J. Cons. int. Explor. Mer, 39(1): 7–14.

Autumn food of adult starry flounders, Platichthys stellatus, from the northeastern Bering Sea and the southeastern Chukchi Sea[1]

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The autumn food of 307 adult flounders, *Platichthys stellatus,* caught by commercial trawl at the northern limit of the flounder's range, is presented. Stomach contents include representatives of 9 phyla and at least 39 genera. The brittle star, *Diamphiodia craterodmeta,* and the protobranch clam, *Yoldia hyperborea,* are dominating foods. Major food items are different in each of the three sampling areas. No significant difference in feeding between sexes is apparent.

Introduction

The starry flounder, *Platichthys stellatus* (Pallas), occurs from southern California northward through the Gulf of Alaska, Bering Sea, and into the Chukchi Sea, as well as from off central Japan and Korea north into the Okhotsk Sea. Information on the food of starry flounders is available from Monterey Bay, California (Orcutt, 1950) and the San Juan Archipelago, Washington (Miller, 1967). Moiseev (1953) examined the food of coastal, small-mouthed, benthophagic flounders (a group to which *P. stellatus* belongs) from the eastern coast of Russia.

The objectives of this study were to describe the food habits of starry flounders at the northern limit of their range and to compare these findings with previous studies.

Methods

Starry flounders were collected in the northeastern Bering Sea (Norton Sound and Port Clarence) and the southeastern Chukchi Sea during a benthic trawl survey (Wolotira, Sample and Morin, 1977; Feder and Jewett, 1978) from 2 September to 13 October 1976 (Fig. 1). All collections were made with a 400-mesh eastern otter trawl towed for 30 minutes. Fish were either examined on board the ship or the digestive tracts were removed and preserved in 10% buffered formalin for later examination in the laboratory. Stomachs and intestines were examined. Each prey item was identified to the lowest taxon possible. The frequency of occurrence method of analysis was used in examining fish at sea. In this method, prey items were expressed as the percentage of fish containing food items relative to the total number of fish analysed. Fish in the laboratory were analysed by the frequency of occurrence method in conjunction with numerical and volumetric analyses of the gut contents. Counts of all items were made, and volumes (measured by water displacement to the nearest 0·1 ml) of each taxon were determined. Fish examined in the field were sexed and measured (total length to the nearest 1·0 mm), and those examined in the laboratory were sexed, measured, and weighed (wet weight to the nearest 0·1 g). The per cent frequency of occurrence (F), the per cent contribution by number (N), the per cent by volume (V), and the index of relative importance (IRI) were calculated for each prey item in each area. The latter index, $IRI = F (N + V)$, was developed by Pinkas, Oliphant and Iverson (1971) and used to rank food importance. Feeding differences between sexes were examined using the Whitney rank test (Zar, 1974) on the IRI.

1. Contribution No. 359 from the Institute of Marine Science, University of Alaska. This study was supported under contract 03–5–022–56 between the University of Alaska and NOAA, Department of Commerce through the Outer Continental Shelf Environmental Assessment Program to which funds were provided by the Bureau of Land Management, Department of Interior.

