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Feeding Habits of Winter Flounder (*Pleuronectes americanus*) in a Habitat Exposed to Anthropogenic Disturbance

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Abstract

The feeding habits of the winter flounder (*Pleuronectes americanus*) were examined in a habitat subjected to chronic anthropogenic disturbance by organic and inorganic nutrient disposal and shipping activity. The macrobenthic community was numerically dominated by the types of polychaetes and amphipods found in a disturbed community. Little variability was found in the diets of 151 winter flounder (100–300 mm total length) in 4 size-classes. Combining all size-classes, winter flounder were found to feed on 18 different genera of macrobenthos. Amphipods and polychaetes dominated the diet. These groups provided from 12–25% of the diet by weight, 16–48% by number, and had index of relative importance values between 552 and 2 510. Major prey items were the amphipod, *Ampelisca abdita* and the polychaete, *Streblospio benedicti*. These diets were compared to those winter flounder captured in habitats where benthic assemblages were not exposed to human perturbation. Regardless of habitat, winter flounder fed on primarily the most abundant and active benthic species. This study supports the contention that winter flounder are in general, opportunistic feeders and usually feed on the most abundant and available prey source.

Key words: benthos, diet, disturbance, flounder, foraging

Introduction

The winter flounder (*Pleuronectes americanus*) is one of the most abundant demersal fishes of the Long Island Sound estuarine system and is an important commercial and recreational fish (Smith *et al*., 1989). Winter flounder feed primarily on benthic invertebrates (Klein-Mcphee, MS 1978) but variation in diet can occur between habitats (Pearcy, 1962; Richards, 1963; Frame, MS 1972; Tyler, 1972; Hacunda, 1981; Macdonald and Green, 1986; Keats, 1990) suggesting winter flounder are opportunistic feeders.

In many areas of Long Island Sound, the composition of the macrobenthic habitat has been altered by anthropogenic disturbances; including hypoxia, dredging, dredge-spoil dumping, shipping traffic and sewage disposal (Rhoads *et al*., 1978; Wolfe *et al*., 1991). In recent years, much attention has focused on how various types of anthropogenic disturbances affect the Long Island Sound estuary. Although Howell and Simpson (1994) studied the correlation between hypoxia and marine fish distribution and abundance, most research has largely been directed towards the effects contaminants have on various marine resources (Gronlund *et al*., 1991; Robertson *et al*., 1991). The consequence of anthropogenic disturbances on the feeding ecology of benthic feeding fishes are less known. Therefore, this information may be necessary for sound management of marine fisheries stocks (Becker and Chew, 1987).

Typically, macrobenthic invertebrate assemblages in habitats exposed to perturbations are

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dominated by opportunistic species char-acterized by small size, high fecundity rates, and ability to colonize the habitat rapidly (Pearson and Rosenberg, 1978; Rhoads *et al*., 1978; Warwick, 1986; McManus and Pauly, 1990). These characteristics allow these species to reach high population densities quickly (Levinton, 1982; Warwick, 1986) and may represent an enhanced forage base for some benthic feeding fishes.

How important are opportunistic benthic species to winter flounder? Since winter flounder are benthic invertebrate feeders, the high density and epifaunal distribution of these opportunists could make them an easily obtainable food source and could be selectively fed upon. To evaluate this suggestion, we examined the diets of winter flounder in a habitat exposed to chronic human perturbation. In particular, our objectives were: (1) describe the diet of different size-classes of winter flounder; (2) compare these diets with prey items potentially available in the benthic habitat; and (3) compare these diets of winter flounder to those captured in habitats where benthic assemblages are not exposed to human perturbation.

Materials and Methods

Trawl samples were made twice monthly to collect winter flounder along the eastern end of New Haven Harbor (Area 1) during September-November of 1989 and 1990. A 9.1 m otter trawl with 50.8 mm #15 nylon mesh and a 38.1 mm mesh cod end was towed for 15 minutes along one transect line (Fig. 1).

