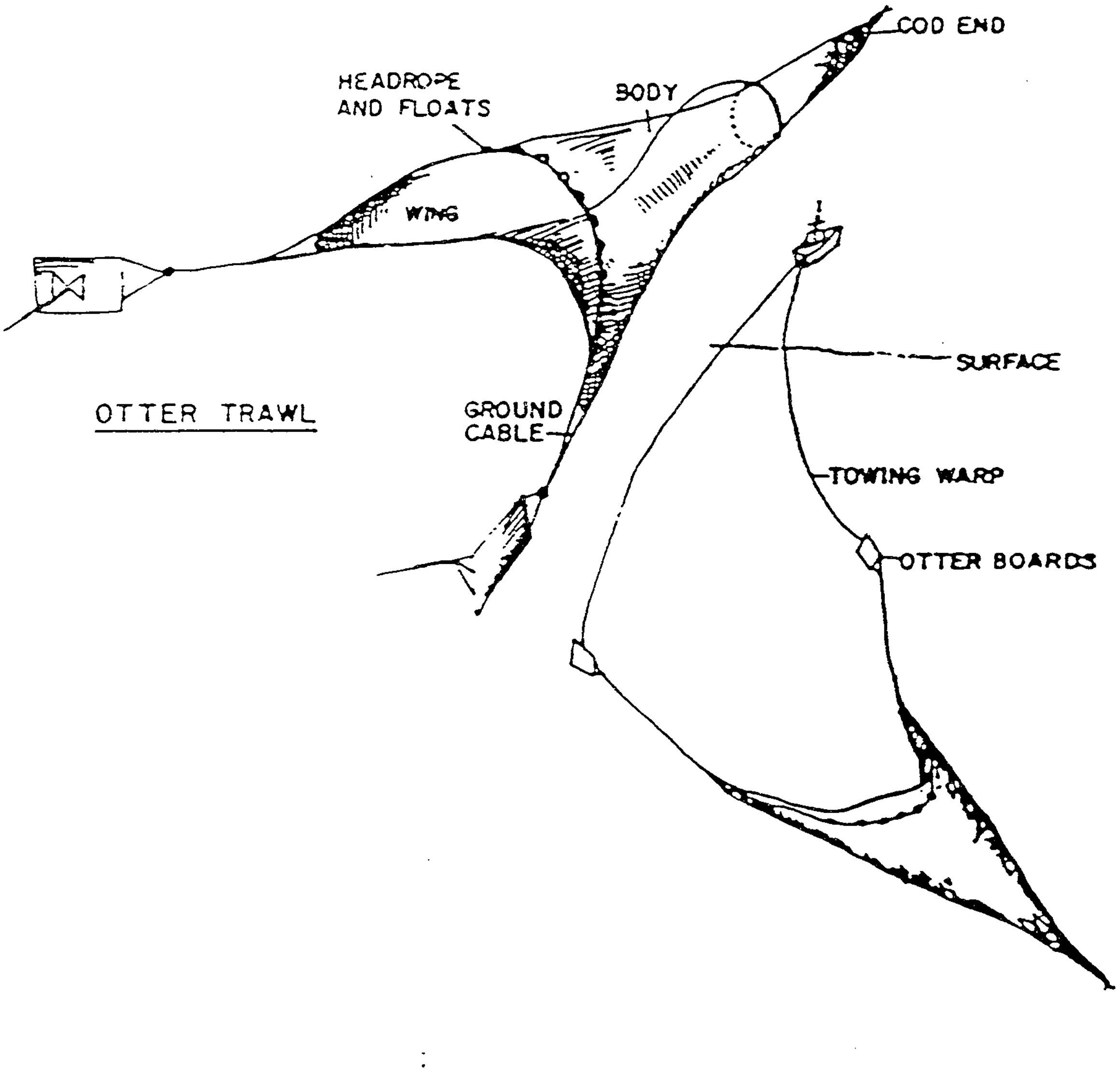
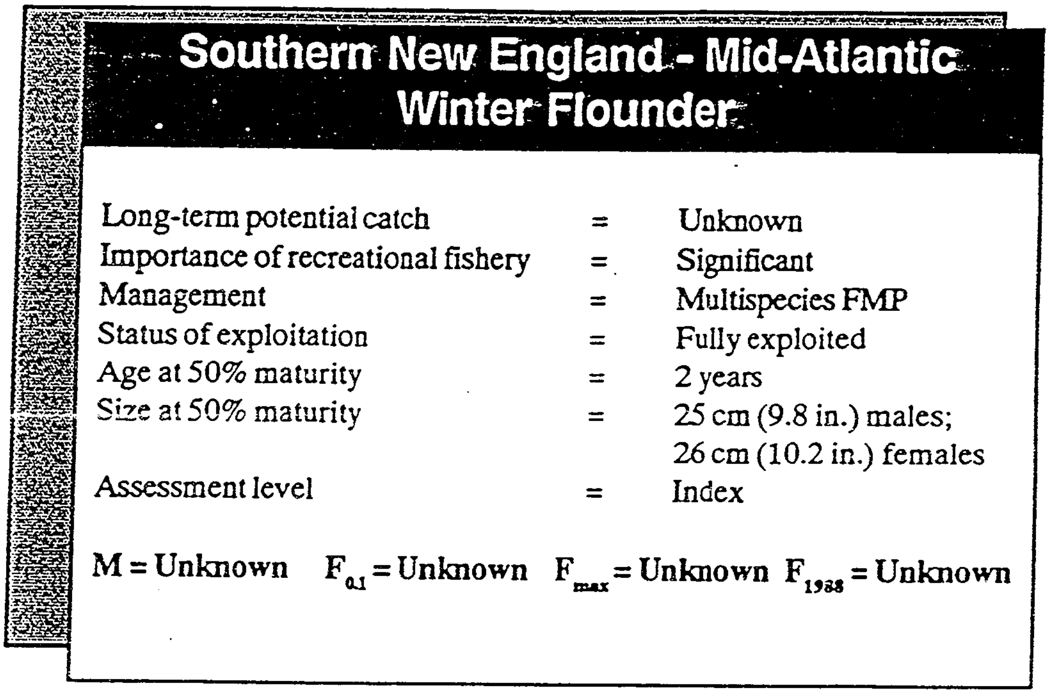


Figure 1. The otter trawl.

Figure 2. Status of winter flounder exploitation.



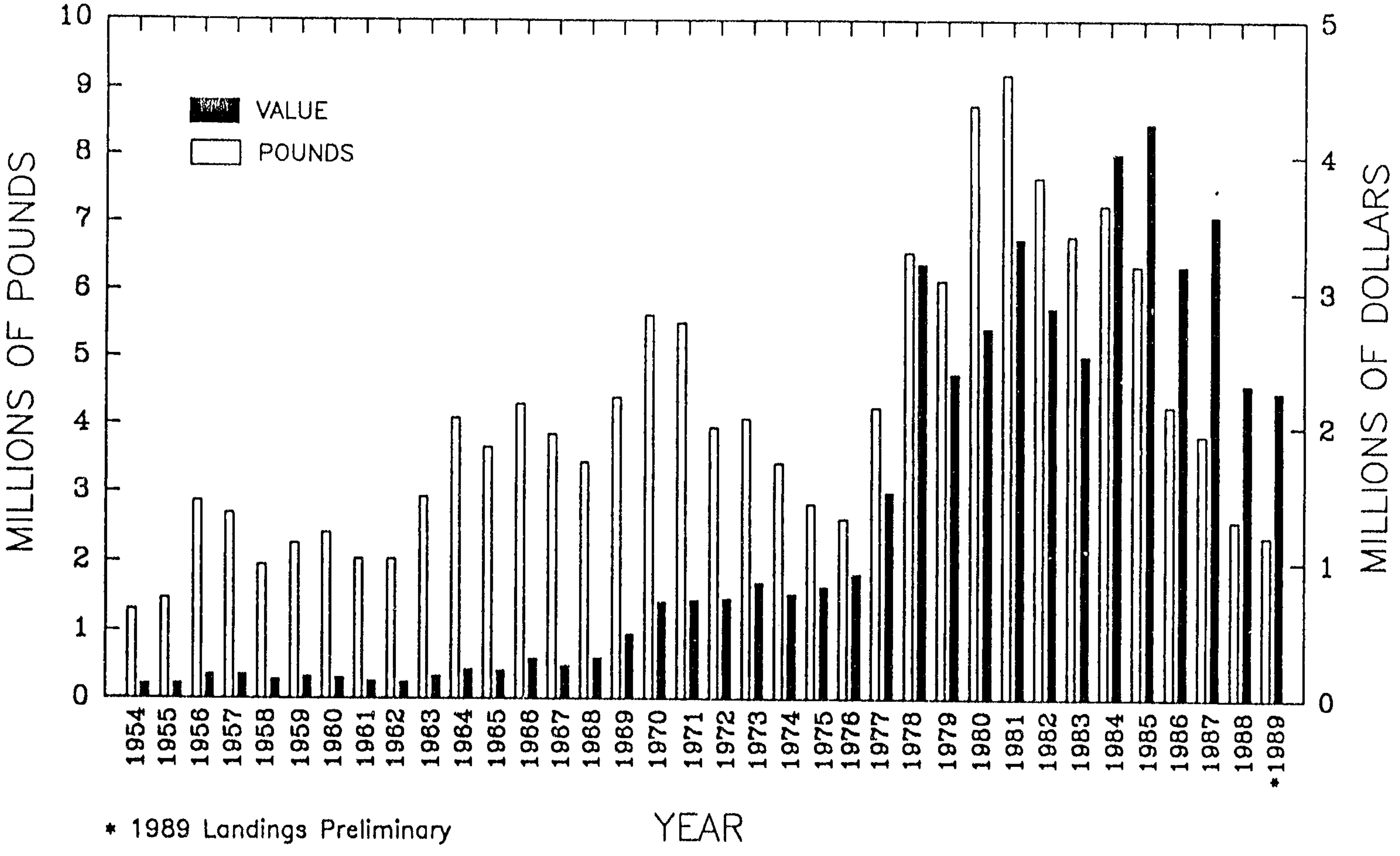
Southern New England - Mid-Atlantic Winter Flounder

Long-term potential catch = Unknown
Importance of recreational fishery = Significant
Management = Multispecies FMP
Status of exploitation = Fully exploited
Age at 50% maturity = 2 years
Size at 50% maturity = 25 cm (9.8 in.) males; 26 cm (10.2 in.) females
Assessment level = Index

M = Unknown $F_{0.1}$ = Unknown F_{max} = Unknown F_{1988} = Unknown

Source NMFS 1989.

FIGURE 3
RHODE ISLAND COMMERCIAL LANDINGS
WINTER FLOUNDER

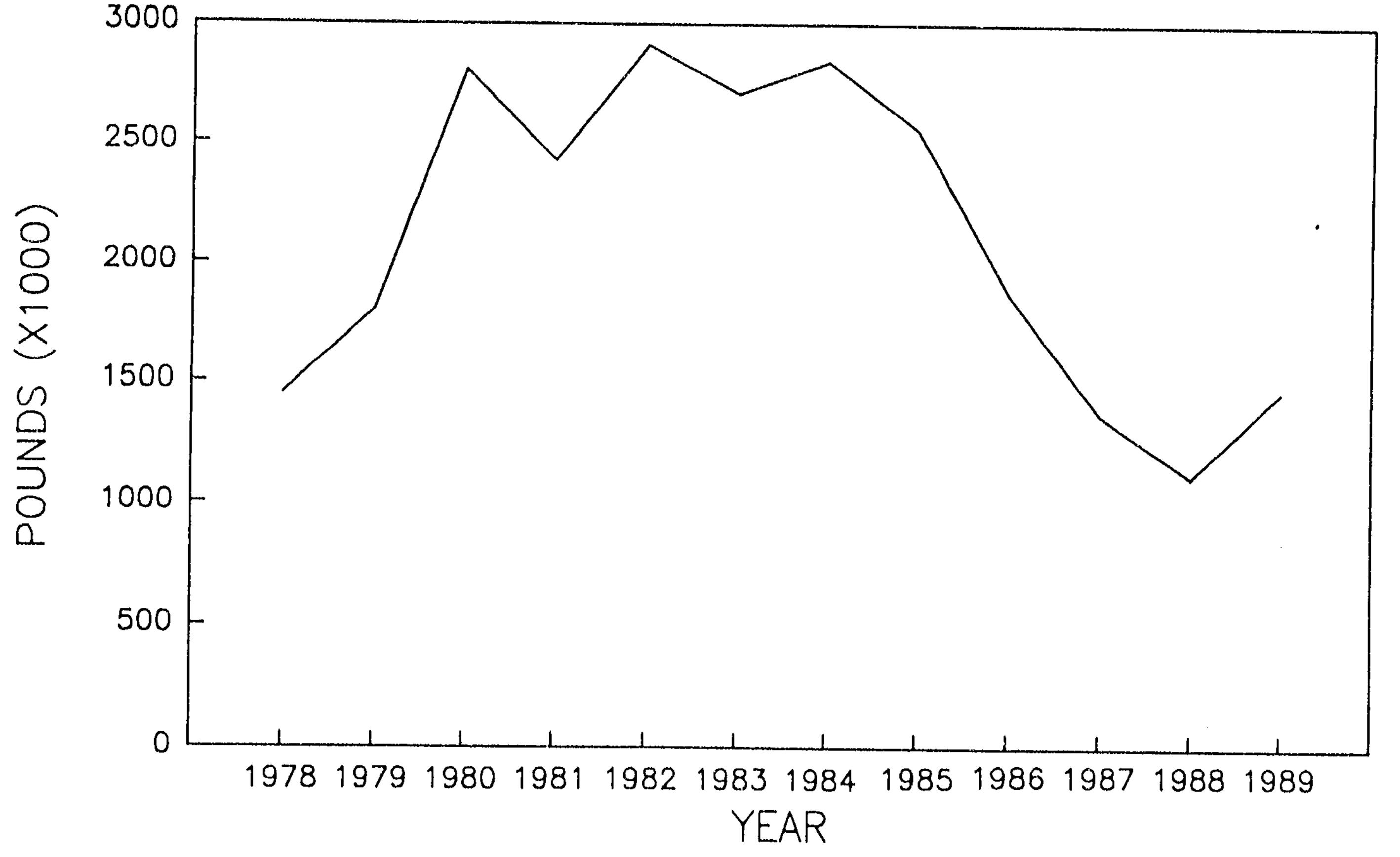


* 1989 Landings Preliminary

(Data Source: National Marine Fisheries Service Statistics Section)