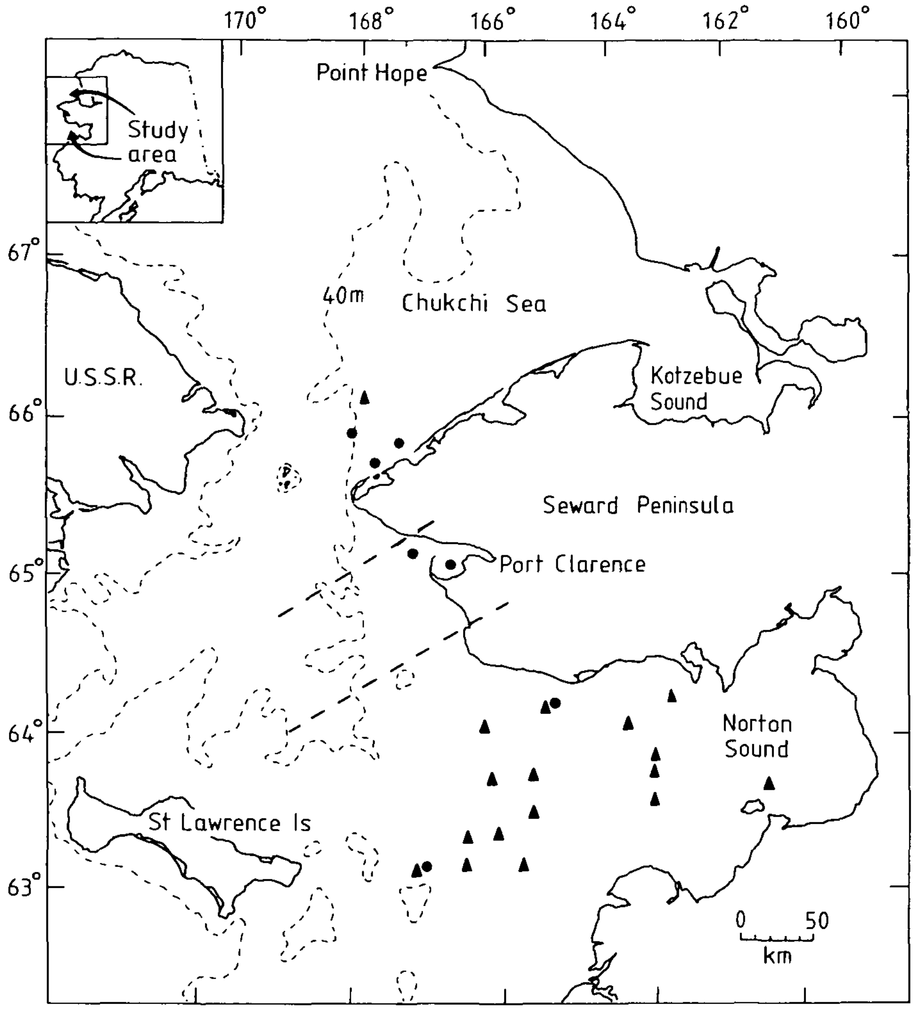

Figure 1. Locations where starry flounders, *Platichthys stellatus*, were collected. Dashed lines are arbitrarily placed to delineate the three sampling areas. Solid triangles, stations where stomach contents were subjected to frequency of occurrence analysis; solid circles, stations where stomach contents were subjected to numerical, volumetric, and frequency of occurrence analyses.

Results

Platichthys stellatus was the second most abundant fish species, by weight, in the survey region. It accounted for 13% of the total fish biomass and occurred at 47% of the stations (Wolotira et al., 1977). Sampling yielded 307 starry flounder digestive tracts from 22 stations. No significant difference was detected in feeding between sexes which were therefore combined. The number of fish examined in Norton Sound, Port Clarence, and the southeastern Chukchi Sea was 142, 134, and 31 respectively. Norton Sound fish ranged from 220 to 660 mm and averaged 381 ± 69 mm; Port Clarence fish ranged from 240 to 440 mm and averaged 325 ± 61 mm. Fish in the southeastern Chukchi Sea ranged from 250 to 520 mm and averaged 397 ± 61 mm.

Ninety-one per cent of all fish examined had food in their digestive tracts. A total of 55 food organisms were identified (Table 1). The food of 131 fish (Norton Sound, 126; southeastern Chukchi Sea, 5) were examined by the frequency of occurrence method only; 176 (Norton Sound, 16; Port Clarence, 134; southeastern Chukchi Sea, 26) were examined by volumetric and numerical, as well as frequency of occurrence methods. Analysis by sampling area revealed distinct differences in predominant species and relative amounts of organisms.