Immediately after capture, winter flounder were measured (total length, TL in mm) and divided into 50 mm size categories. Stomachs were removed by cutting at the esophagus and pyloric constriction. Stomachs were fixed at sea in 10% formalin. The contents were sorted in the laboratory and identified to the lowest possible taxon. Prey items were blot dried and the number of individuals and total weight of each prey type recorded. Portions of prey items were counted as remains unless an anterior end could be found. Total weight included shell weight for molluscs and crustaceans and test weight of echinoderms.

Prior to trawling, bottom salinity and temperature were measured with a YSI model 33 temperature-salinity-conductivity meter. Dissolved oxygen concentrations were determined using the azide modification of the Standard Winkler Titration Methods (Rand *et al*., 1975) and benthic samples were taken along the trawl transect (Fig. 1). Three random benthic samples were taken at one station along the trawl transect using a ponar grab which samples an area of 0.05 m^2. Grab samples were washed through a 0.5 mm sieve, stained with rose bengal and fixed in 10% formalin. Grab samples were sorted in the laboratory and organisms identified to the lowest possible taxon. For analysis, replicate grab samples were pooled and summarized for each sampling year.

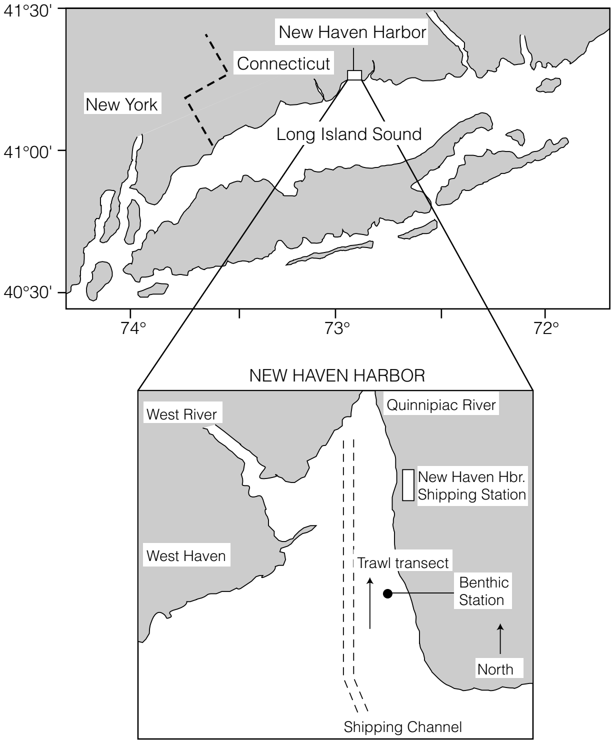

Fig. 1. Map of study area with the location of New Haven Harbor (Area 1) within Long Island Sound and location of trawl transect and benthic station within New Haven Harbor.

The contribution of different prey categories (i.e. taxa) to the diet was determined by three methods: (1) the wet weight of a prey category divided by wet weight of the total stomach contents; (2) the numerical abundance of individuals of a prey category divided by the total number of individual prey in the stomach; and (3) the frequency of occurrence of the number of stomachs in which a prey category occurred divided by the total number of stomachs examined.

To evaluate the importance of each prey item in the diet, an index of relative importance (IRI) developed by Pianka *et al.* (1971) and modified by Hacunda (1981) was used:

$$IRI = (N+W)F$$

where N is the numerical percentage,

W is the weight percentage, and

F is the frequency of occurrence.

Principal prey items were defined as those prey having an IRI>100 (Hacunda, 1981).

Differences in the diets between size-classes of winter flounder were examined. The numerical and weight percent contribution and IRI of each principal prey item in the flounder diet from each size-class of winter flounder was ranked by its total contribution and compared using Kruskal-Wallis nonparametric procedures (Zar, 1984).

The selectivity of major prey items was tested using Shorigin's ratio of food selection (FR) as modified by Jacobs (1974) to correct for intrinsic asymmetry:

$$FR = LOG_{10}\,(r_i \,/\, p_i)$$

where; FR is the forage index,

r_i is percent contribution by number of $prey_i$ in the predator's diet, and

p_i is the percent contribution by number of the same prey item in the benthos.