FIGURE 4

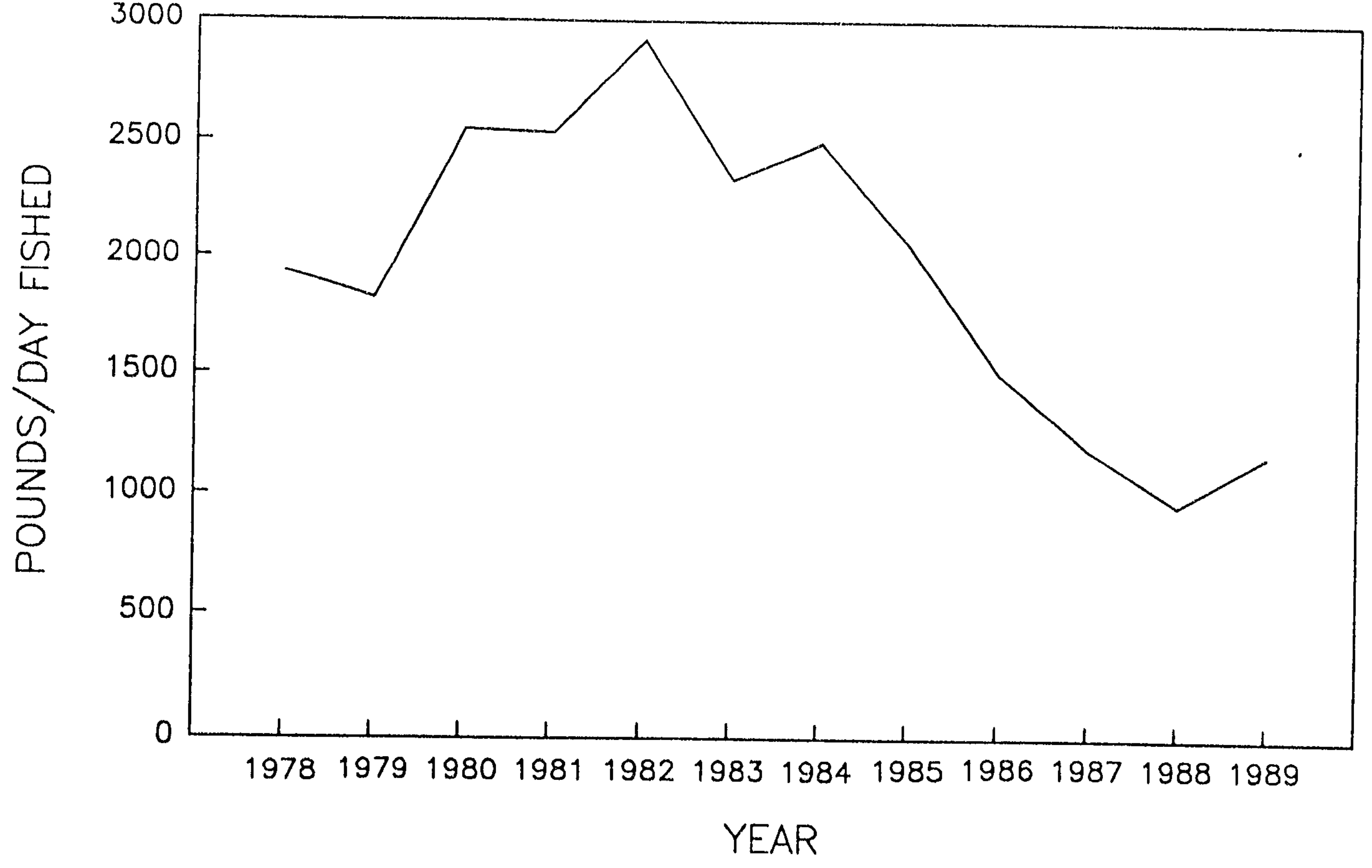
STATISTICAL AREA 539 WINTER FLOUNDER LANDINGS



(DATA SOURCE: NMFS STATISTICS SECTION PT. JUDITH, RI)

FIGURE 5

STATISTICAL AREA 539 WINTER FLOUNDER LANDINGS
CATCH PER UNIT OF EFFORT (CPUE)



(DATA SOURCE: NMFS STATISTICAL SECTION PT. JUDITH, RI)

FIGURE 6

WINTER FLOUNDER ABUNDANCE IN NARRAGANSETT BAY

RIDFW TRAWL SURVEY

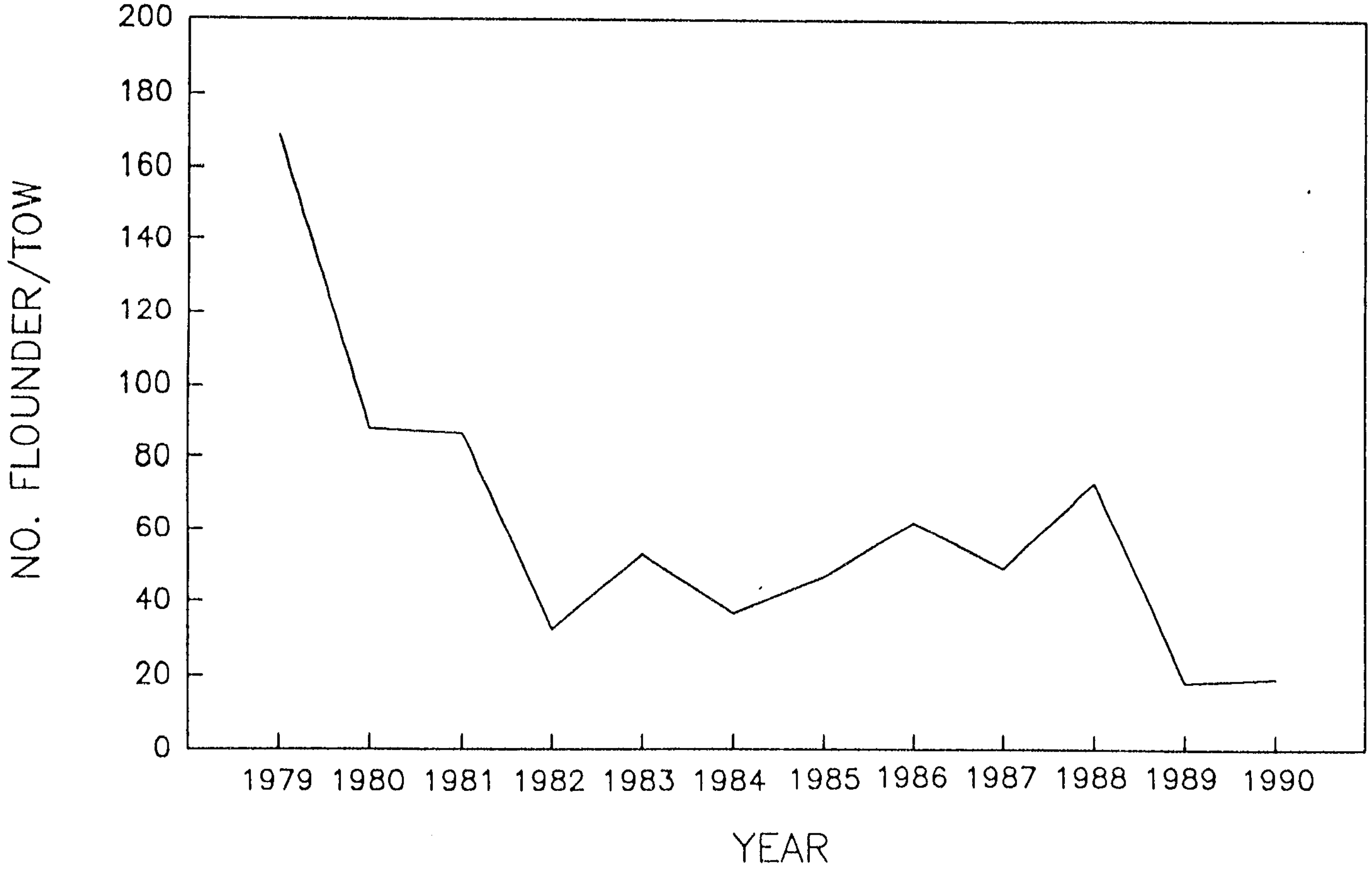


FIGURE 7

WINTER FLOUNDER ABUNDANCE IN SOUTHERN NEW ENGLAND

NMFS SPRING TRAWL SURVEY

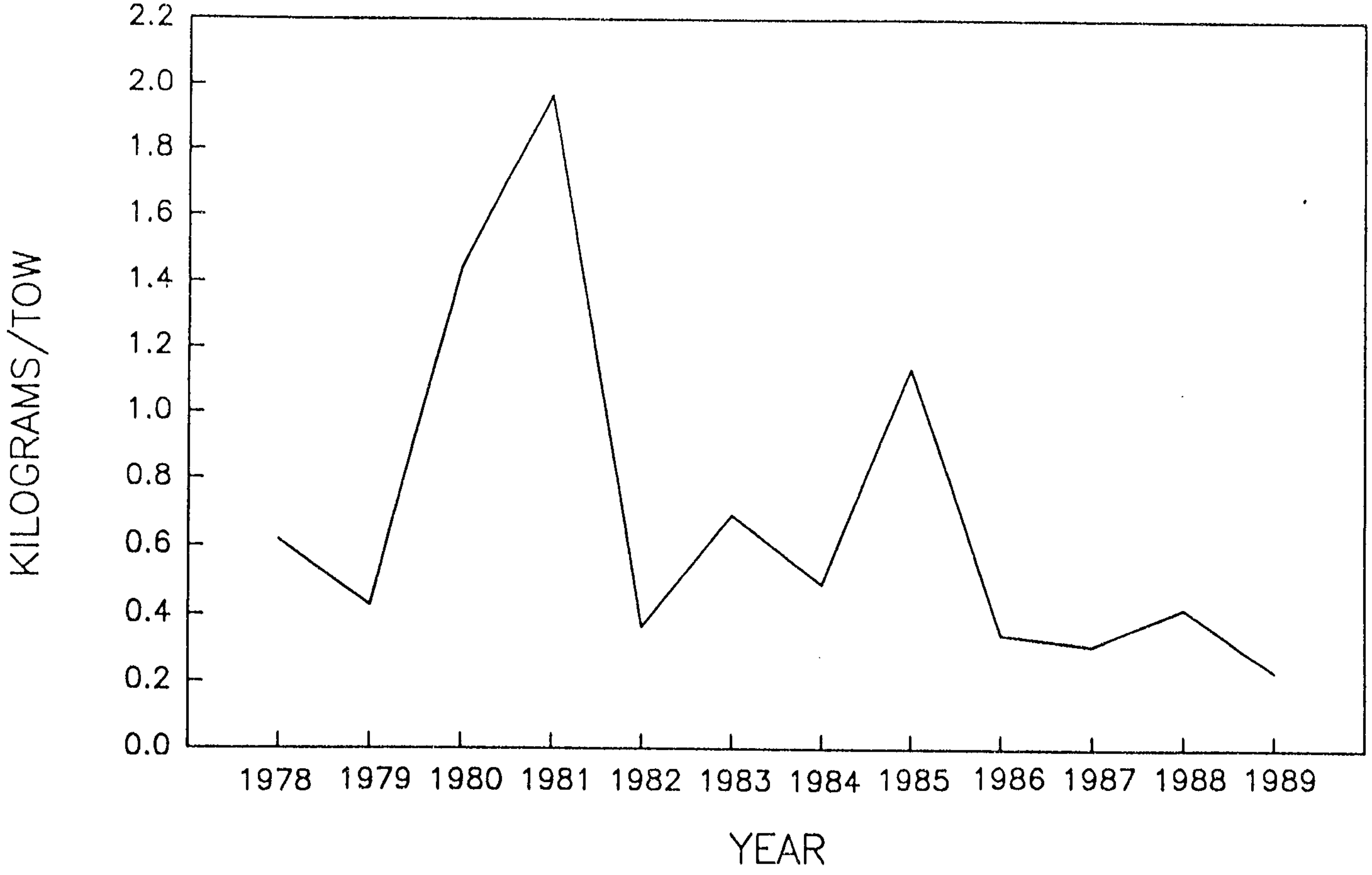
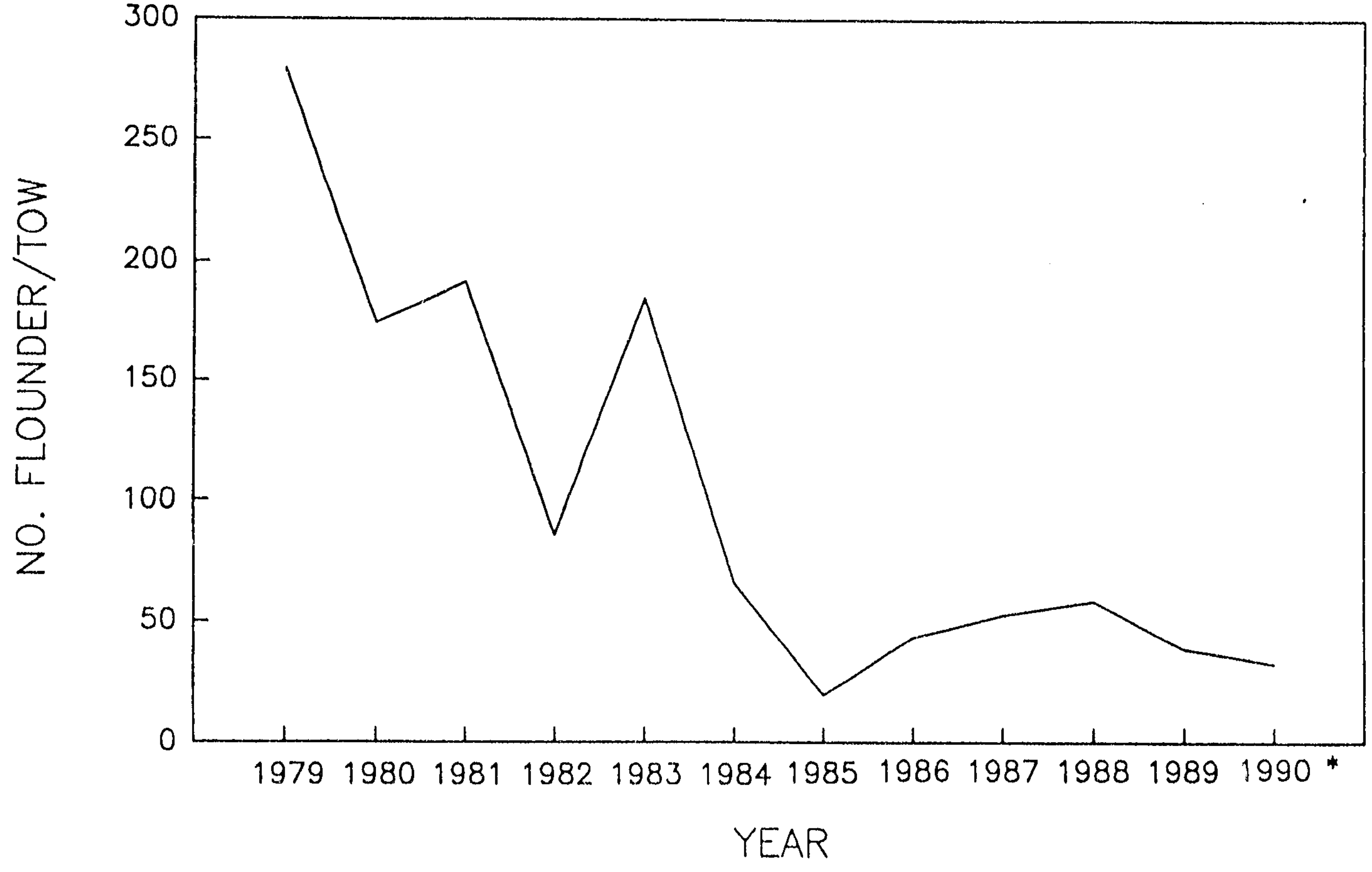