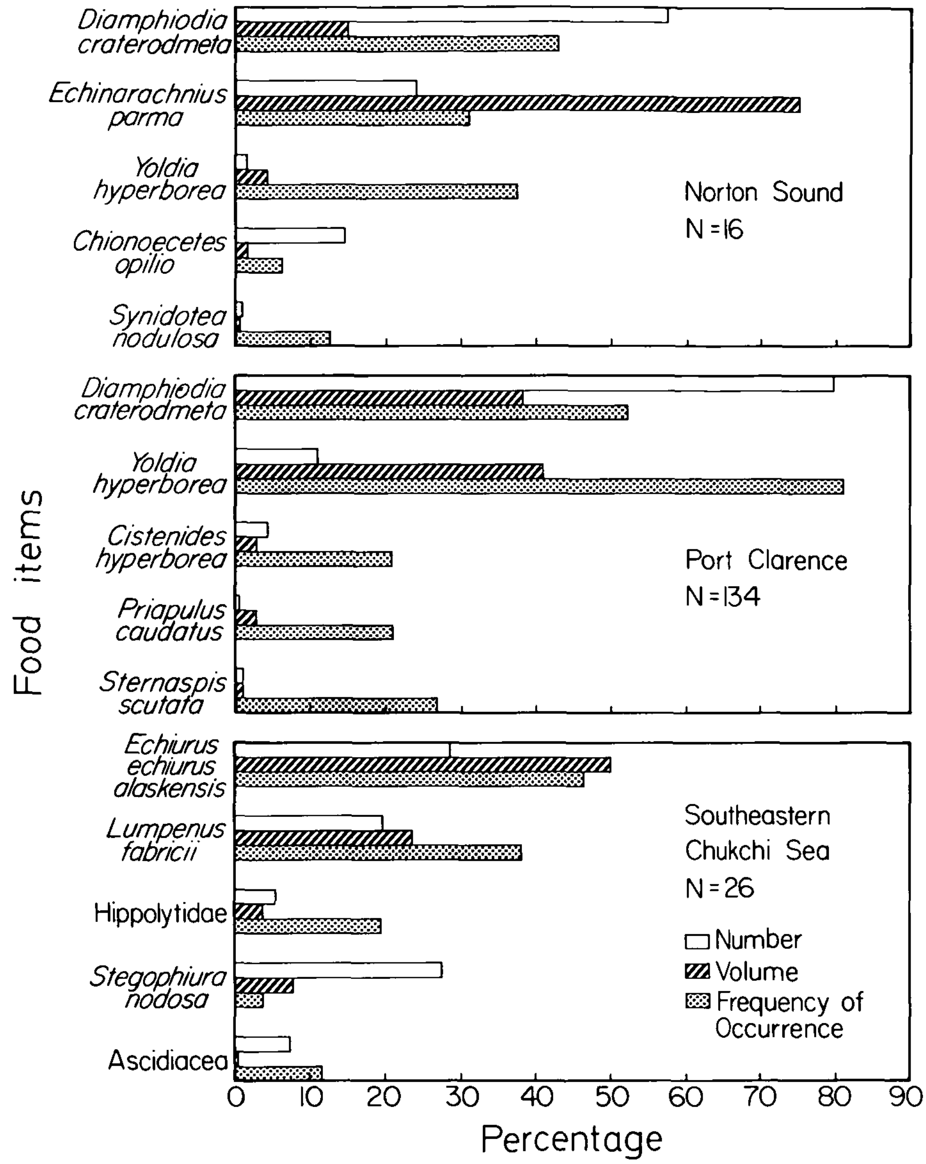

Figure 2. Percentage composition by number, volume, and frequency of occurrence of major food organisms from the Norton Sound, Port Clarence and southeastern Chukchi Sea starry flounders.

Norton Sound

Twenty taxa were identified from 126 Norton Sound starry flounders (Table 1) examined by the frequency of occurrence method, which showed that, in order of decreasing percentage, the dominant prey items were the protobranch clam, *Yoldia hyperborea* (36·5%), the brittle star, *Diamphiodia craterodmeta* (26·2%), the Greenland cockle, *Serripes groenlandicus* (22·0%), and the little black mussel, *Musculus niger* (14·3%).

Thirteen taxa were identified from 16 starry flounders examined by all three food analysis methods (Table 1, Fig. 2). Echinoderms dominated with *Diamphiodia craterodmeta* contributing 57·5% by number, 15·3% by volume, and 43·7% by frequency of occurrence; the sand dollar, *Echinarachnius parma*, contributed 24·2% by number, 75·5% by volume, and 31·2% by frequency of occurrence. In decreasing order of relative importance, the major prey items were *Diamphiodia craterodmeta* (*IRI* = 3187), *Echinarachnius parma* (*IRI* = 3114), *Yoldia hyperborea* (*IRI* = 239), the snow

Table 1. Per cent frequency of occurrence, number and volume of autumn food items
Chukchi Sea. Food items with corresponding percentages represent the level at which