This value ranges from negative infinity to positive infinity with a positive value indicating preference or high accessibility and a negative value indicating avoidance or low accessibility. A value equal or close to 0 indicates random feeding.

To examine differences in the diets of winter flounder between habitats without human perturbation, the ranked values of number, weight and IRI of principal prey found in the present study were compared using nonparametric procedures with those from winter flounder (n = 29) obtained at 2 sites during the same time period in Clinton Harbor, Clinton, Connecticut, USA (Area 2) by Mroczka (MS 1991) and Mroczka (unpublished data). The sites are located on intertidal and subtidal mud flats near the mouth of the Hammonassett River, Clinton, CT. Flounder were sampled using a 1-m beam trawl made of knotless 6.4 mm nylon mesh with one tickler chair and a 3.4 m shrimp trawl with 25.4 mm nylon mesh. Flounder were processed identical to methods described previously.

Case Study

New Haven Harbor is an polyhaline estuary located in south central Connecticut, approximately midway between New York City, New York, USA and Providence, Rhode Island, USA, on the northern shore of Long Island Sound (Fig. 1). The harbor is located at the mouth of the Quinnipiac River and is lined with estuarine embayment, near shore waters, intertidal flats, shellfish concentration areas and developed shore front. The harbor is composed of fine grain (silt-clay) sediments with a high organic content (Tubman, 1979). New Haven Harbor is a significant focus for commercial and industrial activity. The harbor receives an extremely high organic and contaminant load from municipal and industrial discharges as well as intense periods of shipping traffic by large commercial tankers and vessels (Tubman, 1979; Wolfe *et al.*, 1991).

Clinton Harbor is located in Clinton, Connecticut, USA, which is centrally located along the Connecticut southern coastline on the Long Island Sound northern border. The harbor occupies approximately 1 604 km^2 and has a mean tidal range of 1.5 m. Freshwater discharge into the study sites is from the Hammonassett River.

Results

Physical Parameters

The study site in New Haven Harbor (Area 1) exhibited typical estuarine abiotic characteristics throughout the study period. During both years, water temperatures were 11°–20°C with warmer temperatures in September and cooler temperatures in November. Salinity averaged 19–21 ppt. Despite the high nutrient load to the harbor, dissolved oxygen levels generally exceeded 6.0 mg per l and never fell below 4.0 mg per l. Water temperature were 8°–19°C from September–November and salinity averaged 13–19 ppt.

Diet

Overall, the diet of winter flounder (n = 151) collected in Area 1 was composed of 18 different genera from 5 major taxa (Table 1). Polychaetes and amphipods which dominated the diet, provided 12 and 26% of the diet respectively by weight, 32 and 48% by number and had IRI values of 552 and 2 510. The 3 principal prey items were the amphipod *Ampelisca abdita*; the polychaete, *Streblospio benedicti*; and portions of *Nassarius trivitattus*, mainly the foot and operculum.

Winter flounder (100–300 mm TL) from Area 1 were divided into four 50 mm TL size-classes and examined for dietary components. Among size-classes, 5 principal prey items were determined: *A. abdita*, *S. benedicti*, oyster crab, *Pinnixa* sp.; mysid shrimp; *Neomysis americana*, and foot and opercular regions from *N. trivitattus* (Fig. 2). *Ampelisca abdita* and *S. benedicti* were the most important of principal prey comprising up to 77% of the diet. Although hydroids made up a portion of the diet by weight, the inability to discern individuals made counting impossible and thus they were not included in the dietary comparison. There was no significant difference in the number (H = 0.165, $p \geq 0.05$), weight (H = 2.31, $p \geq 0.05$), and the IRI (H = 1.03, $p \geq 0.05$) of each principal prey item between 4 size-classes of winter flounder.

TABLE 1. Diet of 151 winter flounder (size range = 100–300 mm TL) showing index of relative importance (IRI) of prey from Area 1, expressed in percentage weight, number and frequency of the total number of stomachs analyzed (45 stomachs empty). A value less than 0.05 is designated (+).

