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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic)

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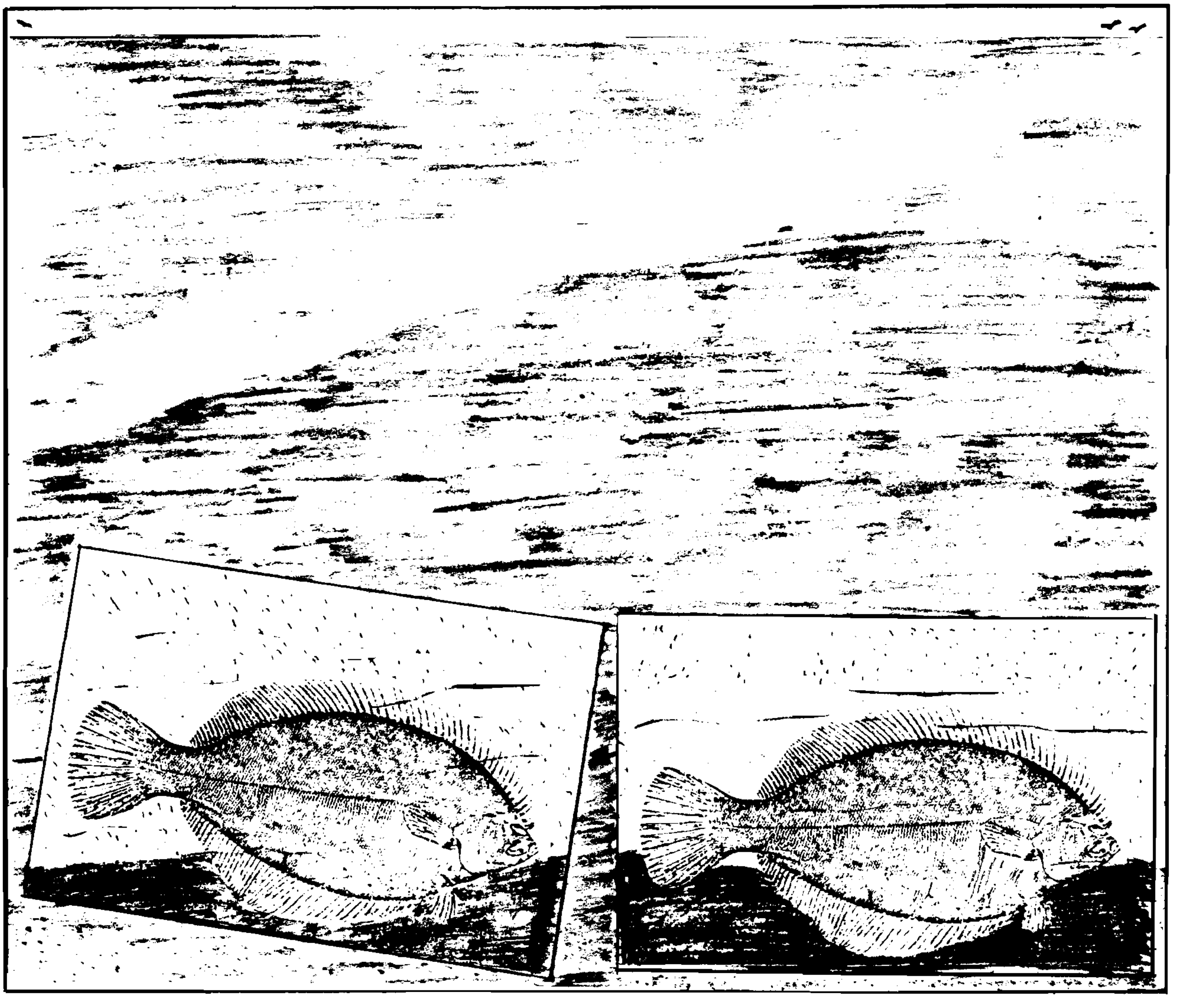

Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic)

WINTER FLOUNDER

by

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Performed for
Coastal Ecology Group
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PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

I am grateful for reviews by Wendy Gabriel, National Marine Fisheries Service, Woods Hole, Massachusetts, and Arnold Howe, Massachusetts Division of Marine Fisheries, Sandwich, Massachusetts.