FIGURE 8

WINTER FLOUNDER ABUNDANCE IN NARRAGANSETT BAY

URI/GSO TRAWL SURVEY



* ONLY FOUR MONTHS DATA WAS AVAILABLE AT THE TIME OF THIS WRITING

FIGURE 9

MEAN LENGTH OF WINTER FLOUNDER CAUGHT
IN SOUTHERN NEW ENGLAND

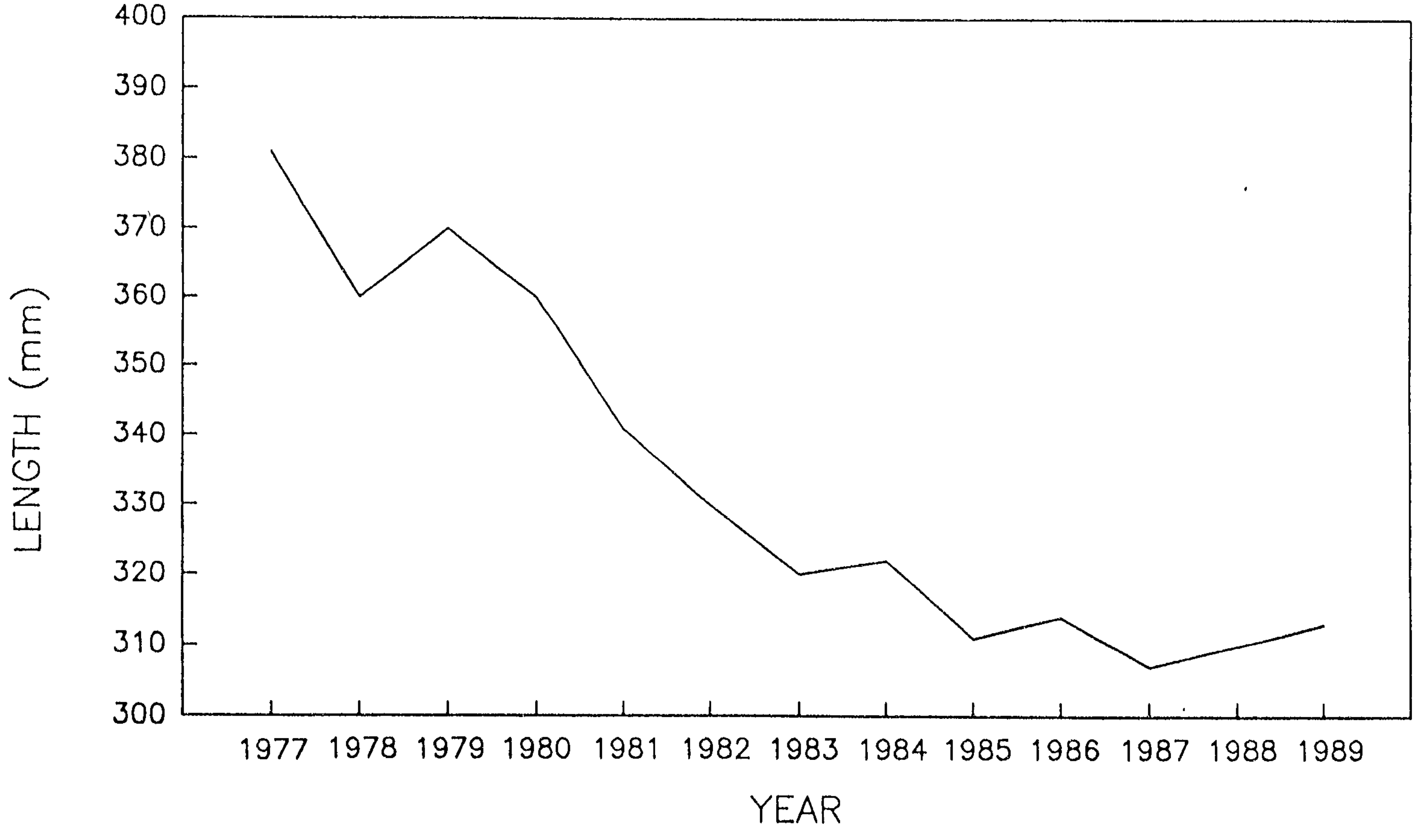
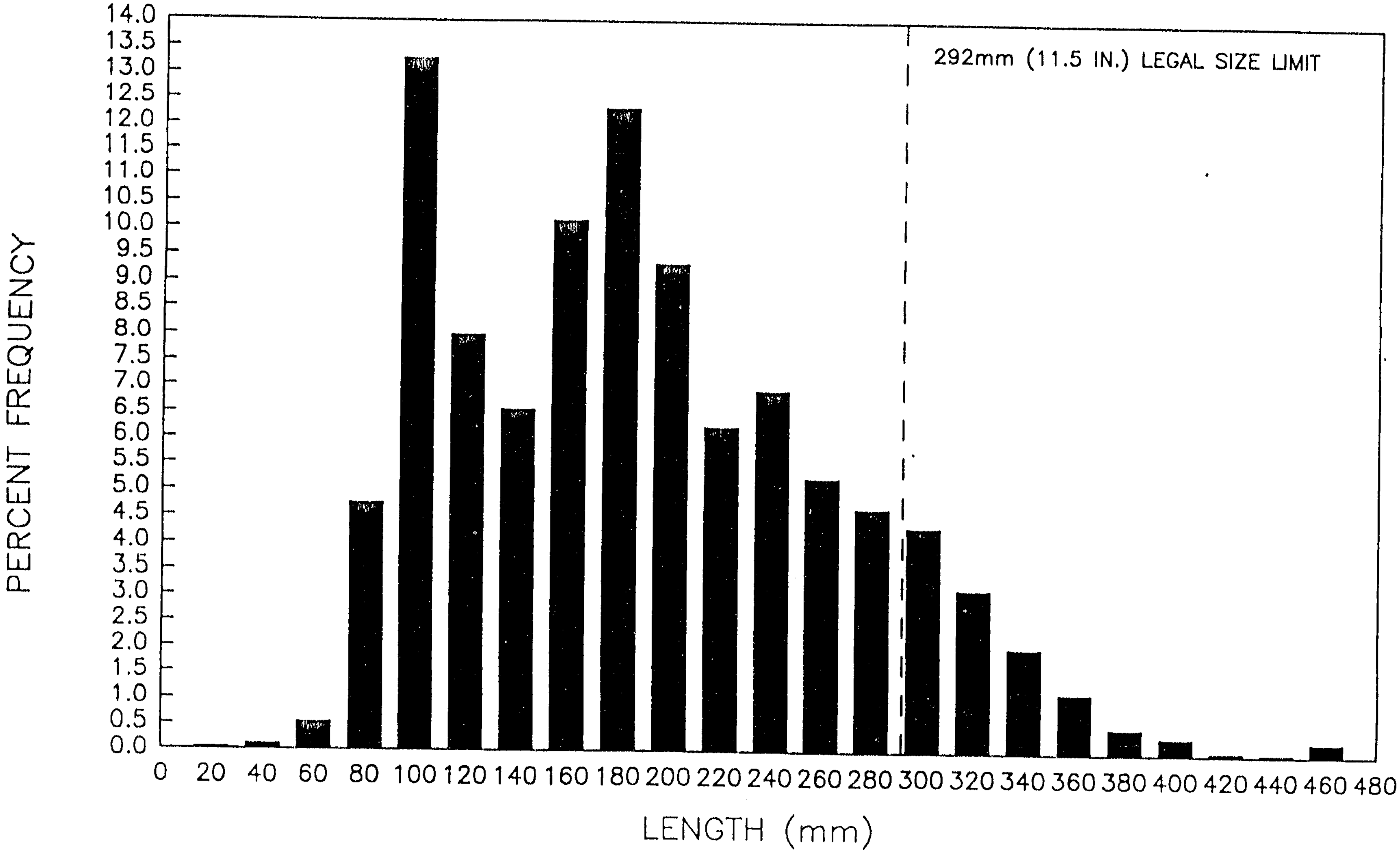


FIGURE 10

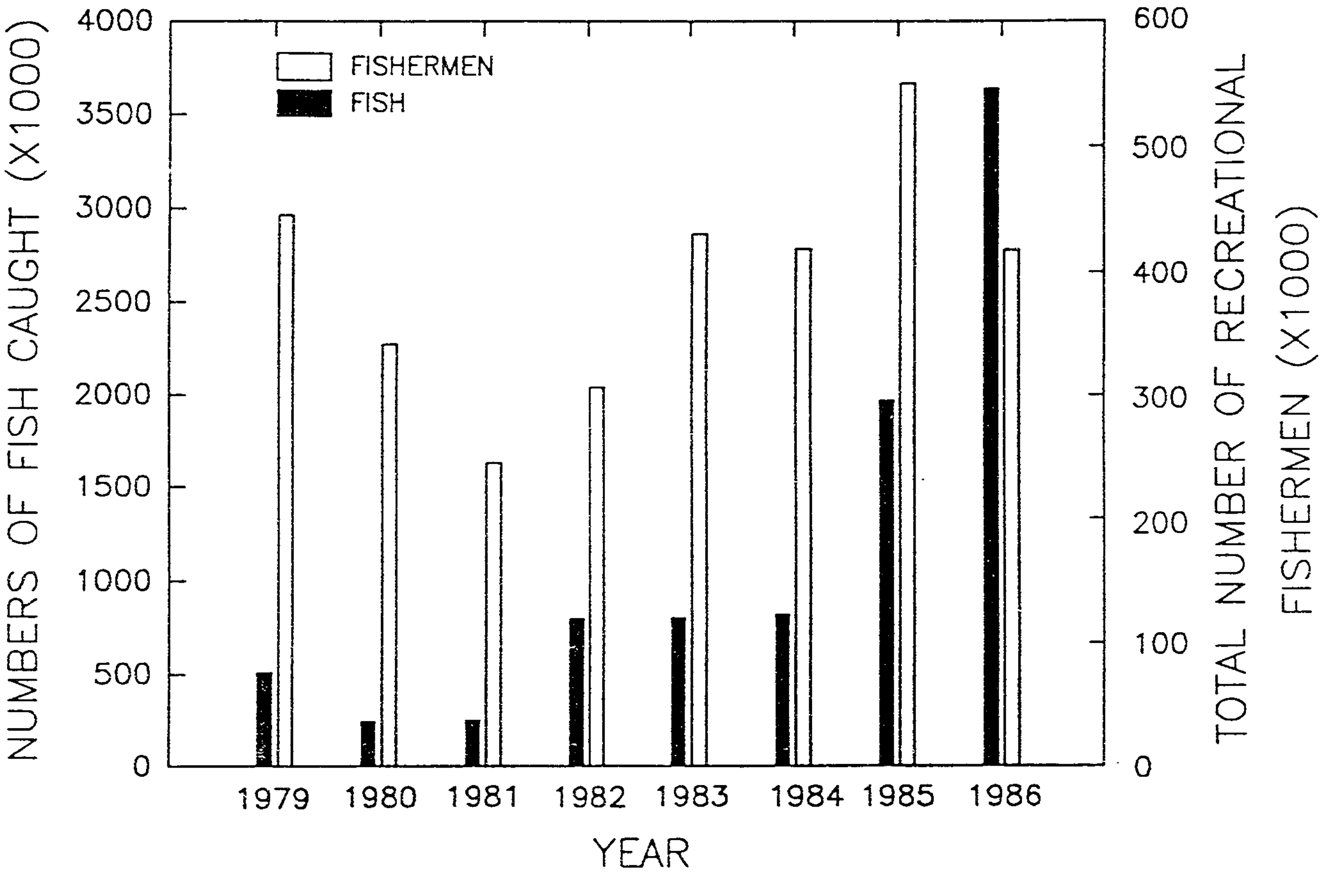
LENGTH FREQUENCY DISTRIBUTION WINTER FLOUNDER IN NARRAGANSETT BAY, RI



(DATA SOURCE: POOLED FROM POWELL 1986 – 1990)

FIGURE 11

NUMBERS OF WINTER FLOUNDER CAUGHT IN R.I. WATERS BY RECREATIONAL FISHERMEN 1979 – 1986



Source: Marine Recreational Fisheries Statistics Survey (NMFS 1979 – 1986)

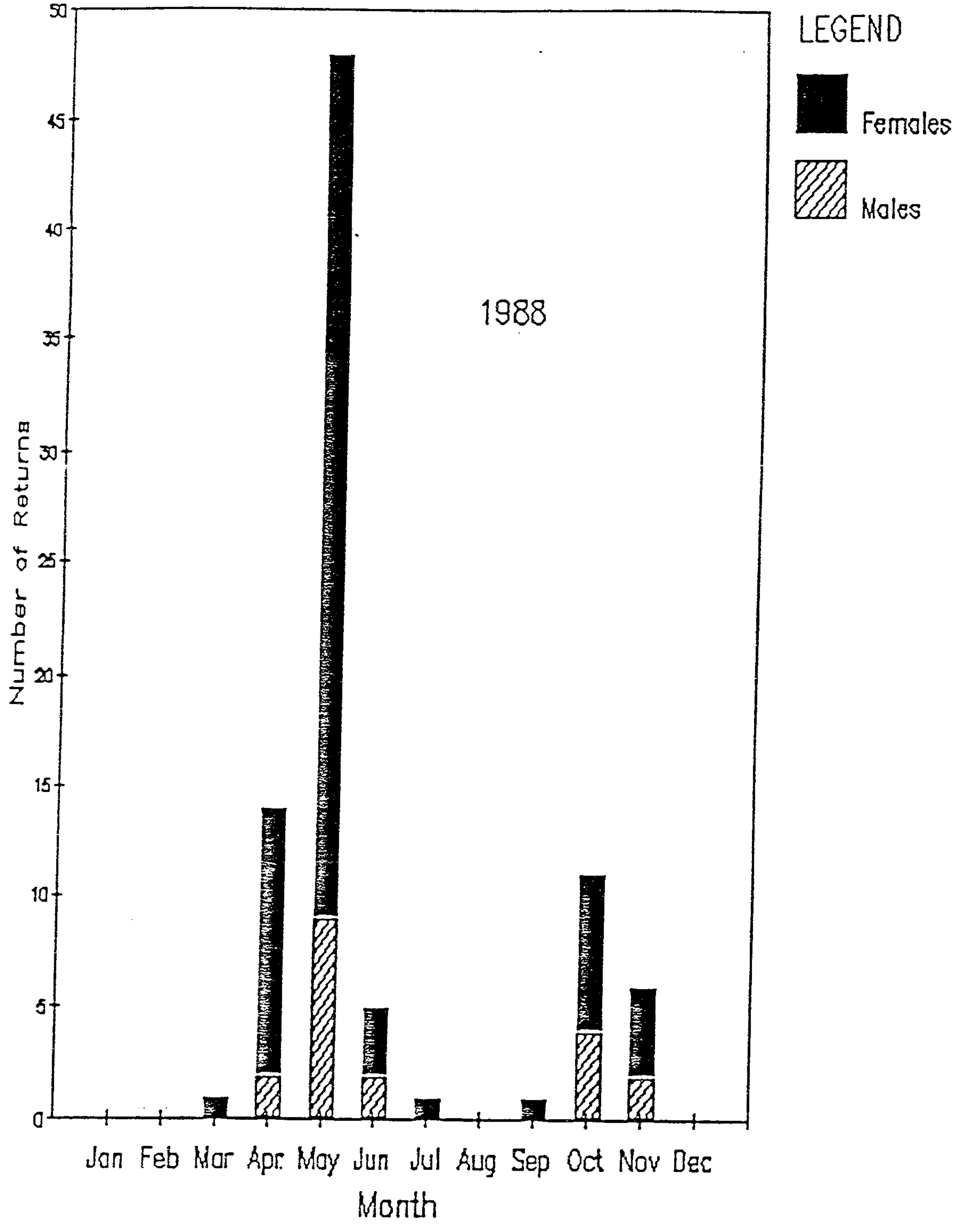


Figure 12. Temporal distribution by month of all 1988 winter flounder tag returns.