Taxon	Weight	Number	Frequency	IRI
Mollusca (Total)	17.25	17.21	13.87	478.00
Bivalve siphons	1.04	0.20	2.64	3.27
Macoma balthica	0.24	0.30	2.64	1.32
Nassarius trivittatus	0.19	+	0.66	0.13
Gastropod foot	15.77	16.69	8.58	278.00
Polychaeta (Total)	12.22	31.72	12.57	552.00
Eteone heteropoda	+	0.16	1.32	0.23
Leitoscoloplos robustus	0.64	0.16	0.66	0.52
Nereis succinea	1.50	0.24	2.07	3.44
Mediomastus ambiseta	+	0.05	0.66	0.02
Streblospio benedicti	7.10	31.11	3.31	124
Polychaeta remains	2.92	–	4.92	–
Crustacea (Total)	46.25	50.70	67.40	6 486.0
Crustacean remains	7.28	–	10.92	–
Cancer irroratus	0.16	+	0.66	0.15
Crangon septemspinosa	6.54	0.16	1.32	8.84
Pagurus longicarpus	1.31	0.18	1.32	1.96
Pinnixa sp.	1.17	1.11	7.26	16.62
Cumacea	+	0.07	0.66	+
Crab Zoea	+	+	0.66	+
Neomysis americana	1.19	0.33	10.76	43.30
Mysidacae remains	2.50	–	1.32	–
Ampelisca abdita	25.51	46.14	27.85	1 996.0
Caprella sp.	0.05	1.78	2.64	4.83
Corophium sp.	+	0.15	1.32	0.17
Unidentified amphipods	0.25	0.24	2.64	1.29
Teleostei (Total)	2.67	0.35	1.98	5.97
Anchoa mitchilli	1.60	0.27	0.66	1.23
Gobiosoma bosci	0.10	0.27	0.66	0.24
Menidia menidia	0.96	+	0.66	0.52
Hydrozoa (Total)	16.28	–	7.84	–
Unidentified remains	5.30	–	5.73	–
Total	100.00	100.00		

Diet Comparison

The diet of winter flounder (n = 29) captured in Area 2 was composed mostly of polychaetes and molluscs (Table 2). The two most important species of polychaetes identified in the stomachs were *Leitoscoloplos robustus* and *S. benedicti*. Bivalve siphons were the only mollusc part to be identified, as no shell remains were found. Some decapod remains were found and the only amphipod was *A. abdita*.

Despite measured differences in the number of prey between the stomach contents of winter flounder between habitats (Fig. 3), no significant difference was found in the ranked number (Mann-Whitney: U = 25, $p \geq 0.05$), weight (Mann-Whitney: U = 30, $p \geq 0.05$), or *IRI* (Mann-Whitney: U = 29, $p \geq 0.05$) of similar prey between habitats. Similar food items, by taxa, were *S. benedicti*, *Pinnixa* sp. and *A. abdita* but with the exception of *S. benedicti* varied in percent contribution to the diet.

Benthos Analyses

The macrobenthic habitat of Area 1 was composed of invertebrate assemblages that are indicative of opportunistic species of disturbed habitats (*sensu* Pearson and Rosenburg, 1978). A total of 25 species were identified from both sampling years with the numerical densites averaging 477±290/0.05 m^2 per year. Only 3