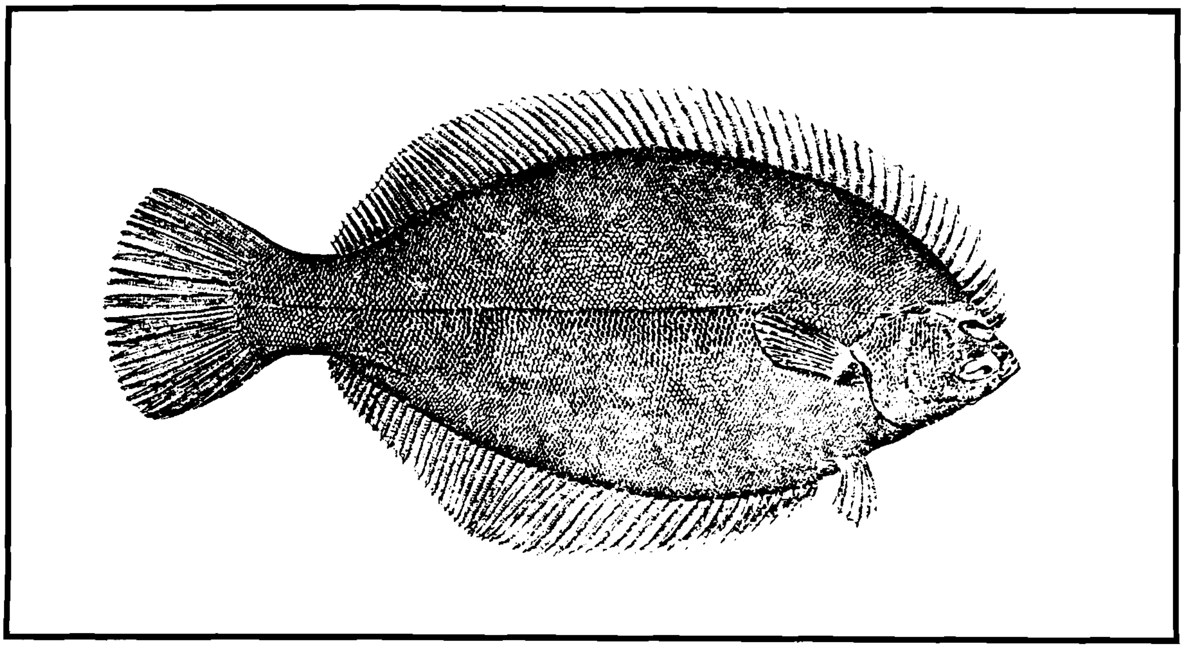

Figure 1. Winter flounder.

WINTER FLOUNDER

NOMENCLATURE/TAXONOMY/RANGE

Scientific name . . . . *Pseudopleuronectes americanus* (Walbaum)
Preferred common name . . . . Winter flounder (Figure 1)
Other common names . . . . . Blackback flounder, lemon sole, black flounder
Class . . . . Osteichthyes
Order . . . . Pleuronectiformes
Family . . . . Pleuronectidae

Geographic range: Winter flounder are found primarily in estuarine and coastal waters along the Atlantic coast of North America from Newfoundland to Georgia (Leim and Scott 1966), except for off-shore populations on Georges Bank and Nantucket Shoal (Figure 2; Bigelow and Schroeder 1953).

MORPHOLOGY/IDENTIFICATION AIDS

The winter flounder, one of the right-eyed flounders, is oval-shaped and thick-bodied; the caudal fin and peduncle are broader than those of other North Atlantic flounders. The anal fin is highest at its midpoint and is preceded by a short sharp spine. The dorsal fin (60-76 rays) originates opposite the anterior edge of the eye, and is about equal in height along its length. The mouth is small, not gaping to the eye. The left (under) half of the jaw is armed with a series of close-set incisors; the right (upper) half has only a few teeth.