Source Powell 1988

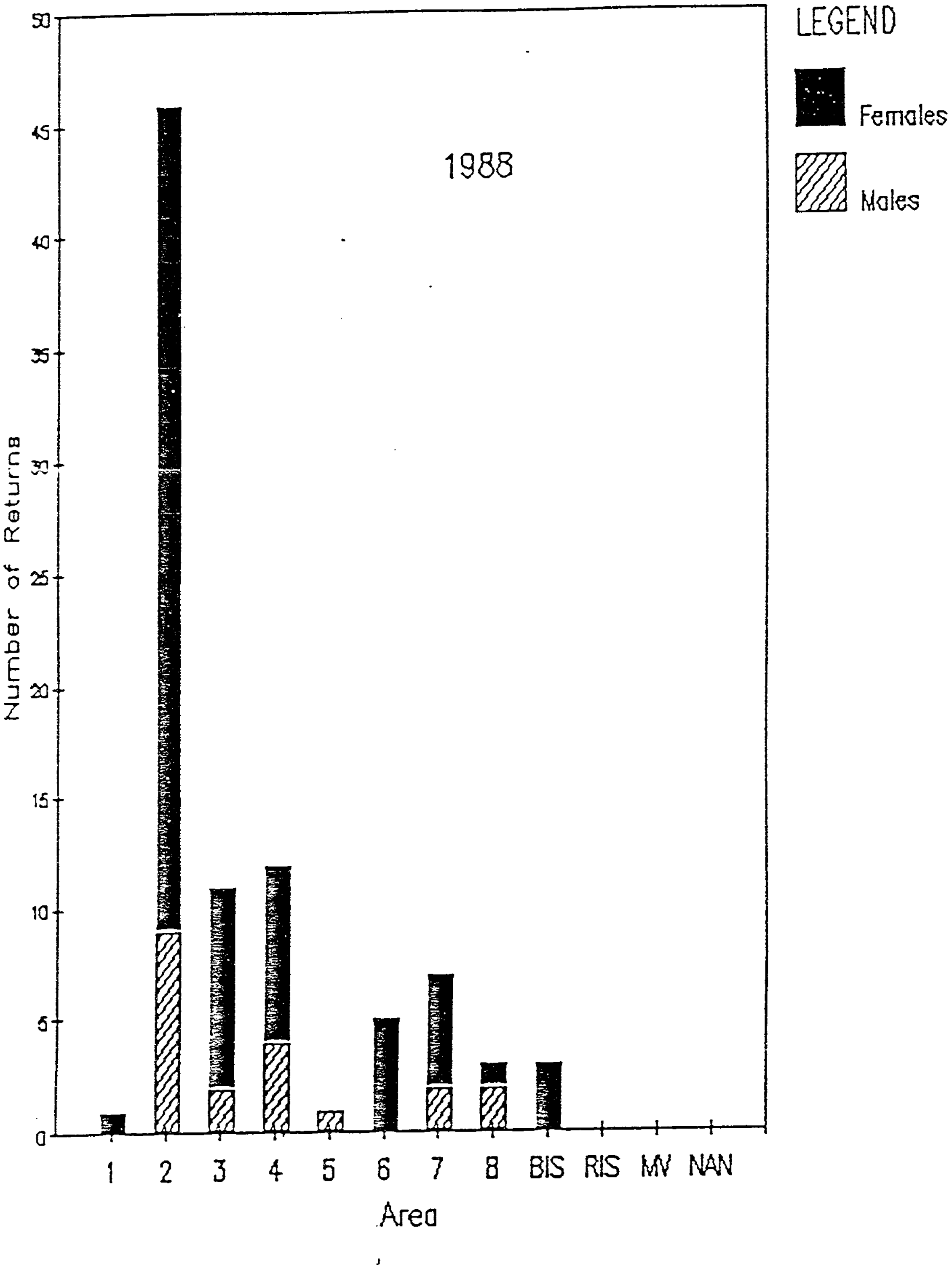
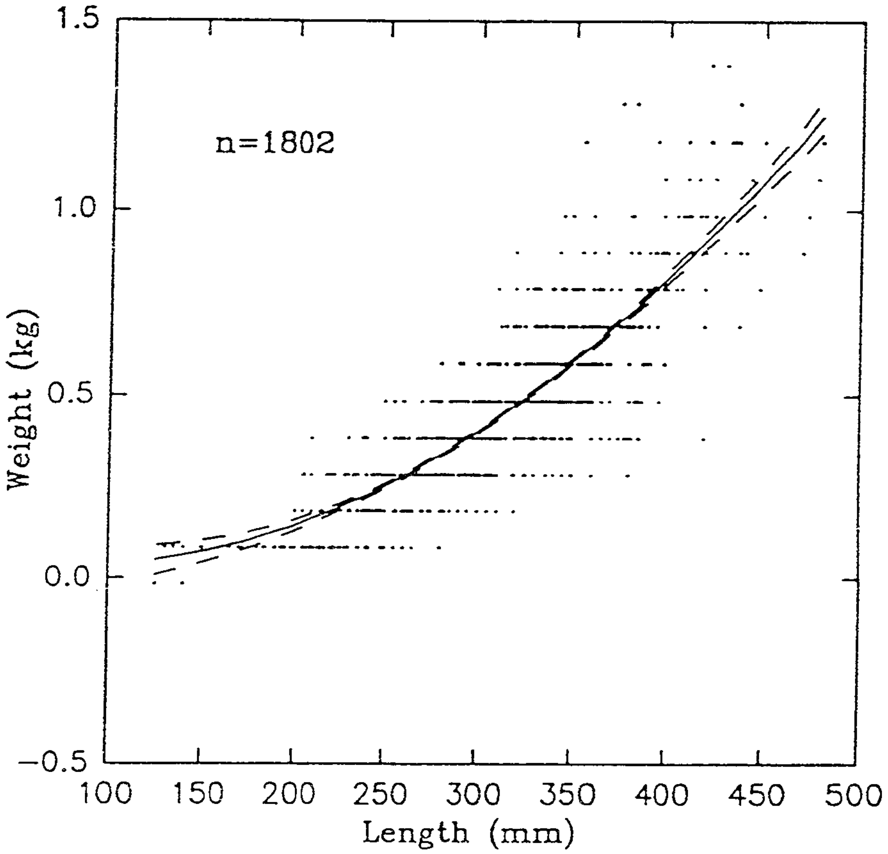


Figure 13. Spatial distribution of winter flounder recreational tag returns by geographic locations.

Source Powell 1988

Figure 14. LENGTH/WEIGHT RELATIONSHIP
RHODE ISLAND RECREATIONAL FISHERY
WINTER FLOUNDER, 1981–1989

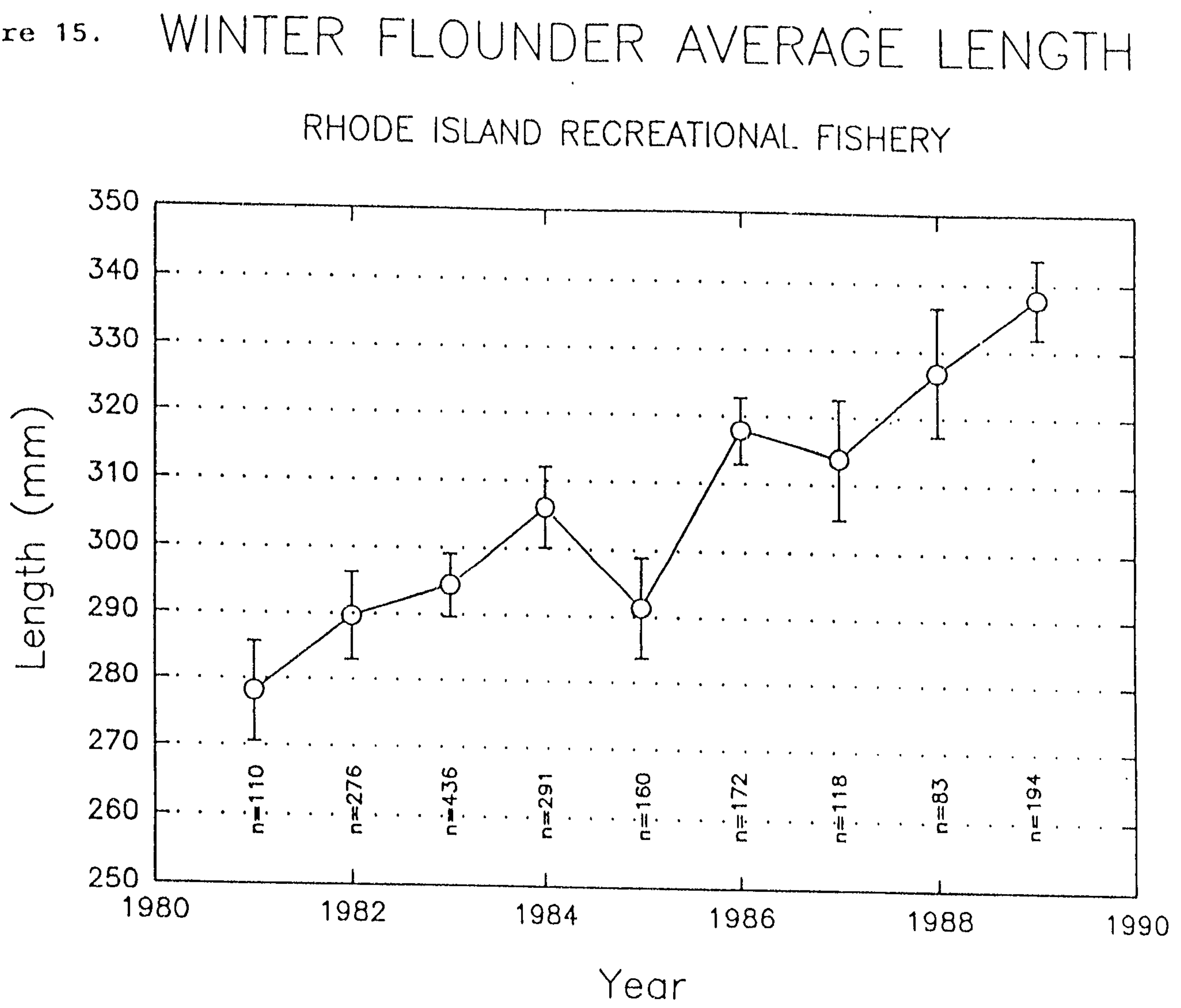


Key: ——— second order regression calculated as $W=0.0860 - 0.012L + 0.00001L^2$ ($R = 0.83$)

\- - - 95% confidence interval

Source: Marine Recreational Fish Survey Unpublished; Karlsson 1990.

Figure 15.



Key: Error bars indicate 95% confidence intervals.

Source: Marine Recreational Fish Survey
Unpublished; Karlsson 1990.

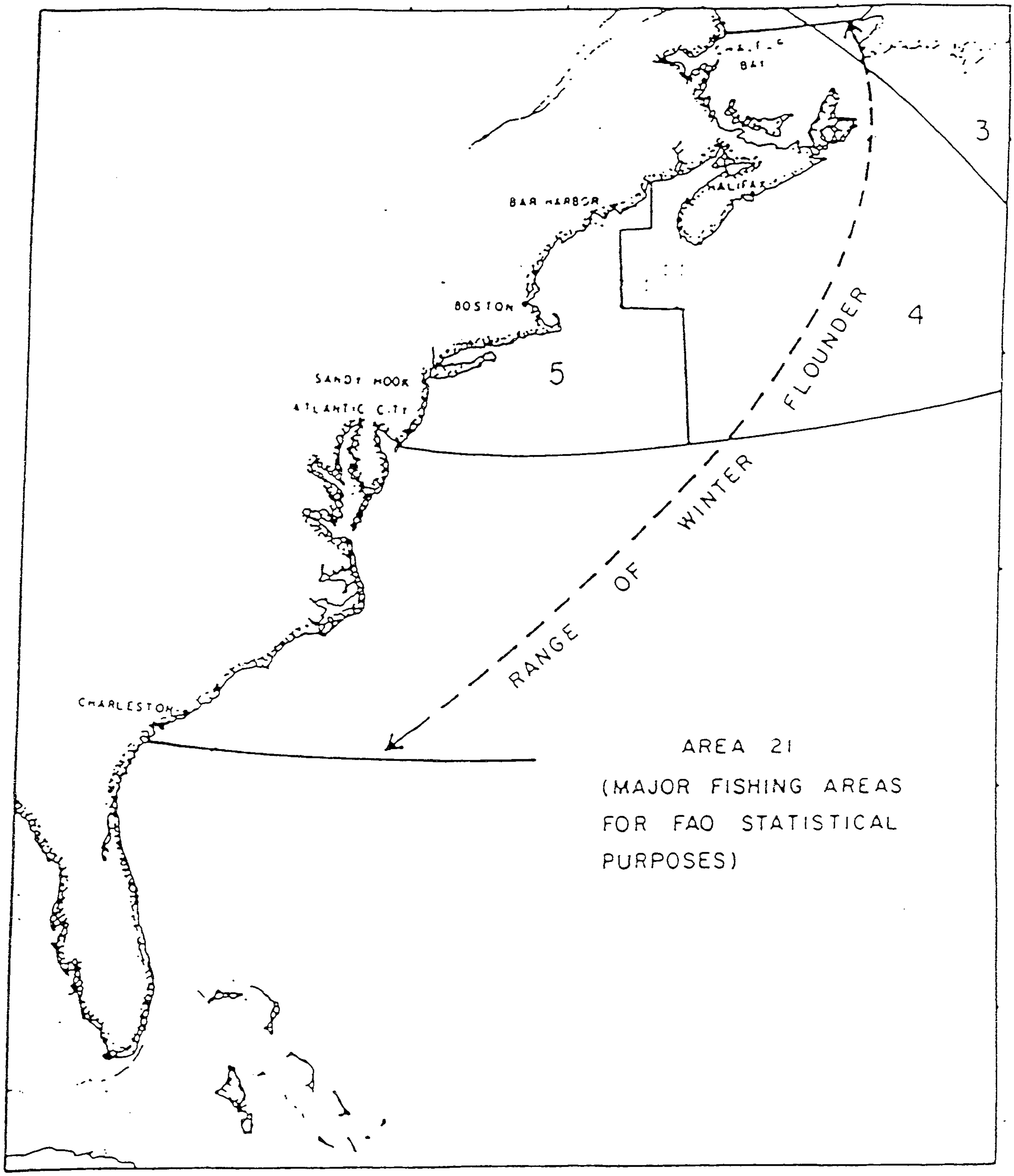


Figure 16. Range of winter flounder.

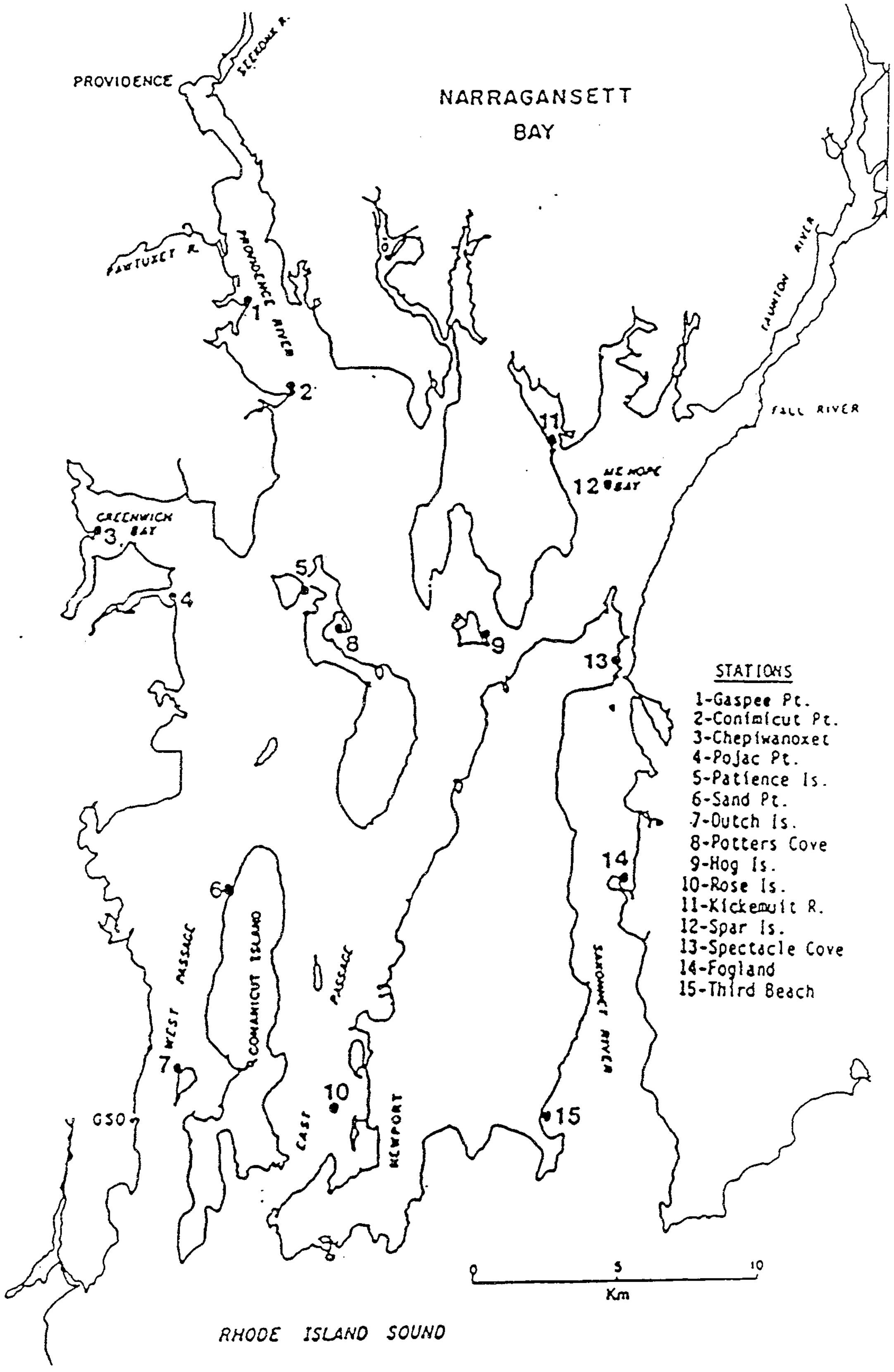


Figure 17. Juvenile finfish survey stations.