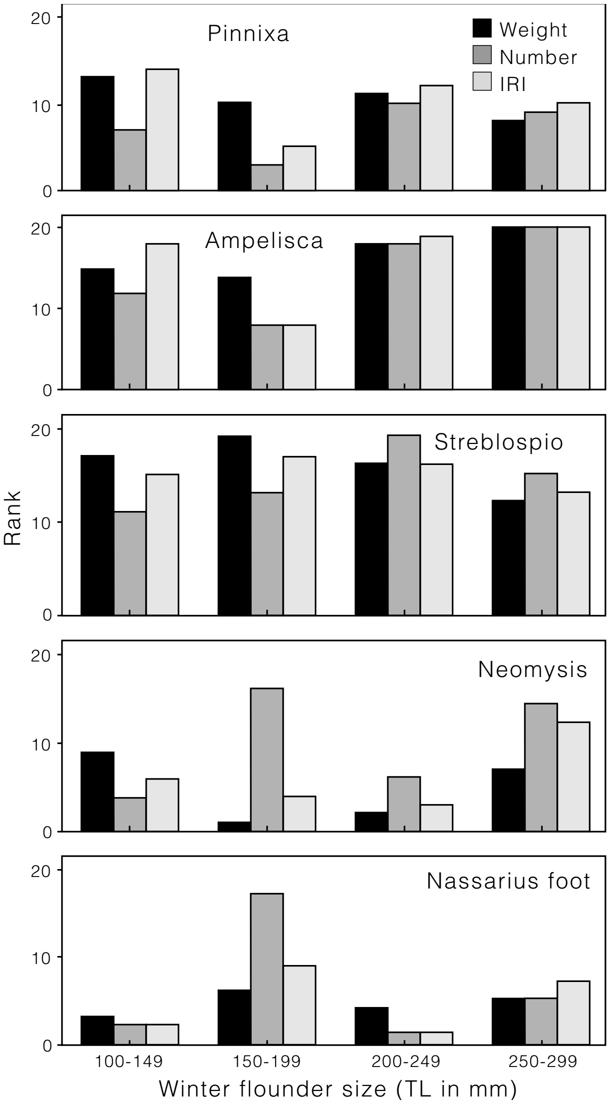

Fig. 2. Dietary comparison of the rank of principal prey items among the 4 size-classes of winter flounder captured in Area 1. Size-classes (TL) were 100–149 mm (n = 32); 150–199 mm (n = 65); 200–249 (n = 31); and 250–300 mm (n = 23). Principal prey are those prey items with IRI >100.

species numerically dominated the macrobenthos; *A. abdita*, and polychaetes; *S. benedicti* and *Mediomastus ambiseta* which made up 91% of the benthic community. *Mulinia lateralis* and *Tellina agilis* were the most common bivalves and represented almost 6% of the total macrobenthic community. The most abundant gastropod was *Nassarius trivittatus* and no decapods were sampled within the macrobenthic community.

The structure of benthic communities differed between habitats (Fig. 4). Area 2 was composed of 27 different species with numerical densities averaging 102.7±23.7/0.05 m^2 per year. Where amphipods were the dominant taxa in the Area 1 (54.2%), polychaetes dominated Area 2 making up 82.7% of the community followed by molluscs (15.3%). *Leitoscoloplos robustus* was the most abundant organism comprising 35% of the community. Species that were similar in abundance between habitats were limited to *S. benedicti* and *T. agilis*.

Foraging Index

The winter flounder in Area 1 had positive foraging indices for two macroinvertebrates. *Nassarius trivitattus* foot and *S. benedicti* had foraging indices of 1.2 and 0.24, respectively. The foraging index was close to zero for *Nereis succinea* and *A. abdita* indicating random feeding (Table 3).

Some species that were abundant within the macrobenthic samples were ignored or were rarely present in stomach samples. The polychaete, *M. ambiseta*, numerically contributed 19.7% to the benthic community but had a negative forage index. Similarly, the bivalves *T. agilis* and *M. lateralis* were disregarded by the winter flounder but together made up almost 6% of the macrobenthic community.

The winter flounder in Area 2 had positive foraging indices for two macroinvertebrates, *S. benedicti* and *A. abdita* (Table 3). Random feeding was found on *L. robustus*. Similar to Area 1 some species that were abundant within the macrobenthic samples were ignored or were rarely present in stomach samples. The bivalve, *Gemma gemma*, and polychaetes, *Eteone heteropoda*, *Nereis succinea*, *Polydora ligni*, and *Scolecolepides viridis*, were disregarded but made up almost 25% of the macrobenthic community.