The winter flounder, like other flatfishes, varies in color, depending

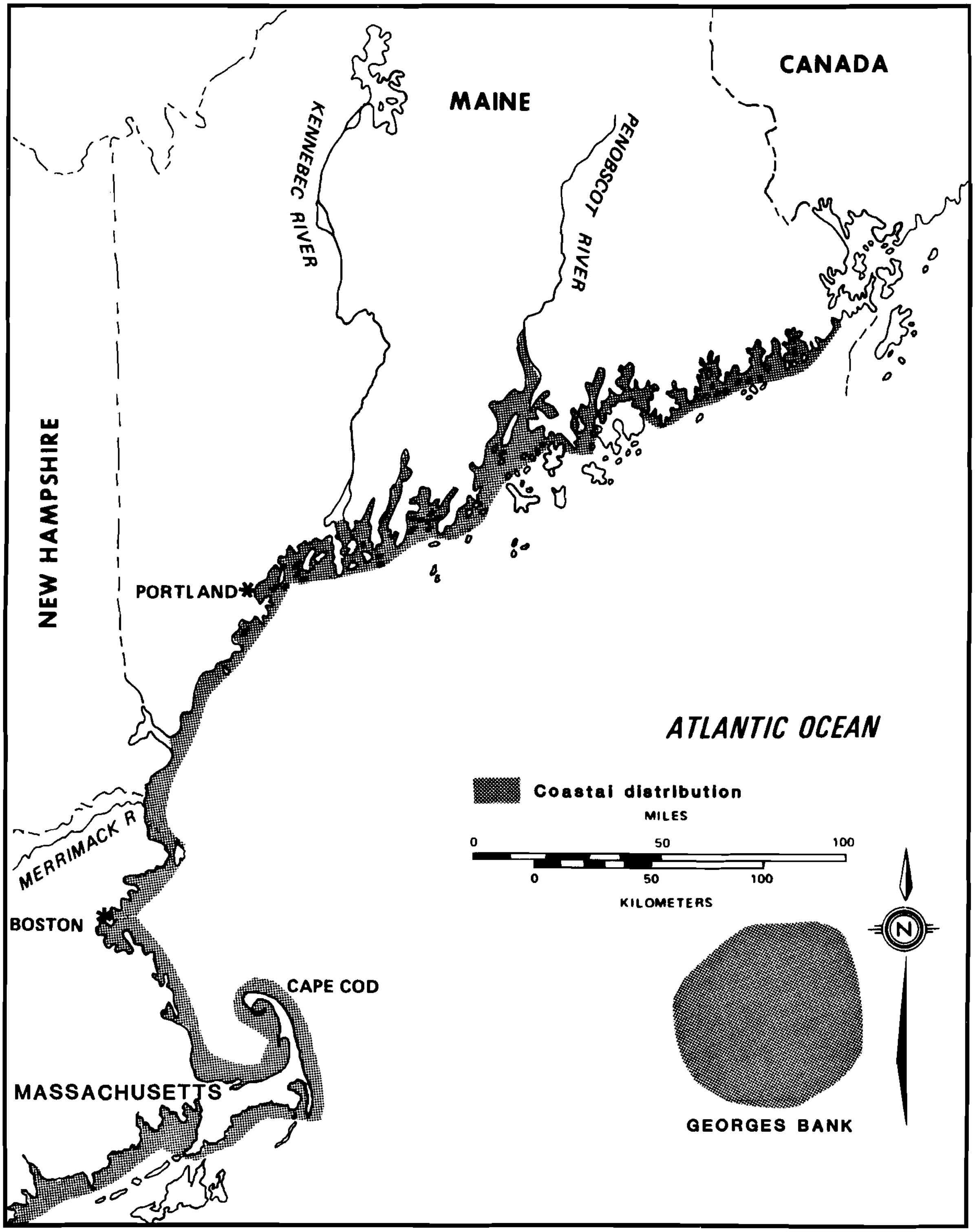

Figure 2. Distribution of winter flounder in the North Atlantic.

largely on the color of the surrounding substrate. Most adults tend to be reddish brown, olive-green, or blackish. Smaller fish generally are paler than larger fish. The blind side is white and, toward the edge, translucent or occasionally yellowish.

SEPARATION FROM OTHER RIGHT-EYED FLATFISHES

Compared with the yellowtail flounder, Limanda ferruginea, the winter flounder has a much straighter lateral line, a less concave dorsal head profile, and fewer fin rays.

The winter flounder lacks the mucous pits that are conspicuous on the left (blind) side of the head of the witch flounder (Glyptocephalus cynoglossus); it also has three times as many dorsal rays as the witch flounder.

The scales between the eyes are smooth in the smooth flounder (Liopsetta putnami), but rough in the winter flounder. Between the two, the winter flounder also has the greater number of anal fin rays.

Several morphological characteristics that distinguish larvae of winter flounder from those of the other flounders common in the western north Atlantic were given by La Roche (1980).