Source Powell 1986

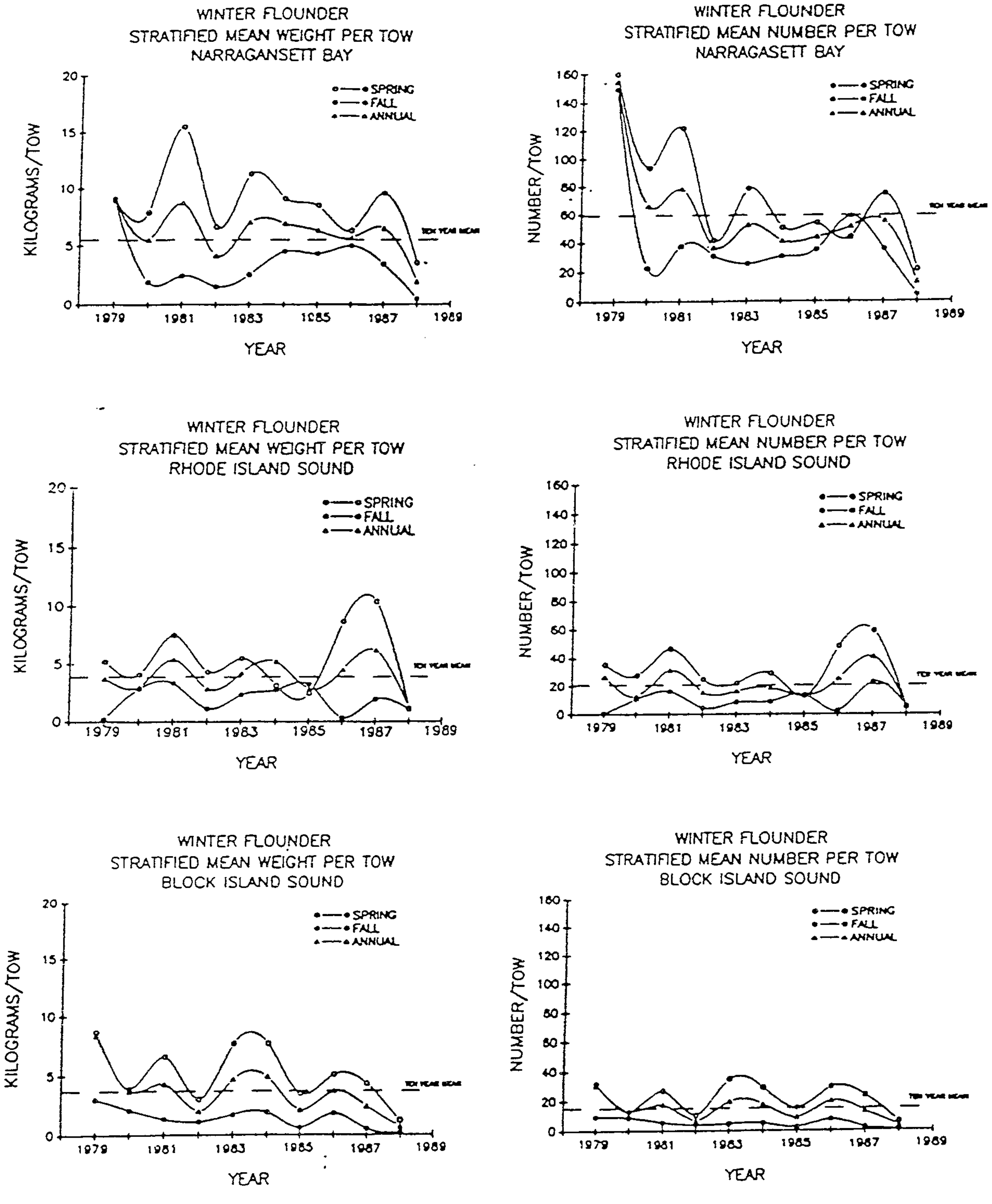


Figure 18. Indices of abundance for stratified mean weight per tow.

Source Lynch and Karlsson 1989.

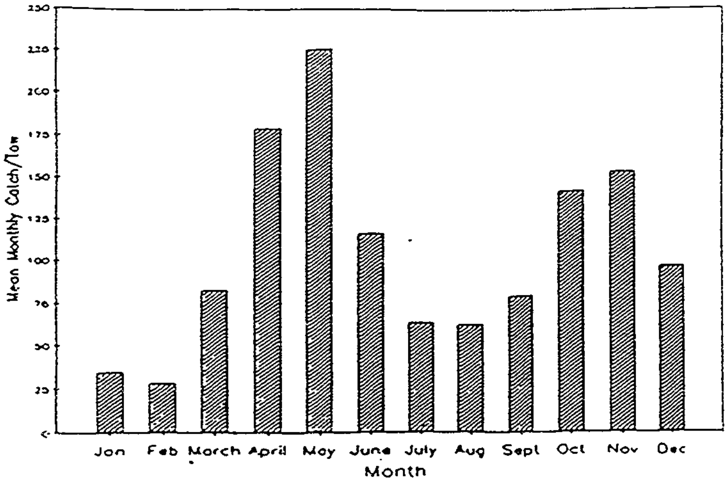


Figure 19. Seasonal abundance of winter flounder at Fox Island, Narragansett Bay, 1959-1987.

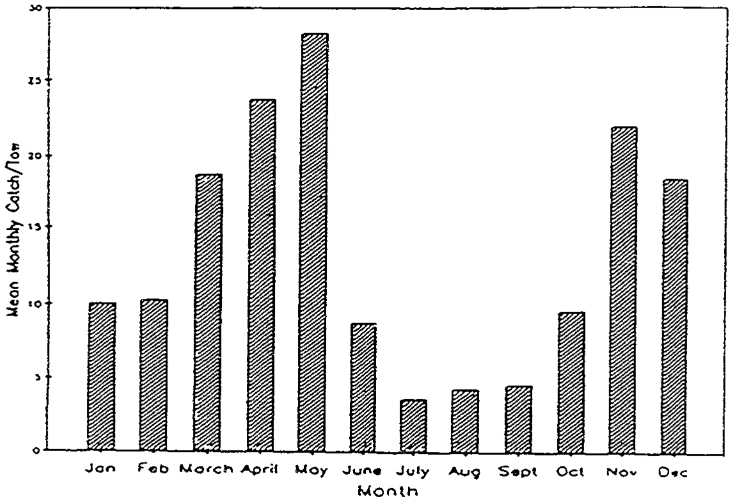


Figure 20. Seasonal abundance of winter flounder in Mt. Hope Bay, 1971-1985.

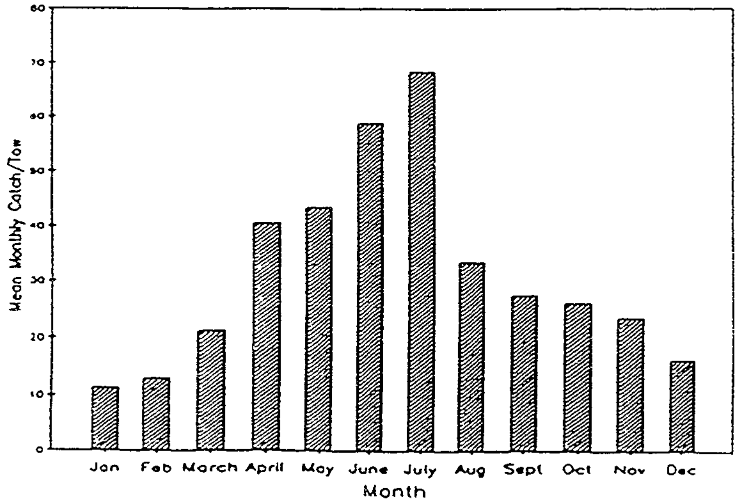


Figure 21. Seasonal abundance of winter flounder at Whale Rock, Narragansett Bay, 1959-1987.

Source Powell 1989b.

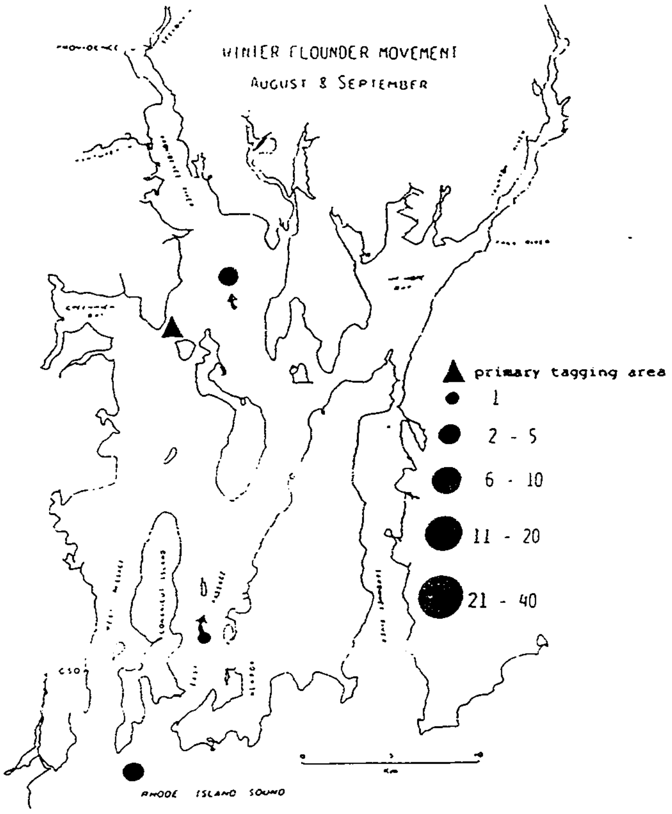


Figure 22. August and September winter flounder movement in Narragansett Bay. Dot size indicates number of tag returns from each element.

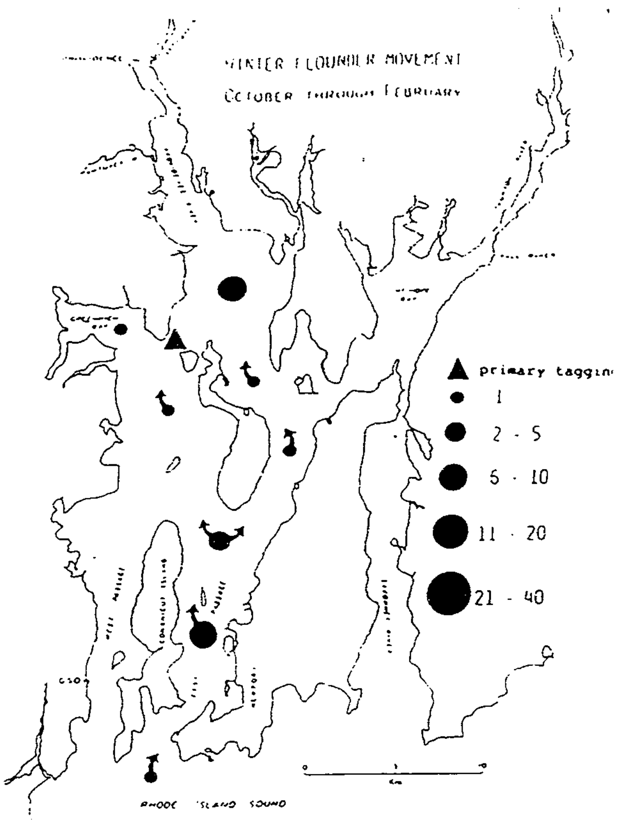


Figure 23. October through February winter flounder movement in Narragansett Bay. Dot size indicates number of tag returns from each element

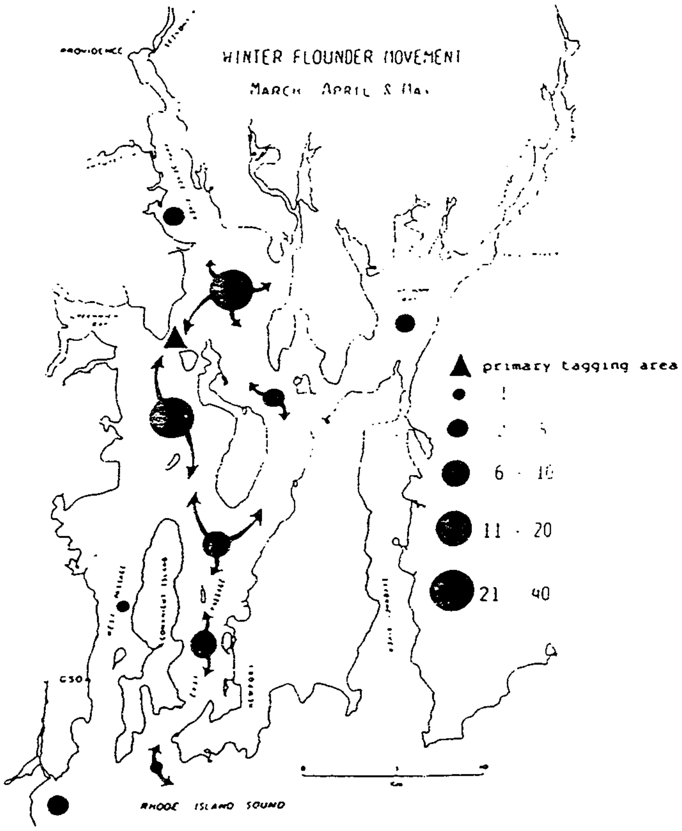


Figure 24. March, April and May movement of winter flounder in Narragansett Bay. Dot size indicates number of tag returns from each element.

Source Powell 1986.