Discussion

Regardless of habitat, winter flounder fed on primarily the most abundant and active benthic species. *Leitoscoloplos robustus* made up the primary food for the winter flounder in the Area 2 and *S. benedicti* was important in the diets from both areas. *Leitoscoloplos robustus* is a subsurface deposit-feeder but is active on the sediment surface where it defecates (Bianchi, 1988). *Streblospio benedicti* is a surface deposit-feeder, which actively extend palps to comb the sediment surface while feeding (Gosner, 1978; Dauer, 1984). These characteristics were probably more attractive to flounder than other prey items, as winter flounder are sight feeders and are attracted to movement when searching for prey (MacDonald, 1982). In addition, most of the molluscan fragments were either gastropod foot and opercular regions or bivalve siphons with very little shell found. Winter

TABLE 2. Diet of 29 winter flounder (size range = 50–200 mm TL) showing index of relative importance (IRI) of prey from Area 2 expressed in percentage weight, number and frequency of the total number of stomachs analyzed (0 stomachs empty). A value less than 0.05 is designated (+).

Taxon	Weight	Number	Frequency	IRI
Mollusca (Total)	4.80	7.80	50.91	642.0
Bivalve siphons	4.80	7.80	50.91	642.0
Polychaeta (Total)	87.07	82.78	100.00	16 985.00
Eteone heteropoda	0.16	0.60	10.07	7.65
Leitoscoloplos robustus	76.94	26.63	87.91	9 104.00
Nereis succinea	0.65	0.55	4.94	5.92
Glycera sp.	1.42	0.06	2.56	3.78
Streblospio benedicti	4.86	54.91	82.78	4 947.00
Polychaeta remains	3.04	–	7.14	–
Crustacea (Total)	2.68	9.45	78.55	952.00
Decapod remains	1.04	–	19.23	–
Pinnixa sp.	0.11	0.11	2.56	0.56
Ampelisca abdita	1.31	7.35	43.95	381.0
Edotea trilobota	0.22	1.52	10.25	17.83
Harpacticoids	+	0.47	2.56	1.21
Unidentified remains	5.08	–	36.63	–
Total	100.00	100.00		

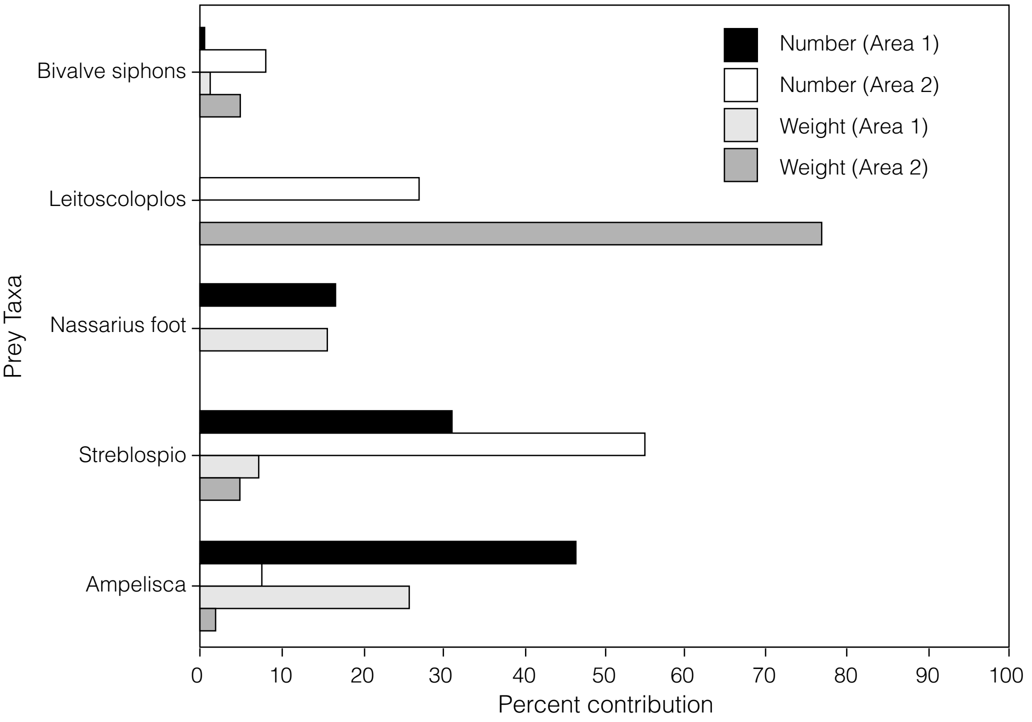

Fig. 3. Dietary comparison of the percent contribution of principal prey from New Haven Harbor (Area 1) and Clinton Harbor (Area 2).