REASONS FOR INCLUSION IN THE SERIES

By virtue of its abundance in estuarine and nearshore waters, the winter flounder is one of the most important commercial and sport fishes in the Northeastern United States. In Massachusetts, it is considered a major contributor to the commercial and sport fisheries (Pierce and Howe 1977).

LIFE HISTORY

Spawning

The winter flounder spawns in coastal waters as early as December in the Southern United States and as late as June in Canada. Typically, eggs are deposited over a sandy substrate at depths of 2 to 80 m (Bigelow and Schroeder 1953).

Most spawning takes place at salinities of 31 to 32.5 ppt in inshore waters, and on Nantucket Shoal and Georges Bank at slightly higher salinities (32.7 to 33 ppt, respectively; Bigelow and Schroeder 1953). Water temperature during spawning is usually between 0 and 3 °C but may be as high as 6 °C (Bigelow and Schroeder 1953). The winter flounder spawns at slightly higher temperatures on Georges Bank than in inshore waters (Lux et al. 1970).

The stage of maturity of the winter flounder is largely governed by size rather than age. Flounders grow faster and mature at a younger age in the south than in the north. In Newfoundland, males mature at age VI and females at age VII (Kennedy and Steele 1971); in New York, winter flounder mature at age II or III (Perlmutter 1947).

The fecundity of winter flounder reported by Bigelow and Schroeder (1953) ranged from 0.5 to 1.5 million eggs per female. Saila (1961) reported that in Rhode Island waters 193,000 eggs were produced by a fish 249 mm total length (TL) and 1.34 million by a fish 428 mm TL. In the Weweantic Estuary in Massachusetts, numbers of eggs ranged from 435,000 for a fish 350 mm TL to 3.3 million for a fish 450 mm TL (Topp 1967). In Newfoundland, Kennedy and Steele (1971) reported a fecundity range from 99,000 eggs for a fish 220 mm TL to 2.6 million for a fish 440 mm TL (mean = 0.59 million eggs at a mean length of 340 mm TL). The following equations for estimating fecundity on the basis of weight have been published:

$$\log F = 2.3894 + 1.2403 \log W$$
(Kennedy and Steele 1971)

$$\log F = 0.0697 + 1.0659 \log W$$
(Topp 1967)

$$\log F = 2.6712 + 1.1383 \log W$$
(Saila 1961)

where F = fecundity in thousands of eggs and W = total weight in grams.

Eggs

Winter flounder eggs are demersal, adhesive, and 0.74 to 0.85 mm in diameter (Bigelow and Schroeder 1953). They have no oil globule when deposited, but acquire one later (Breder 1924). Incubation time was 15 to 18 days at 2.8 to 3.3 °C (Bigelow and Schroeder 1953), 25 days at 3 °C, and 7 days at 12 to 14 °C (Rogers 1976). Incubation time was inversely related to water temperature and salinity (Rogers 1976).

Winter flounder eggs seem to be most abundant in water with a salinity of 10 to 30 ppt; at salinities below 5 ppt or above 40 ppt, some embryos survive, but are usually deformed (Rogers 1976). The optimal salinity for egg survival is 15 to 35 ppt.

Many embryos become inviable or abnormal at temperatures below freezing (-1.8 to 0 °C) and temperatures above 10 °C (Williams 1975). The optimum water temperature range for survival is 0 to 10 °C (Williams 1975).

Larvae

In studies by Bigelow and Schroeder (1953) and La Roche (1980), winter flounder larvae were 2.4 to 3.5 mm TL at the time of hatching. A major characteristic of the newly hatched larvae was the broad vertical band of pigment cells dividing the postanal portion of the body. At a water temperature of 3.9 °C the larvae were about 5 mm TL, and the yolk sac was absorbed in 12 to 14 days. La Roche (1980) provides a detailed description of larval development.

Winter flounder undergo a rapid metamorphosis at a much smaller size than other flatfishes of the North Atlantic region (Bigelow and Schroeder 1953). Their metamorphosis is complete when the larvae are 8 to 9 mm TL (Laurence 1975); this transformation took 80 days at a water temperature of 5 °C and 49 days at 8 °C. No metamorphosis was evident at 2 °C (Bigelow and Schroeder 1953).

In aquaria, winter flounder larvae engage in upward swimming bouts and then sink to the bottom where they remain for a short time (Sullivan 1915; Bigelow and Schroeder 1953). The larvae of other flatfish species are more pelagic. Winter flounder larvae are continuous, visual, daylight feeders that cease feeding at night (Laurence 1977).