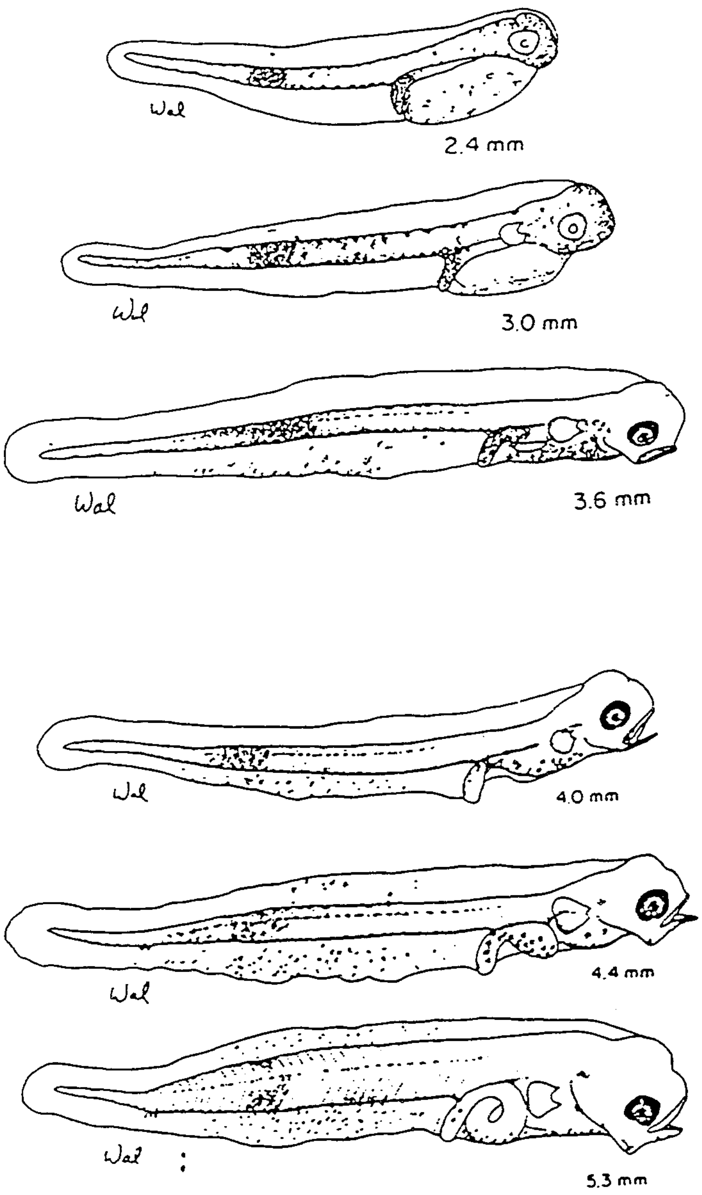


Figure 25. Yolk-sac larvae of *Pseudopleuronectes americanus* (2.4mm-3.6mm), and flexion larvae (5.3mm) (Laroche 1981).

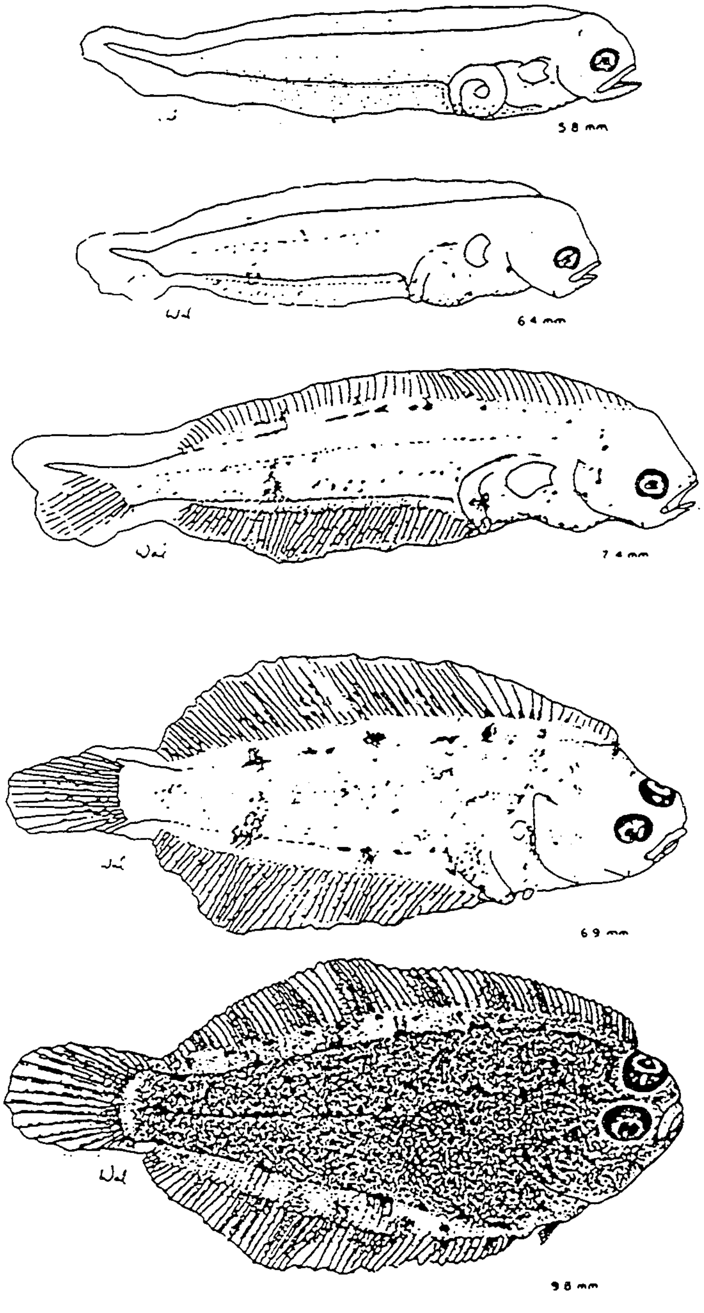


Figure 26. Flexion larvae (5.8mm-7.4mm) to flexion, transforming larvae (6.9mm) and postflexion, transforming larvae (9.8mm) of *Pseudopleuronectes americanus* (Laroche 1981).

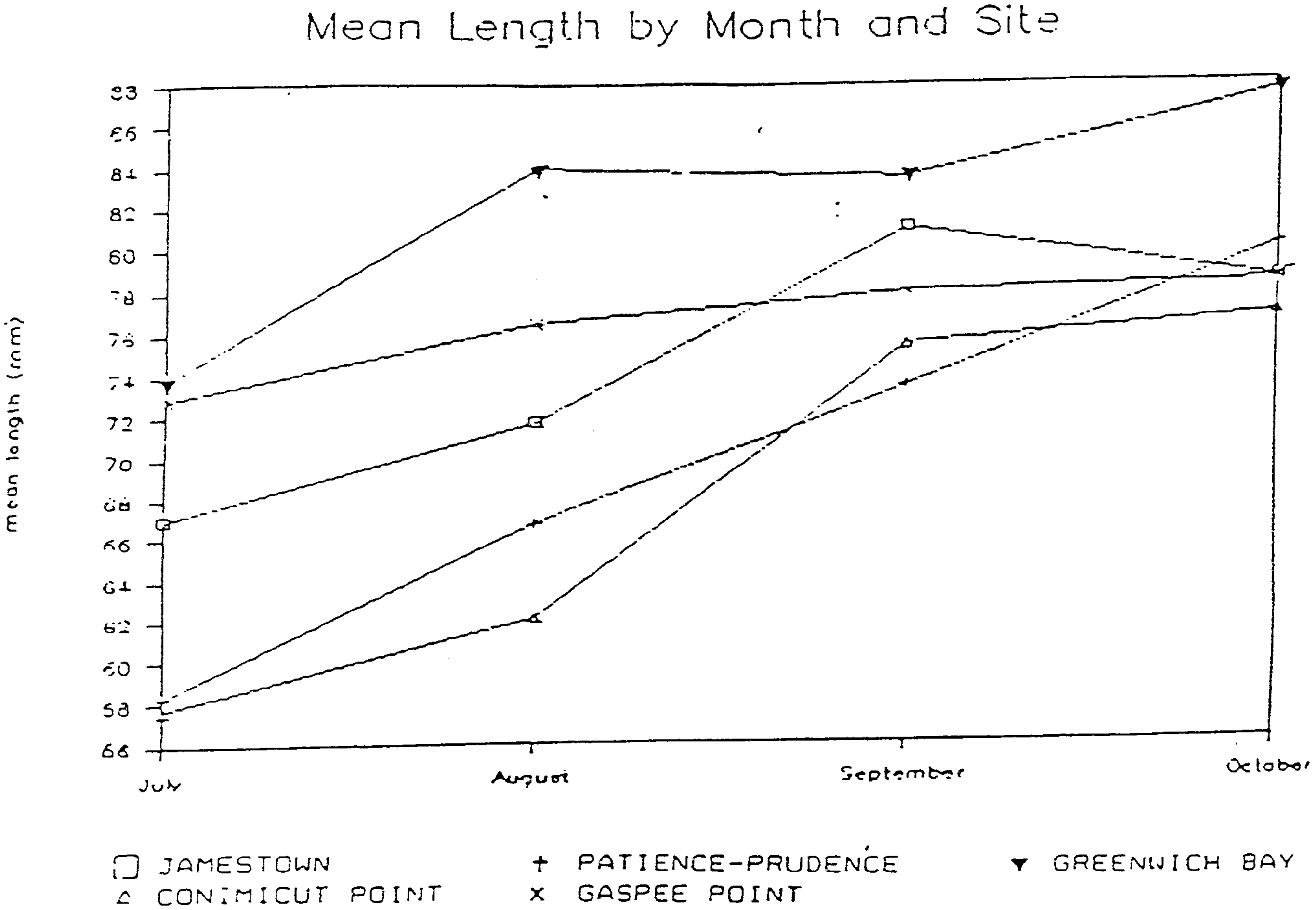
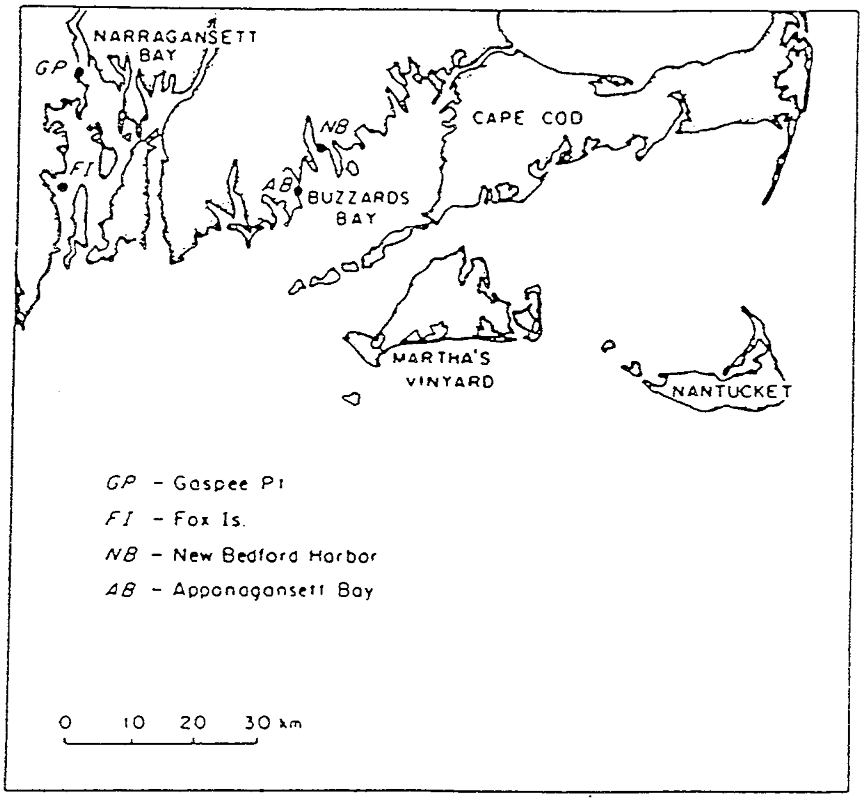


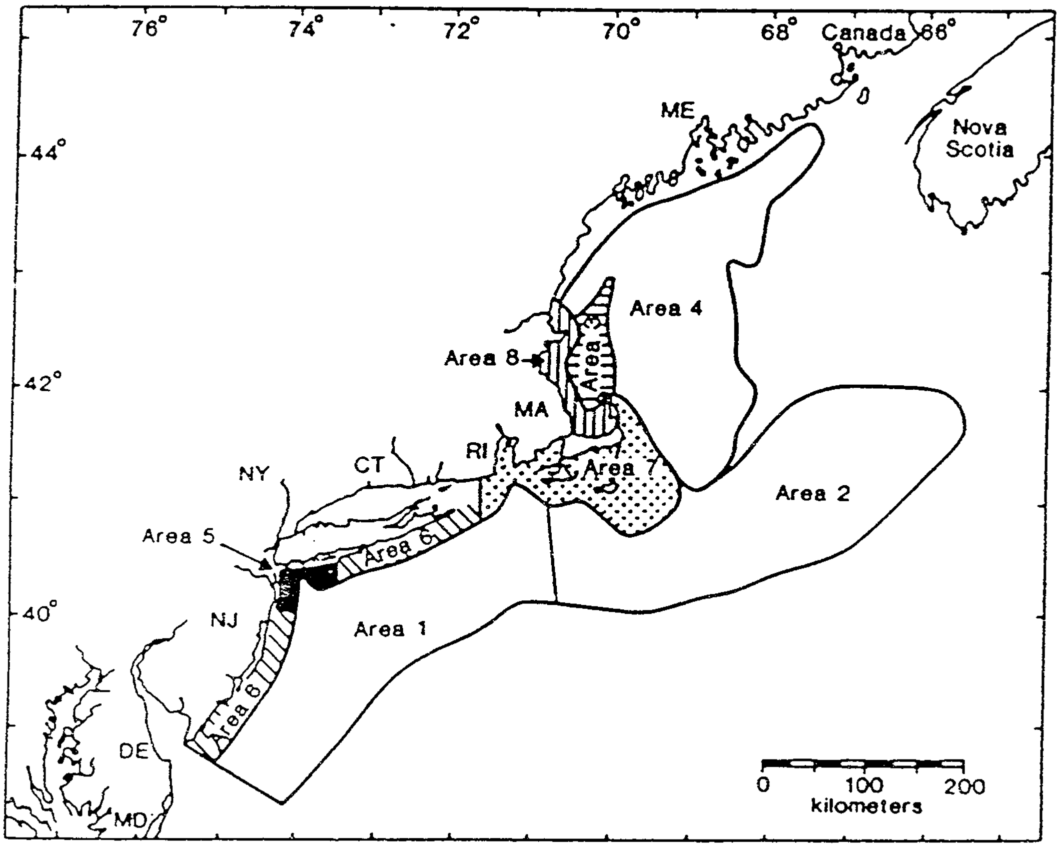
Figure 27. Monthly mean length of young-of-year winter flounder in Narragansett Bay (Buckley and Caldarone 1988).

Figure 28. Study areas in Narragansett Bay, RI, and Buzzards Bay, MA, where mature adult winter flounder were collected.

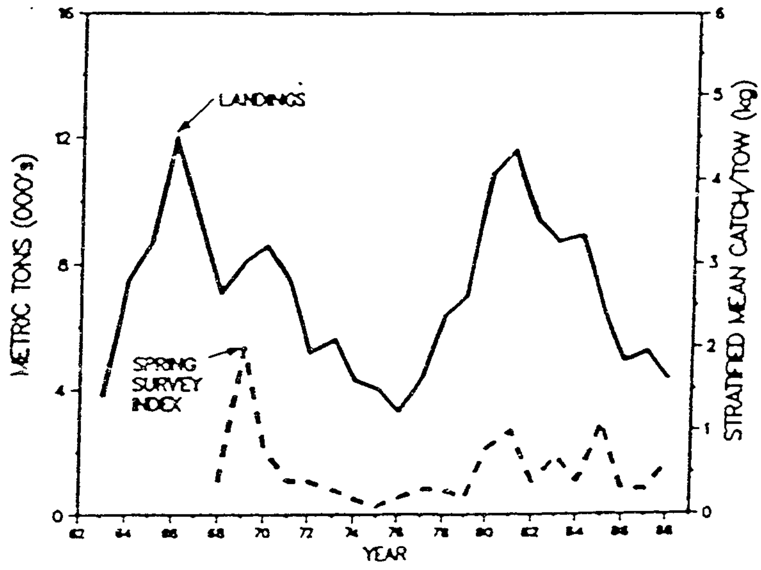


Source: Black et al. (1988).

Figure 29. Survey area in the Northwest Atlantic with discrete geographic zones delineated.



Source: Ziskowski et al. (1987).


Southern New England - Mid-Atlantic

Category	1980	1981	1982	1983	Year 1984	1985	1986	1987	1988
USA recreational	2.7	3.3	3.2	5.0	6.4	7.9	3.3	4.0	3.9
Commercial									
USA	10.9	11.6	9.4	8.7	8.9	6.6	4.9	5.2	4.3
Canada	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Other	-	-	-	-	-	-	-	-	-
Total nominal	13.6	14.9	12.6	13.7	15.3	14.5	8.2	9.2	8.2

Table 1. Recreational catches and commercial landings (1,000 mt) in southern New England (NMFS 1989).