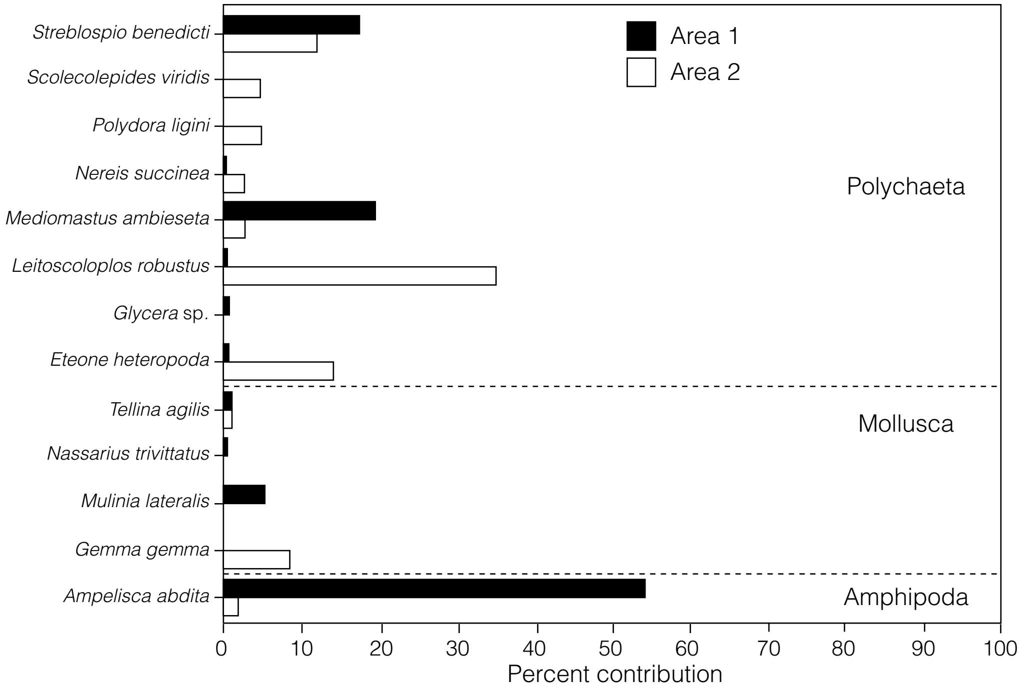

Fig. 4. A comparison of the percent contribution of the dominant macrobenthic invertebrates from New Haven Harbor (Area 1) and Clinton Harbor (Area 2).

TABLE 3. Log of Forage Index of winter flounder from macrobenthic organisms in Area 1 and Area 2, with comments on habitat and feeding mode (from Gosner, 1978).

Genera	Habitat	Feeding mode	Forage Index Area 1	Forage Index Area 2
Ampelisca	epifaunal	Filter feeder	-0.07	0.69
Eteone	infaunal	Predator	-0.50	-1.37
Gemma	infaunal	Filter feeder	[a]	∞
Glycera	infaunal	Predator	∞	[a]
Illynassa	epifaunal	Surface deposit	[a]	[a]
Leitoscoloplos	infaunal	Subsurface deposit	[a]	-0.13
Mediomastus	infaunal	Subsurface deposit	-2.62	∞
Mulinia	infaunal	Filter feeder	∞	∞
Nassarius	epifaunal	Surface deposit	1.2	[a]
Nereis	epifaunal	Surface deposit	-0.01	-0.78
Polydora	infaunal	Surface deposit	[a]	∞
Scolecolepides	infaunal	Surface deposit	[a]	∞
Spio	infaunal	Surface deposit	[a]	∞
Streblospio	infaunal	Surface deposit	0.24	0.66
Tellina	infaunal	Subsurface deposit	∞	∞

[a] Not present in benthic habitat.

flounder probably nipped off these body regions as these were the most exposed and active parts of the body.