Juveniles

After metamorphosis, winter flounder are benthic and seldom lose contact with the substrate. Most juveniles spend much of their first 2 years in or near shallow natal waters, where they move in response to extreme heat or cold (Topp 1967). After metamorphosis, the juveniles prefer a substrate of sand or sand and silt (Clayton et al. 1978). Older juveniles in estuaries gradually move seaward as they grow larger (Mulkana 1966).

Adults

The seasonal movements of winter flounder differ between populations north and south of Cape Cod. A 5-year tagging study by Howe and Coates (1975) showed that winter flounder north of Cape Cod moved about only locally in inshore waters, while those south of Cape Cod dispersed more than 3 mi offshore in a southwesterly direction. Adults from Martha's Vineyard and coastal populations from south of Cape Cod mixed in Nantucket Sound (Pierce and Howe 1977).

Water temperature seems to be the most important environmental factor determining seasonal distribution (McCracken 1963). In Rhode Island, adult winter flounder lived in cooler offshore waters during summer and in shallow inshore waters in winter and early spring (Saila 1961). In Newfoundland, winter flounder remained in shallow water during summer as long as food was available and water temperatures did not exceed 15 °C (Van Guelpen and Davis 1979). Temperature is a less important factor in the distribution of juveniles, which tolerate higher temperatures than adults (Pearcy 1962).

Indications are that a local population is defined by fish inhabiting several adjacent estuaries (Pierce and Howe 1977). Although a large percentage of winter flounder in a tagging study were recaptured at or near the original tagging locations, Saila (1961) reported that the same breeding area is not always reoccupied each season. On a larger geographic scale, there is evidence that winter flounder north and south of Cape Cod and from Georges Banks compose three separate groups (Lux et al. 1970; Pierce and Howe 1977).

GROWTH CHARACTERISTICS

Growth Rate

The rate of growth of the winter flounder is rapid until age V or VI and then decreases, particularly in males (Lux 1973). After the first 2 years, females grow faster than males (Briggs 1965; Lux 1973; Howe and Coates 1975). An exception is in Newfoundland, where the growth rates of the sexes are similar (Kennedy and Steele 1971).

The growth rate also differs between fish from areas relatively close geographically. Lengths of flounder at the same age were significantly different among certain bays on Long Island (Lobell 1939; Poole 1966). Flounder grow to a larger size in the Georges Bank population than in inshore populations (Bigelow and Schroeder 1953). According to Berry et al. (1965), there is no typical growth rate for the winter flounder because the populations may be exposed to different rates of exploitation or live under different environmental conditions. In addition, the extended spawning period (up to 4 months) can make comparisons difficult between age groups and locations.

Lux (1973) gave the following von Bertalanffy growth equations for winter flounder from Georges Bank:

$$\text{male } l_t = 550\ [1 - e^{-0.37(t-0.05)}]$$
$$\text{female } l_t = 630\ [1 - e^{-0.31(t-0.05)}]$$

Length-Weight Relationships

The length-weight relationships published for adults and larvae are presented in Table 1.

THE FISHERY

Commercial and Recreational

The winter flounder supports valuable commercial and sport fisheries in the coastal waters of New England. The total commercial catch in the five coastal New England States was 15,500 metric tons (t) in 1983 (U.S. Department of Commerce 1983). From 1935 to 1980, the annual commercial landings in New England ranged between 6,000 and 15,000 t. The otter trawl is the principal fishing gear.

The winter flounder is a highly valued sport species because it is

Table 1. Published length-weight relationships for adult and larval winter flounder.

Equation	Location	Source
Adults		
$\log_{10}W = 3.138 \log_{10}L - 5.239$ where W = g, L = mm	Georges Bank	Lux (1969)
$\log_{10}W = 3.1441 \log_{10}L - 2.072$ (female)		
$\log_{10}W = 2.9833 \log_{10}L - 1.9041$ (male) where W = g, L = cm	Newfoundland	Kennedy and Steele (1971)
Larvae		
$\log_{10}W = 4.769 \log_{10}L - 1.347$ where W = mg, L = mm	Laboratory-reared	Laurence (1979)

seasonally abundant in nearshore areas and easily captured from boat or shore. In New England the sport catch has been reported to surpass the commercial catch in some years (Deuel 1973).