	Norton Sound Fe = 126[1,2]	Norton Sound Fe = 16[3,4]			
		Per cent			Index of relative importance
Food items	Per cent frequency	Frequency F	Number N^7	Volume V^8	$F(N+V)$
Rhynchocoela	–	6·2	0·1	1·6	10·5
Annelida					
Polychaeta	2·4	6·2	0·1	<0·1	1·0
Polynoidae	0·8	–	–	–	–
Nephtys sp.	–	–	–	–	–
Nephtys rickettsi	–	–	–	–	–
Glycinde armigera	–	–	–	–	–
Lumbrineris sp.	–	–	–	–	–
Sternaspis scutata	–	–	–	–	–
Arenicola glacialis	–	–	–	–	–
Cistenides hyperborea	0·8	6·2	0·1	<0·1	0·8
Lysippe labiata	–	–	–	–	–
Mollusca					
Pelecypoda	–	–	–	–	–
Yoldia sp.	–	–	–	–	–
Yoldia hyperborea	36·5	37·5	1·9	4·5	239·2
Yoldia seminuda	–	–	–	–	–
Musculus niger	14·3	–	–	–	–
Musculus corrugatus	–	–	–	–	–
Cyclocardia ventricosa	–	6·2	0·1	<0·1	0·8
Clinocardium ciliatum	–	–	–	–	–
Serripes groenlandicus	22·0	12·5	0·2	0·2	4·9
Mya sp.	0·8	–	–	–	–
Lyonsia norvegica	–	–	–	–	–
Gastropoda					
Naticidae	–	–	–	–	–
Polinices pallida	–	–	–	–	–
Admete sp.	–	–	–	–	–
Cylichna occulta	–	–	–	–	–
Turridae					
Oenopota sp.	0·8	–	–	–	–
Arthropoda					
Crustacea	–	–	–	–	–
Balanidae	0·8	–	–	–	–
Cumacea					
Leucon sp.	–	–	–	–	–
Diastylis sp.	–	–	–	–	–
Diastylis sulcata	–	–	–	–	–
Isopoda					
Saduria entomon	0·8	–	–	–	–
Synidotea nodulosa	0·8	12·5	0·9	0·3	15·4
Amphipoda	–	12·5	0·2	<0·1	3·2
Haustoriidae	–	–	–	–	–
Pontoporeia femorata	–	–	–	–	–
Decapoda					
Hippolytidae	–	–	–	–	–
Crangon sp.	–	–	–	–	–
Crangon dalli	–	6·2	0·1	0·3	2·6
Argis lar	0·8	–	–	–	–
Chionoecetes opilio	–	6·2	14·3	1·6	99·2
Paguridae					
Labidochirus splendescens	0·8	–	–	–	–
Echiuroidea					
Echiurida					
Echiurus echiurus alaskensis	4·8	–	–	–	–
Priapulida					
Priapulus caudatus	4·8	6·2	0·3	0·4	4·6

from adult starry flounders of Norton Sound, Port Clarence, and the southeastern identifications were made. Fe = number of fish examined.

Port Clarence Fe = 134[3,5]				Chukchi Sea Fe = 26[3,6]			
Per cent			Index of relative	Per cent			Index of relative
Frequency *F*	Number N^9	Volume V^{10}	importance *F(N+V)*	Frequency *F*	Number N^{11}	Volume V^{12}	importance *F(N+V)*
–	–	–	–	–	–	–	–
11·2	0·7	0·7	15·3	–	–	–	–
–	–	–	–	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
26·9	1·2	1·0	58·8	–	–	–	–
–	–	–	–	3·8	0·9	4·5	20·8
20·9	4·5	3·0	155·9	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
3.0	<0·1	<0·1	0·3	–	–	–	–
0·7	<0·1	0·2	0·2	–	–	–	–
81·3	10·9	41·5	4 267·1	–	–	–	–
0·7	<0·1	0·6	0·5	–	–	–	–
7·5	0·1	0·6	5·3	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
–	–	–	–	–	–	–	–
3·0	<0·1	<0·1	0·4	–	–	–	–
9·0	0·1	0·6	6·4	–	–	–	–
9·0	0·1	0·4	4·8	–	–	–	–
2·2	<0·1	<0·1	0·2	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
1·5	<0·1	<0·1	<0·1	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
–	–	–	–	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
–	–	–	–	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
6·7	0·3	<0·1	2·7	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
–	–	–	–	–	–	–	–
26·9	0·7	<0·1	30·6	–	–	–	–
6·0	0·2	0·1	2·1	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
1·5	<0·1	<0·1	<0·1	–	–	–	–
–	–	–	–	19·2	5·7	3·7	180·6
1·5	<0·1	<0·1	<0·1	–	–	–	–
–	–	–	–	–	–	–	–
0·7	<0·1	<0·1	<0·1	–	–	–	–
0·7	0·3	2·2	1·9	–	–	–	–
–	–	–	–	–	–	–	–
–	–	–	–	46·1	28·3	50·9	3 654·1
20·9	0·3	2·8	66·0	–	–	–	–

Cont'd

Table 1 cont'd.

	Norton Sound Fe = 126 [1,2]	Norton Sound Fe = 16[3,4]			
		Per cent			Index of relative importance
Food items	Per cent frequency	Frequency F	Number N[7]	Volume V[8]	F(N+V)
Echinodermata					
Echinoidea					
Echinarachnius parma	4·8	31·2	24·2	75·5	3 114·4
Ophiuroidea					
Diamphiodia craterodmeta	26·2	43·7	57·5	15·3	3 186·7
Stegophiura nodosa	5·6	–	–	–	–
Urochordata					
Ascidiacea	–	–	–	–	–
Pelonaia corrugata	–	–	–	–	–
Chordata, Pisces	5·7	–	–	–	–
Osteichthyes					
Eleginus gracilis	–	–	–	–	–
Myoxocephalus sp.	–	–	–	–	–
Lumpenus fabricii	2·4	–	–	–	–

1 Fish examined at sea
2 Includes 14 empty fish
3 Fish examined in the laboratory
4 Includes 1 empty fish
5 Includes 7 empty fish
6 Includes 4 empty fish

crab, *Chionoecetes opilio* (*IRI* = 99), and the isopod, *Synidotea nodulosa* (*IRI* = 15).