Although relatively abundant in the macrobenthos of both habitats, *M. ambiseta*, *G. gemma* and *T. agilis* were ignored or avoided as prey items by winter flounder most likely due to differences in spatial distributions and behaviour. *Gemma gemma* and *T. agilis* are small infaunal clams and avoid predation by burrowing within the sediment (Pihl *et al.*, 1992). Steimle *et al.* (1993)

suggested the nut clam, *Nucula proxima*, avoided predation from winter flounder because of its infaunal habitats. Similarly, *M. ambiseta* is a burrowing, subsurface deposit feeding polychaete (Gaston and Nasci, 1988), so it is not as active at the sediment-water interface as species like *S. benedicti* or *L. robustus*.

Although there was some similarity in species composition, the overall structure of benthic communities differed between habitats. Area 1 had a higher density with fewer different species and was numerically dominated by *A. abdita* whereas Area 2 was dominated by *L. robustus*. Furthermore, species in highest abundance in Area 2 like *L. robustus*, is a later successional stage polychaete (Rhoads, 1974). Opportunistic species, like *S. benedicti*, that were found in Area 2 was likely due to the mild natural disturbance that occurs in intertidal habitats from exposure on ebb tides (Levinton, 1982).

Similar to other studies on fish diets, ampeliscan amphipods are important food sources. Collie (1987) found ampeliscans to be an important dietary component of yellowtail flounder (*Limanda ferruginea*) off southern Nantucket, Massachussetts, USA. Franz and Tanacredi (1992) report *A. abdita* made up 88% of the diet in winter flounder in the anthropogenically disturbed habitat of Jamaica Bay, New York, USA. Kaiser and Spencer (1994) determined gurnards (*Aspitrigila cuculus*), lesser spotted dogfish (*Scyliorhinus canicula*) and whiting (*Merlangius merlangus*) migrated into beam trawl scavenged areas to feed on *Ampelisca spinipes*. Ampeliscans, in particular *A. abdita*, are a tube-dwelling amphipod occurring in dense population on the sediment surface in habitats where recent or chronic anthropogenic disturbance has occurred (Rhoads *et al.*, 1978).

Ampelisca abdita is presumably less active on the sediment surface except for movement by ventral appendages for water circulation. The dense population of these amphipods and probable low search and handling time apparently account for its extreme importance in the diet of flounder from Area 1. However, the importance (IRI = 381) of *A. abdita* in the diet of flounder from Area 2 could not be explained, where these invertebrates were in low abundance. Although young-of-year winter flounder are limited in movement (Saucerman and Deegan, 1991), it is possible that older fish undertake some daily migration and may forage for these prey items in adjacent habitats where they are in higher abundance. The positive foraging index calculated for flounder in Area 2 may provide some evidence for this.

The continual human disturbance to Area 1 allows for the dominance of *A. abdita*. A macrobenthic monitoring study by Pellegrino (1990) reported the dominance of *A. abdita* in New Haven Harbor during June, August and October from 1988–90 throughout the same general area as this study. Furthermore, the highest secondary production in New Haven Harbor was in areas dominated by *A. abdita* and the presence of these species may enhance the community (Pellegrino, 1990). However, a change in environmental conditions favourable to these species could impact the energy structure and value of the community to winter flounder. Franz and Tanacredi (1992) suggested a decrease in the population density of *A. abdita* in Jamaica Bay, New York, USA could significantly reduce the value of the habitat as a nursery area for winter flounder.

This study supports the contention that winter flounder are in general, opportunistic feeders and usually feed on the most abundant and available prey source. They do, however, seem to select certain prey items such as *A. abdita* and this may be advantageous to the population. The high secondary production by *A. abdita*, density, and importance to all sizes of the winter flounder may improve stocks of winter flounder in New Haven Harbor as was found in other habitats (Franz and Tanacredi, 1992). However, since winter flounder production has not been quantified in New Haven Harbor, future study should be focused on production to biomass of winter flounder with *A. abdita* and other prey items.

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