Population Dynamics

The age and size of winter flounder recruited into the fishery varies with the location and the type of fishery. Briggs (1965) reported that flounder recruited into the sport fishery at South Shore Bay, Long Island, were from 200 to 260 mm TL. In Nova Scotia, recruits into the commercial fishery were 3 to 4 years old and weighed an average of 363 g (Dickie and McCracken 1955). In Narragansett Bay, Rhode Island, winter flounder were fully recruited into the commercial catch at age III (250 mm TL; Saila et al. 1965).

Estimated natural mortality rates of winter flounder ranged from 50% to 54% and total annual mortality (natural and fishing) ranged from 72% to 78% (Poole 1969). Total annual mortality rates estimated by Berry et al. (1965) on the basis of age composition for two different Long Island populations were 56% for males and 65% for females in one population, and 51% for males and 58% for females in the other. The instantaneous mortality rates of winter flounder in Nova Scotia were 0.321 (natural) and 0.475 (fishing) (Dickie and McCracken 1955). South of Cape Cod, Howe et al. (1976) reported instantaneous mortality rates of 0.1125 (natural) and 0.2445 (fishing).

Two important factors affecting mortality are translocation of larvae out of the estuary by drift (Pearcy 1962) and predation (Dickie and McCracken 1955). Jeffries and Johnson (1974) reported that winter flounder abundance in Narragansett Bay may be partially governed by annual or seasonal changes in climate. Because each population does not usually disperse beyond local waters, the degradation of an estuary may have a drastic effect on the abundance of recruits in nearby coastal waters.

ECOLOGICAL ROLE

Food Habits

Larvae begin to feed 2 to 3 weeks after they hatch. They first feed on copepods and phytoplankton, but as they reach metamorphosis, their diet is composed of copepod nauplii, small polychaetes, nemerteans, and ostracods. For detailed descriptions of the food habits of larval and juvenile winter flounder, see Pearcy (1962). Laurence (1977), who studied the effects of food density on larval growth and survival, reported that the larvae died from starvation in 2 weeks at prey (nauplius) densities of <0.1/ml; critical prey density was about 0.5/ml. Plankton density influenced survival more than it did growth. Laurence (1977) demonstrated that the density of prey was probably the most important factor affecting survival.

Adult winter flounder fed largely on organisms of three phyla: Annelida, Cnidaria, and Mollusca. In the study by Langton and Bowman (1981), the percentages of composition (numbers) of prey in flounder stomachs were as follows: Annelida 27% (mostly polychaete worms), Cnidaria 26%, Anthozoa 25%, Mollusca 16%, and Hydrosoa 4%. The composition varied among geographic locations. Tyler and Dunn (1976) reported that the maintenance ratio was 7.9 cal/g. Detailed studies of the food of adult winter flounder were made by Langton and Bowman (1981), Wells et al. (1973), Kennedy and Steele (1971), Olla et al. (1969), Mulkana (1966), and Frame (1973).

Feeding Behavior

Winter flounder primarily feed visually and only during daylight (Olla et al. 1969; MacDonald 1983). In the Bay of Fundy, those in nearshore waters usually fed in the intertidal zone (Wells et al. 1973). They moved inshore about 2 h after low tide and returned to the sublittoral zone about 2 h before the next low tide (Tyler 1971b).

When feeding, the winter flounder lies motionless with its head raised off the bottom, braced by the dorsal fin. When a prey is sighted, the fish remains motionless, pointing toward the prey, and then lunges forward and downward to capture it. If no prey is sighted, the fish moves to a new location, changing position from four to five times per minute (Olla et al. 1969).

Competition

The winter flounder has relatively few competitors for food and space. In many estuaries it is the most abundant demersal species (Richards 1963; Oviatt and Nixon 1973). The highly productive estuarine and coastal habitats it occupies, combined with its omnivorous food habits, tend to reduce competition. Jeffries and Johnson (1974) suspected that the early spawning and the short period of time to metamorphosis permit the larvae to reach the juvenile stage before potential competitors enter the bays and estuaries.

Predators

Adult winter flounder are the prey of many of the larger estuarine and coastal predators such as striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), goosefish (*Lophius americanus*), spiny dogfish (*Squalus acanthias*), oyster toadfish (*Opsanus tau*), and sea raven (*Hemitripterus americanus*) (Dickie and McCracken 1955; Grosslein and Azarovitz 1982).