Table 2. *Pseudopleuronectes americanus*. Growth of winter flounder from yolk absorption through metamorphosis at 3 temperatures

Weeks after yolk absorption	Temperature					
	2°C		5°C		8°C	
	Mean dry weight (µg)	Specific growth (%/day)	Mean dry weight (µg)	Specific growth (%/day)	Mean dry weight (µg)	Specific growth (%/day)
1[a]	10.3	-	14.2	-	11.1	-
2	12.0	2.2	9.2	negative	22.9	10.4
3	9.3	negative	30.8	19.1	87.9	19.2
4	11.2	2.7	60.1	9.8	206.0	12.2
5	18.9	7.5	122.8	9.7	429.9	10.5
6	29.9	6.6	197.6	8.2	708.9	7.2
7	*		200.8	0.8	1453.4[b]	10.3
8			603.5	13.4		
9			649.6	1.1		
10			602-8	negative		
11			1033.8[b]	7.7		

[a] Yolk absorbed 14 days after hatching at 2°C, 10 days at 5°C, and 7 days at 8°C.

[b] Metamorphosed.

*Complete mortality.

Table taken from Laurence 1975.

Table 3. Dates of winter flounder spawning at different geographic locations from north to south.

Date	Peak	Area	Investigator
Mar.-June	----	Long Pond, Conception Bay, Newfoundland	Kennedy and Steele (1971)
Mar.-May	Apr.	Boothbay Harbor, Maine	Hahn(pers. commun. in Bigelow and Schroeder, 1953)
Feb.-May	----	Eel Pond, Woods Hole, Mass.	Sherwood and Edwards(1901)
Jan.-May	Feb.-Mar.	South of Cape Cod and Massachusetts Bay	Bigelow and Schroeder(1953)
Mid. Feb.-Apr.	Mar.	Mystic River estuary, Conn.	Pearcy (1962)
Dec.-May	Varies with water temp.	Southern New England-New York	Pearlmutter (1947)
Nov.-Apr.	----	Indian River Bay Del.	Fairbanks et al. (1971)

Table taken from Klein-MacPhee, 1978.

Table 4. Fecundity values for winter flounder.

Number of eggs X 1000	Age, weight or size(TL) of fish	Investigator
$\bar{x}$ 500 Maximum 1,500	1,531 g	Bigelow and Schroeder(1953)
435-3,329	3 yr(300-400mm) to 5 yr(400-450mm)	Topp(1968)
93-1,340 $\bar{x}$ 610	210 g, 250mm to 1,052 g, 430mm $\bar{x}$ 334mm	Saila (1962)
99-2,604 $\bar{x}$ 590	111g, 220mm to 1,300g, 440mm $\bar{x}$ 340mm	Kennedy and Steele(1971)

Table taken from Klein-MacPhee, 1978.

Table 5. Summary statistics for length and age at metamorphosis and growth and developmental rates of laboratory-reared winter flounder (*Pseudopleuronectes americanus*). Average values (SD) are presented by population. Pop. = population, m = number of metamorphs, l = number of larvae at termination of rearing, r_{la} = correlation coefficient between length and age, r_{gd} = correlation coefficient between growth and developmental rates. CV′ = coefficient of variation, t = t-statistic. The test for differences between the CVs is presented in the text. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Pop.	m	l	Length at metamorphosis[a]	Age at metamorphosis[b]	r_{la}	Growth rate[c]	Developmental rate[d]	r_{gd}	CV′ length	CV′ age	t
1	61	1	7.57 (0.35)	57.4 (6.05)	0.21	6.58 (0.87)	1.75 (0.17)	0.72***	0.046	0.105	5.65***
2	90	6	7.55 (0.37)	54.7 (6.70)	0.24*	6.88 (0.98)	1.85 (0.21)	0.71***	0.050	0.123	7.38***
3	32	5	7.72 (0.32)	57.0 (8.67)	0.48**	6.94 (0.95)	1.79 (0.27)	0.85***	0.043	0.153	5.66***
4	119	15	7.80 (0.34)	61.0 (7.65)	0.38***	6.59 (0.80)	1.66 (0.21)	0.76***	0.044	0.126	9.65***
5	47	31	8.01 (0.26)	66.2 (4.19)	0.02	6.34 (0.56)	1.51 (0.26)	0.71***	0.033	0.064	3.99***
6	34	4	7.79 (0.39)	57.8 (7.94)	0.58***	6.92 (0.77)	1.76 (0.23)	0.73***	0.050	0.138	5.34***
7	63	25	8.00 (0.29)	60.3 (6.85)	0.11	6.97 (0.87)	1.67 (0.19)	0.84***	0.036	0.114	7.13***
8	12	2	7.83 (0.28)	56.7 (7.79)	0.79***	7.13 (0.62)	1.79 (0.24)	0.86***	0.037	0.140	3.83***
9	9	2	7.96 (0.20)	60.7 (6.11)	0.37	6.85 (0.68)	1.66 (0.17)	0.88**	0.026	0.103	2.88*
10	15	2	8.03 (0.34)	64.0 (2.91)	0.27	6.58 (0.67)	1.56 (0.07)	0.64**	0.043	0.046	0.24
11	13	1	7.94 (0.33)	56.6 (5.67)	0.61*	7.29 (0.58)	1.78 (0.17)	0.62*	0.043	0.102	2.98**
12	10	2	7.95 (0.32)	60.9 (5.10)	0.57	6.79 (0.50)	1.65 (0.14)	0.52	0.042	0.086	2.18*
13	49	10	7.99 (0.44)	61.6 (5.86)	0.45***	6.78 (0.70)	1.63 (0.17)	0.49***	0.056	0.096	3.86***
14	53	7	7.98 (0.38)	59.5 (7.35)	0.18	7.08 (1.00)	1.70 (0.22)	0.78***	0.048	0.124	5.76***
15	19	1	7.70 (0.34)	56.3 (5.78)	0.42	6.92 (0.72)	1.79 (0.18)	0.60**	0.045	0.104	3.29***
16	14	19	8.35 (0.34)	63.2 (4.17)	0.07	7.18 (0.74)	1.58 (0.11)	0.67**	0.042	0.067	1.62
17	8	4	8.23 (0.32)	65.5 (4.44)	0.28	6.75 (0.76)	1.53 (0.11)	0.76*	0.041	0.070	1.32
18	14	1	7.65 (0.54)	57.7 (7.31)	0.85***	6.62 (0.49)	1.75 (0.22)	0.08	0.073	0.129	3.01**
Total	662	138	7.83 (0.40)	59.5 (7.34)	0.421***	6.79 (0.84)	1.71 (0.21)	0.68***	0.051	0.123	20.70***

[a] Total length (mm). [b] Age (d) since hatching. [c] Growth rate × 100.
[d] Developmental rate × 100.

Table taken from Chambers and Leggett 1987.

Table 6. Measurements (millimeters) of larval *Pseudopleuronectes americanus*. Specimens above dashed line are yolk-sac larvae.

Standard length	Total length	Body depth at pectoral fin base	Body depth at anus	Maximum body depth at pectoral fin base	Maximum body depth at anus	Snout to anus length	Head length	Eye diameter	Upper jaw length	Snout length	Pectoral fin length
2.4	2.5	0.20	0.14	—	—	0.92	0.39	0.17	—	0.08	0.05
2.6	2.7	0.18	0.15	—	—	0.92	0.38	0.16	—	0.10	0.04
2.6	2.6	0.24	0.14	—	—	0.85	0.39	0.17	—	0.11	0.04
2.7	2.7	0.24	0.15	—	—	0.94	0.42	0.17	—	0.10	0.04
2.8	2.8	0.25	0.14	—	—	0.90	0.39	0.17	—	0.10	0.08
2.8	2.9	0.24	0.14	—	—	0.98	0.39	0.18	—	0.10	0.05
2.8	3.0	0.24	0.15	—	—	1.0	0.42	0.18	0.16	0.12	—
2.9	3.0	0.19	0.13	—	—	0.96	0.39	0.17	0.14	0.12	0.06
2.9	3.0	0.21	0.14	—	—	0.90	0.40	0.18	—	0.12	0.04
2.9	3.0	0.24	0.15	—	—	0.96	0.42	0.18	0.16	0.14	0.06
3.0	3.2	0.24	0.15	—	—	1.0	0.42	0.18	0.18	0.14	0.05
3.3	3.4	0.25	0.14	—	—	1.0	0.42	0.18	0.18	0.10	0.06
3.3	3.5	0.34	0.15	—	—	1.0	0.42	0.18	0.18	0.08	0.10
3.4	3.6	0.36	0.14	—	—	1.1	0.42	0.20	0.18	0.08	0.10
3.4	3.6	0.38	0.15	—	—	1.2	0.48	0.20	0.19	0.10	0.20
3.5	3.7	0.33	0.14	—	—	1.1	0.44	0.18	0.17	0.09	0.20
3.5	3.7	0.34	0.15	—	—	1.2	0.46	0.20	0.20	0.09	0.20
3.5	3.7	0.34	0.15	—	—	1.1	0.45	0.18	0.19	0.10	0.19
3.6	3.8	0.33	0.14	—	—	1.2	0.47	0.20	0.21	0.13	0.20
[1]3.7	3.9	0.48	0.24	—	—	1.4	0.66	0.24	0.26	0.12	0.30
[1]4.0	4.3	0.42	0.19	—	—	1.5	0.62	—	0.26	—	0.26
[1]4.2	4.3	0.60	0.30	—	—	1.5	0.78	0.27	0.26	0.18	0.32
[1]4.4	4.5	0.50	0.22	—	—	1.6	0.70	0.26	0.22	0.14	0.32
[1]4.4	4.5	0.50	0.22	—	—	1.5	0.68	0.24	0.22	0.15	0.30
[1]4.5	4.8	0.66	0.32	—	—	1.6	0.80	0.28	0.24	0.12	—
[1]4.5	4.6	0.70	0.35	—	—	1.7	0.82	0.27	0.26	0.18	0.30
[1]4.6	4.7	0.74	0.38	—	—	1.8	0.92	0.32	0.38	0.20	0.28
[2]4.8	4.9	0.80	0.46	—	—	1.8	0.88	0.31	0.30	0.18	0.30
[1]4.9	5.2	0.78	0.44	—	—	1.8	0.98	—	—	—	0.40
[1]4.9	5.2	—	—	—	—	2.0	1.1	0.34	0.32	0.20	0.45
[1]5.1	5.3	0.85	0.54	—	—	2.0	1.0	0.33	0.32	0.14	0.44
[1]5.2	5.4	0.96	0.64	—	—	2.0	1.0	0.34	0.38	0.24	0.44
[2]5.3	5.5	0.94	0.58	—	—	2.1	0.98	0.33	0.34	0.22	0.44
[1]5.4	5.5	0.90	0.60	—	—	2.1	1.1	0.33	0.35	0.18	—
[2]5.6	5.7	1.1	0.82	—	—	2.3	1.2	0.34	0.40	0.24	0.48
[1]5.7	5.8	1.1	0.78	—	—	2.1	1.2	0.34	0.40	0.22	0.45
[1]5.7	5.8	1.1	0.72	—	—	2.2	1.1	0.34	0.40	0.26	0.46
[2]5.8	6.1	1.1	0.70	—	—	2.3	1.2	0.36	0.36	0.20	0.52
[2]6.0	6.2	1.1	0.80	—	—	2.3	1.3	0.36	0.36	0.20	0.48
[2]6.2	6.3	1.3	0.88	—	1.0	2.4	1.3	0.36	0.42	0.26	0.55
[2]6.3	6.4	1.3	0.98	1.4	1.2	2.4	1.4	0.40	0.48	0.26	0.54
[2]6.3	6.4	1.3	0.88	—	1.1	2.4	1.4	0.36	0.44	0.28	0.50
[2]6.4	6.5	1.2	0.86	1.3	1.1	2.4	1.3	0.34	0.40	0.20	0.48
[2]6.5	6.7	1.2	0.84	1.3	1.0	2.6	1.4	0.38	0.42	0.26	0.42
[3]6.6	6.7	1.3	0.96	1.4	1.2	2.5	1.4	0.38	0.42	0.22	0.52
[3]6.6	6.8	1.4	1.1	1.6	1.5	2.4	1.6	0.39	0.48	0.28	0.58
[2]6.8	6.9	1.3	1.0	1.4	1.3	2.5	1.5	0.38	0.40	0.26	0.50
[2]6.9	7.2	1.3	0.96	1.4	1.2	2.6	1.5	0.40	0.46	0.27	0.52
[2]7.0	7.3	1.4	1.1	1.5	1.2	2.7	1.5	0.41	0.44	0.28	0.64
[2]7.1	7.3	1.3	0.94	1.4	1.2	2.6	1.3	0.39	0.44	0.24	0.58
[2]7.3	7.8	1.7	1.4	1.8	1.7	2.6	1.8	0.46	0.44	0.32	0.54
[2]7.4	7.7	1.4	1.1	1.5	1.2	2.4	1.5	0.38	0.44	0.26	0.50
[3]5.7	—	1.7	1.2	1.8	1.6	2.0	1.6	0.48	0.49	0.22	—
[3]6.0	—	1.7	1.3	1.7	1.7	2.4	1.7	0.46	0.48	0.34	0.40
[3]6.2	—	1.9	1.3	2.2	1.8	2.3	1.7	0.46	0.46	0.38	0.34
[3]6.4	—	2.2	1.5	2.4	2.1	2.3	1.7	0.54	0.51	0.34	0.10
[3]6.6	7.7	1.6	1.3	1.8	1.7	2.4	1.8	0.46	0.44	0.38	0.42
[3]6.6	—	1.7	1.4	1.8	1.9	2.5	1.8	0.48	0.44	0.34	0.41
[3]6.9	8.2	1.9	1.5	2.1	2.1	2.3	1.8	0.50	0.46	0.40	0.30
[3]7.0	8.4	1.9	1.5	2.0	2.1	2.4	1.8	0.46	0.42	0.36	0.30
[3]7.0	8.4	2.2	1.7	2.4	2.4	2.2	2.0	0.58	0.56	0.44	0.10
[3]7.1	8.5	2.0	1.5	2.1	1.8	2.4	1.9	0.51	0.40	0.40	0.20
[3]7.3	7.9	2.5	1.8	2.8	2.2	2.4	2.0	0.62	0.38	0.38	—

[1] = preflexion larvae; [2] = flexion larvae; [3] = postflexion larvae.

Table taken from Laroche 1981.

Table 7. von Bertalanffy Growth Parameters for 10 Stocks of Winter Flounder From New Jersey to Newfoundland

Stock	Linf	K	to	w
NJ	387.4	.308	-.658	119.32
WLIS	341.6	.366	-.229	125.03
ELIS	400.3	.410	-.046	164.12
CT	402.0	.430	.485	172.86
RI	409.8	.435	.547	178.26
SCAPE	431.4	.369	.309	159.19
NCAPE	403.9	.400	.284	161.56
CAN	445.4	.237	.189	105.56
NFLD	503.5	.131	-.662	65.96
GB	571.8	.430	.624	245.87

KEY: Linf = mean asymptotic length
K = Brody Growth coefficient
to = age where Lt(length attained at age t) equals zero
w = Linf * K

Table taken from Gibson 1989a.