Predation is a major cause of mortality in larval and juvenile winter flounder. The larvae were heavily preyed upon by the small hydromedusa *Saria tubulosa* (Pearcy 1962). Tyler (1971a) reported that the great cormorant (*Phalacrocorax carbo*), the great blue heron (*Ardea herodias*), and the osprey (*Pandion haliaetus*) are also predators of winter flounder.

Parasites

The microsporidian parasite *Glugea hertwigi* is most common and may cause high mortality among winter flounder less than 30 mm long (TL) (Mulkana 1966). Klein-MacPhee (1978) provided a detailed list of the principal parasites of the winter flounder.

ENVIRONMENTAL REQUIREMENTS

Water Temperature

Winter flounder are commonly found in water temperatures of 0 to 25 °C. Olla et al. (1969) reported that winter flounder fed at water temperatures as high as 22 °C, but burrow into the bottom at higher temperatures. McCracken (1963) gave a preferred temperature range of 12 to 15 °C. Huntsman and Sparks (1924) reported a maximum temperature tolerance of about 30 °C. Under controlled conditions, winter flounder can acclimate to higher temperature regimes; for example, Everich and Gonzalez (1977) reported that the critical thermal maximum increased from 26 to 32 °C as the acclimation temperature increased from 4 to 23 °C. An extended period of unusually hot weather caused heavy mortality in coastal waters of Long Island Sound (Nichols 1918). Juvenile winter flounder tend to be more tolerant of high temperatures than adults.

Salinity

Adult winter flounder commonly live in salinities of 5 to 35 ppt (Bigelow and Schroeder 1953). Extremes in salinity may lower egg and larval survival and hatching success (see the section on eggs and larvae).

Contaminants

In a study in the Weweantic River, Massachusetts, chlorinated hydrocarbon insecticides and their breakdown products (DDT, DDE, heptachlor, heptachlor epoxide, and dieldrin) were found in various tissues of the winter flounder (Smith and Cole 1970; Smith 1973). Concentrations of DDT, DDE, and heptachlor epoxide were highest in ripening ovaries. Agricultural runoff was the major source of the contaminants (Smith and Cole 1970). Topp (1967) reported that this contamination caused high mortality in the Weweantic River.

In studies of the effects of silver on the eggs and larvae of winter flounder, Klein-MacPhee et al. (1984) found that concentrations of silver greater than 54 µg/l sometimes caused high mortality of the eggs and yolk-sac larvae, and that exposure to 92 µg/l significantly increased egg mortalities. In contrast, Voyer et al. (1982) reported that silver in concentrations up to 166 µg/l did not increase egg mortality.

Disease

About 14% of the winter flounder examined from the New York Bight had fin erosion (Ziskowski and Murchelano 1975). It is not known if the disease is infectious or noninfectious, but it is not usually fatal. Although the precise cause of fin rot erosion is not known, its high incidence in association with high sediment contamination suggests that contact of the fins with toxic sediment is an important factor in the development of the disease (Sherwood 1982).

The microsporidian *Glugea hertwigi*, found in the digestive tract of winter flounder, was described by Stunkard and Lux (1965). The incidence of infection in samples ranged from 54% in Martha's Vineyard to zero on Georges Bank (Stunkard and Lux 1965).

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, life history, and environmental requirements of coastal fishes and aquatic invertebrates. They are designed to assist with environmental impact assessments. From 1935 to 1980, the annual commercial landings of winter flounder in New England ranged from 6,000 to 15,000 t; the sport catch exceeded the commercial catch in some years. Winter flounder are found in waters with temperatures of 0 to 25 °C and they usually spawn at 0 to 3 °C. Reported fecundities are 0.5 to 1.5 million eggs per female. Metamorphosis from larva to juvenile is complete in 49-80 days, depending on temperature. Juveniles remain in or near shallow natal waters for much of their first 2 years. Adults of some populations move more than 3 miles offshore to cooler waters in summer. These adults live in shallow inshore waters in winter and early spring. Adult winter flounder feed largely on annelids, cnidariids, and mollusks.

17. Document Analysis a. Descriptors

Estuaries	Fishes	Salinity
Fisheries	Life cycles	Contaminants
Feeding habits	Temperature	

b. Identifiers/Open-Ended Terms

Winter flounder, *Pseudopleuronectes americanus*	Environmental requirements Ecological role

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