TABLE 8: COMPOSITION OF STOMACH CONTENTS OF WINTER FLOUNDER (Pseudopleuronectes americanus) DURING THE YEAR

	MONTH											
SPECIES:	J	F	M	A	M	J	J	A	S	O	N	D
Capitella capitata				x						x		
Nereis succinea					x	x						
Prionospio heterobranchia					x	x			x			
Eteone longa						x						
Harmothoe extenuata						o						
Harmothoe imbricata						o						
Podarke obscura						o						
Nematodes						o						
Microdeutopus grullotalpa				1	2	1			1			
Microdeutopus anomalous						2						
Corophium insidiosum				2	3	4						
Ampelisca abdita				3	1					1		
Ampelisca vadorum						3						
Gammarus lawrencianus				4								
Lysianopsis alba					4	5						
Ostracods						x						
Solemya velum					x				x			
Tellina agilis									x			
Diastoma alternatun						o			x			
Mitrella lunata									x			
Crepidula convexa									x			
Haminoea solitaria									x			
Hydrobia totteni									x			
Molgula manhattensis									*	*		

x = present in stomach contents
o = present particularly in fish <20 cm
* = present only in fish >20 cm; 95% of diet of fish >27 cm
1-4 = order of abundance

SOURCE: Worobec,M.N. 1982. Field analysis of winter flounder (Pseudopleuronectes americanus) in a coastal saly pond: abundance, daily ration, and annual consumption. Ph.D. Thesis, University of Rhode Island, Kingston.

TABLE 9: FOOD ORGANISMS FOUND IN STOMACHS OF WINTER FLOUNDER FROM DIFFERENT GEOGRAPHIC AREAS
Point Judith and Narrow River estuary, RI (Mulkana,1966)

COELENTERATA:	Diphasia fallax
NEMERTINEA:	Cephalothorax linearis
OLIGOCHAETA:	Clitella arenarius
POLYCHAETA:	Arabella iricolor
	Autolytus cornutus
	Capitella capitata
	Eumida sanguinea
	Lumbrinereis sp.
	Neanthes caudata
	Nereis virens
	Nephtys incisa
	Prionospio malmgreni
	Pygiospio elegans
PELECYPODA:	Gemma gemma
	Mytilus edulis
	Nucula proxima
	Tellina agilis
AMPHIPODA:	Aeginella longicornus
	Ampelisca macrocephala
	Carinogammarus mucronatus
	Cymedusa filosa
	Gammarus annulatus
	Lembos smithi
	Microdeutopus gryllotalpa
COPEPODA:	Acartia sp.
	Temora longicornis
CUMACEA:	Cyplaspis varians
	Oxyrostylis smithi
ISOPODA:	Chiridotea caeca
	Edotea montoea
	Idotea viridis
	Leptochelia savignyi
OSTRACODA:	Cylindroleberis mariae
	Pontocypris edwardsi
	Sarsiella americana
DECAPODA:	Crangon septemspinosus
	Neopanope texana sayi
	Polyonyx machrocheles
MISCELLANEOUS:	Invertebrate eggs

SOURCE: Mulkana, 1966; cited in Klein-MacPhee, 1978.

TABLE 10: Relative importance of prey species of the winter flounder in Narragansett Bay by frequency of occurence.

SPECIES	TOTAL # STOMACHS	FREQ. OCCURENCE	% FREQ.
Nephtys incisa (P)	266	59	22.18
Ceriantiopsis americanus (A)	266	49	18.42
Pherusa affinis (P)	266	21	7.89
Nereis virens (P)	266	18	6.77
Maldanopsis elongata (P)	266	13	4.89
Polydora ligni (P)	266	7	2.63
Ampelisca abdita (C)	266	4	1.50
Leptocheirus pinguis (C)	266	3	1.13
Prionospio heterobranchia (P)	266	2	0.75
Pagurus longicarpus (C)	266	2	0.75
Eumida sanguinea (P)	266	1	0.38
Eteone longa (P)	266	1	0.38
Arabella iricolor (P)	266	1	0.38
Pandora ornata (M)	266	1	0.38
Capitella capitata (P)	266	1	0.38
Ninoe nigripes (P)	266	1	0.38
Neopanope texana sayi (C)	266	1	0.38

SOURCE: Bharadwaj, A. 1988. The feeding ecology of winter flounder (Pseudopleuronectes americanus) in Rhode Island waters. M.S. Thesis, University of Rhode Island, Kingston.

Table 11. Parasites of winter flounder

rasite	Location	Distribution	Reference
ylum Protozoa			
yptobia bullocki	blood	Atlantic	Margolis and Arthur(1979)
spp.	blood	Atlantic	Margolis and Arthur(1979)
emogregarina platessae	blood	Atlantic	Margolis and Arthur(1979)
ceolariidae gen. *sp*.	gills	Atlantic	Margolis and Arthur(1979)
ypanosoma murmanensis	blood	Atlantic	Margolis and Arthur(1979)
ugea stephani	intestinal submucosa	Atlantic	Margolis and Arthur(1979)
	intestinal wall pyloric ceca	Woods Hole	Stunkard and Lux(1965)
oroza	intestinal wall	Woods Hole	Linton(1901)
sema stephani	intestinal wall, pyloric caeca	S.New England	Pellegrino(1973)
der Myxosporida			
ratomyxa acadiensis	gall bladder	Atlantic	Margolis and Arthur(1979)
xidium spp.	gall bladder	Atlantic	Margolis and Arthur(1979)
ylum Plathelminthes			
ass Trematoda			
yptocotlye lingua	skin, fins	S.New England	Pellegrino(1973)
yptocotyle lingua metacercaria	skin,gills	Atlantic	Margolis and Arthur(1979)
rogenes varicus	intestine,stomach	Atlantic	Margolis and Arthur(1979)
	alimentary tract	Canada	Scott(1976,1982)
	stomach,intestine	Canada	Ronald(1960)
llodistomum furcigerum	intestine,stomach	Atlantic	Margolis and Arthur(1979)
	alimentary tract	Canada	Scott(1976,1982)
nolinea laticauda	stomach	Atlantic	Margolis and Arthur(1979)
	Alimentary tract	Canada	Scott(1976,1982)
miurus spp.	intestine,stomach	Atlantic	Margolis and Arthur(1979)
	stomach	S.New England	Pellegrino(1973)
appendiculatus	stomach	Woods Hole	Linton(1940)
	stomach,intestine	S.New England	Pellegrino(1973)
levinseni	stomach, intestine	S.New England	Pellegrino(1973)

new host record

Table 11. Parasites of winter flounder (pg.2)

arasite	Location	Distribution	Reference
ecithaster gibbosus	intestine,stomach	Atlantic	Margolis and Arthur(1979)
	alimentary tract	Canada	Scott(1976,1982)
lagioporus varius	intestine,stomach	Atlantic	Margolis and Arthur(1979)
	intestine, pyloric caeca	S.New England	Pellegrino(1973)
. spp. probable new species	intestine, pyloric caeca	S.New England	Pellegrino(1973)
odocotyle atomon	intestine,stomach	Atlantic	Margolis and Arthur(1979)
	intestine	Woods Hole	Linton(1940)
	alimentary tract	Canada	Scott(1976,1982)
	intestine	Canada	Cooper(1915)
	alimentary tract	Canada	Heller(1949)
	intestine,stomach pyloric caeca	S.New England	Pellegrino(1973)
odocotyle simplex	intestine	Atlantic	Margolis and Arthur(1979)
odocotyle alssoni * new host record	intestine	S.New England	Pellegrino(1973)
odocotyle reflexa * new host record	intestine	S.New England	Pellegrino(1973)
odocotlye spp. probable new species	intestine	S.New England	Pellegrino(1973)
teganoderma formosum	intestine,pyloric caeca	Atlantic	Margolis and Arthur(1979)
	alimentary tract	Canada	Scott(1976,1982)
teringophorus furciger	intestine	Woods Hole	Linton(1940)
	alimentary tract	Canada	Heller(1949)
tenakron vetustum	intestine	Atlantic	Margolis and Arthur(1979)
	alimentary tract	Canada	Scott(1976,1982)
tephanostomum baccatum	superficial musculature	Passamoquoddy	Wolfgang(1954)
	dermal surfaces	Bay; Atlantic	Margolis and Arthur(1979)
. baccatum metacercaria	skin,gills,fins musculature	Atlantic	Margolis and Arthur(1979)
ebouria sp.	intestine	Woods Hole	Linton(1940)
epocreadium trullaforme	intestine	Woods Hole	Linton(1940)
ymbephallus vitellosus(Linton)	intestine	Woods Hole	Linton(1940)

Table 11. Parasites of winter flounder (pg. 3)

Parasite	Location	Distribution	Reference
Distomum appendiculatum	intestine	Woods Hole	Linton(1901)
Distomum grandiporum	intestine	Woods Hole	Linton(1901)
D. spp.	cysts on viscera and intestinal walls	Woods Hole	Linton(1901)
Homalometron pallidum	stomach,intestine	Woods Hole	Linton(1940)
	intestine	S.New England	Pellegrino(1973)
Parahemiurus merus ** new host record	intestine	S.New England	Pellegrino(1973)
Gyrodactylus pleuronecti	fins,gills,body surface	Newfoundland	Cone(1981)
Class Cestoidea			
Bothrimonus sturionis	intestine	Atlantic	Margolis and Arthur(1979)
Bothriocephalus claviceps	intestine	Atlantic	Margolis and Arthur(1979)
	intestine	Passamaquoddy Bay	Ronald(1958)
B. spp.	intestine	S.New England	Pellegrino(1973)
Tetrarhynchus bisculcatus	encysted stomach wall	Woods Hole	Linton(1901)
T. spp.	encysted peritoneum	Woods Hole	Linton(1901)
Diplocotyle olrikii	intestine	Canada	Heller(1949)
	intestine	Passamaquoddy Bay	Ronald(1958)
Phylum Nematoda			
Contracaecum aduncum	stomach,intestine body cavity,muscles	Canada	Heller(1949)
C. gadi	intestinal tract encysted on all internal organs	Gulf St. Lawrence	Ronald(1963)
C. spp.(larvae)	external surface of internal organs, mesenteries,muscles	Gulf St. Lawrence	Ronald(1963)
	intestine,stomach mesenteries,muscles	Atlantic	Margolis and Arthur(1979)

Table 11. Parasites of winter flounder (pg. 4)

rasite	Location	Distribution	Reference
ntracaecum spiculigerum	intestinal mesentaries	S.New England	Pellegrino(1973)
cullanus heterochrous	intestine,stomach	Atlantic	Margolis and Arthur(1979)
	intestine	Miscou Bank Grand-Riviere	Ronald(1963)
isakinae gen. spp. (larva)	viscera,body cavity	Atlantic	Margolis and Arthur(1979)
caris spp.	intestine	Woods Hole	Linton(1901)
matoda gen. spp.	viscera,muscles,stomach intestine,mesenteries	Atlantic	Margolis and Arthur(1979)
ocanema decipens (larva)	muscles,viscera	Atlantic	Margolis and Arthur(1979)
ocanema spp. (larva)	muscles, body cavity, mesenteries,viscera	Atlantic	Margolis and Arthur(1979)
ynnascaris adunca	intestine,stomach, body cavity,vuscera, muscles	Atlantic	Margolis and Arthur(1979)
rranova spp.	Axial musculature,body cavity,intestine exterior of pyloric caeca	Gulf St. Lawrence	Ronald(1963)
omachinae (larvae)	external surface of internal organs, musculature,body cavity	Gulf St.	Ronald(1963)
ylum Acanthocephala			
rynosoma spp.	encysted in mesentery and on outside internal organs	Grand-Riviere	Ronald(1963)
rynosoma spp. juvenile	intestinal mesentaries	S.New England	Pellegrino(1973)
hinorhynchus acus gadi	body cavity,intestine	Atlantic	Margolis and Arthur(1979)
	intestine	Woods Hole	Linton(1901)
	intestine, mesenteries	Atlantic	Margolis and Arthur(1979)
	intestine	S.New England	Pellegrino(1973)
	digestive tract	Gulf St. Lawrence	Ronald(1957,1963)

Table 11. Parasites of winter flounder (pg. 5)

asite	Location	Distribution	Reference
inorhynchus laurentianus	digestive tract	Gulf St.	Ronald(1963)
	Lawrence		
	intestine	Atlantic	Margolis and Arthur(1979)
spp.	intestine	S.New England	Pellegrino(1973)
	intestine	S.New England	Pellegrino(1973)
ylum Arthropoda			
class Copepoda			
nthochondria cornuta	gill cavity	Bay of Fundy	Stock(1915)
	gill cavity	Atlantic	Margolis and Arthur(1979)
er Branchiura			
ulus funduli	body surface,fins	Atlantic	Margolis and Arthur(1979)
spp.	body surface	S.New England	Pellegrino(1973)
melanops	body surface	Atlantic	Margolis and Arthur(1979)
megalops	entire body surface	Magdalen Is.	Ronald(1958)
m. spinosus	entire body surface	Magdalen Is.	Ronald(1958)

Table 12. Pollutant residues (µg/g, wet weight) in the liver of winter flounder collected during winter season (November 1986-February 1987).
WN=Warwick Neck WR=Whale Rock QP=Quonochontaug Pond

	WN	WR	QP
	n=26	n=27	n=20
PCBs	0.630 ± 0.283	0.259 ± 0.237	0.196 ± 0.182
	n=24	n=23	n=19
Pb	1.465 ± 0.546	1.748 ± 0.896	1.211 ± 0.631
	n=24	n=23	n=19
Cd	0.274 ± 0.350	0.194 ± 0.112	0.182 ± 0.086
	n=24	n=27	n=21
Hg	0.142 ± 0.105	0.131 ± 0.090	0.051 ± 0.038
	n=24	n=27	n=21
As	0.051 ± 0.034	0.043 ± 0.033	0.033 ± 0.014

Table 13. Pollutant residues (µg/g, wet weight) in the liver of winter flounder collected during spring season (May-June 1987).
WN=Warwick Neck WR=Whale Rock QP=Quonochontaug Pond

	WN	WR	QP
	n=19	n=23	n=57
PCBs	0.823 ± 0.326	0.501 ± 0.255	0.381 ± 0.136
	n=19	n=23	n=57
Pb	0.525 ± 0.134	0.869 ± 0.216	0.408 ± 0.241
	n=19	n=23	n=57
Cd	0.289 ± 0.081	0.234 ± 0.090	0.174 ± 0.057
	n=19	n=21	n=57
Hg	0.441 ± 0.158	0.252 ± 0.105	0.228 ± 0.099
	n=19	n=21	n=57
As	0.027 ± 0.010	0.057 ± 0.037	0.039 ± 0.028

Table 14. Pollutant residues (µg/g, wet weight) in the muscle of winter flounder collected during winter season (November 1986-February 1987).

WN=Warwick Neck WR=Whale Rock QP=Quonochontaug Pond

	WN	WR	QP
	n=14	n=14	n=14
PCBs	0.397 ± 0.157	0.163 ± 0.070	0.202 ± 0.119
	n=14	n=14	n=14
Pb	0.574 ± 0.5152	0.513 ± 0.147	0.557 ± 0.145
	n=14	n=14	n=14
Cd	0.146 ± 0.075	0.127± 0.019	0.134 ± 0.040
	n=14	n=14	n=14
Hg	0.197 ± 0.084	0.161 ± 0.044	0.189 ± 0.101
	n=14	n=14	n=14
As	0.027 ± 0.009	0.012± 0.005	0.022 ± 0.010

Table 15. Pollutant residues (µg/g, wet weight) in the muscle of winter flounder collected during spring season (May-June 1987).

WN=Warwick Neck WR=Whale Rock QP=Quonochontaug Pond

	WN	WR	QP
	n=14	n=14	n=14
PCBs	0.170 ± 0.058	0.102 ± 0.043	0.139 ± 0.027
	n=14	n=14	n=14
Pb	0.750 ± 0.127	0.453 ± 0.187	0.624 ± 0.116
	n=14	n=14	n=14
Cd	0.268± 0.024	0.147 ± 0.088	0.229 ± 0.054
	n=14	n=14	n=14
Hg	0.135 ± 0.057	0.123 ± 0.064	0.115 ± 0.046
	n=14	n=14	n=14
As	0.020 ± 0.006	0.015 ± 0.007	0.021 ± 0.009

Source: Lee et al. (1988).