Port Clarence

The gut contents of 134 fish were examined by all three methods of analysis (Table 1, Fig. 2). Forty food items were identified; most of the species were annelids and molluscs. The brittle star, *Diamphiodia craterodmeta*, was the primary food (*IRI* = 6149). It provided 79·5% of the diet numerically, 38·2% volumetrically, and 52·2% by frequency of occurrence. Nearly 600 of these tiny brittle stars (disc diameter 1·5–7·0 mm) were found in a single gut; in general 20 to 200 were observed per digestive tract.

Yoldia hyperborea was the second most important prey species (*IRI* = 4267): numerically 10·9%; volumetrically 41·5%; and frequency of occurrence 81·3%. The tube-dwelling polychaete, *Cistenides hyperborea*, the priapulid worm, *Priapulus caudatus*, and the polychaete, *Sternaspis scutata*, ranked third (*IRI* = 156), fourth (*IRI* = 66), and fifth (*IRI* = 59) respectively.

Generally whole organisms were consumed, but of *Priapulus caudatus* the caudal appendage was occasionally the only portion taken.

Southeastern Chukchi Sea

A sample of 26 starry flounders from the southeastern Chukchi Sea was examined by the three methods of analysis (Table 1, Fig. 2). Only eight taxa were identified. The proboscis worm, *Echiurus echiurus alaskensis*, dominated the prey (*IRI* = 3654), and contributed 28·3% by number, 50·9% by volume, and 46·1% by frequency of occurrence. In general only the anterior portion of the *Echiurus* was consumed.

The prickleback fish, *Lumpenus fabricii*, was second in importance (*IRI* = 1658) yielding 19·8% by number, 23·3% by volume and 38·5% by frequency of occurrence. *Lumpenus* ranged from 85 to 160 mm (total length), and was always swallowed whole. As many as 18 fish were found in a single gut. Hippolytid shrimps ranked third (*IRI* = 181); the brittle star, *Stegophiura nodosa*, fourth (*IRI* = 135); and unidentified tunicates (Ascidiacea) fifth (*IRI* = 88).

Five additional starry flounders examined only by the frequency of occurrence method consumed similar organisms.

Although *Diamphiodia craterodmeta* and *Yoldia hyperborea* were food organisms of major importance in Norton Sound and Port Clarence, they were completely absent from Chukchi Sea fish.

Discussion

Major food groups consumed by adult *Platichthys stellatus* at the northern limits of its range during the autumn are similar to food groups taken by the fish in other geographic localities (Orcutt, 1950; Moiseev, 1953; Miller, 1967). The main prey items taken by starry flounders in the present study were the brittle star, *Diamphiodia craterodmeta*, and the protobranch

Fort Clarence Fe = 134[3,5]				Chukchi Sea Fe = 26[3,6]			
Per cent			Index of relative importance	Per cent			Index of relative importance
Frequency *F*	Number *N*[9]	Volume *V*[10]	*F(N+V)*	Frequency *F*	Number *N*[11]	Volume *V*[12]	*F(N+V)*
0·7	<0·1	<0·1	<0·1	–	–	–	–
52·2	79·5	38·2	6 148·6	–	–	–	–
0·7	<0·1	<0·1	<0·1	3·8	27·4	7·8	135·5
–	–	–	–	11·5	7·5	0·1	88·4
0·7	<0·1	<0·1	<0·1	–	–	–	–
–	–	–	–	3·8	9·4	9·3	72·2
0·7	<0·1	6·2	4·7	3·8	0·9	0·4	5·0
0·7	<0·1	0·7	0·5	–	–	–	–
–	–	–	–	38·5	19·8	23·3	1 657·6

7 Total number of food items – 1021
8 Total volume of food – 317 ml
9 Total number of food items – 8465
10 Total volume of food – 1204 ml
11 Total number of food items – 106
12 Total volume of food – 268 ml

clam, *Yoldia hyperborea.* Although brittle stars are reported from *P. stellatus* stomachs in other areas, they were seldom important food items (Orcutt, 1950; Moiseev, 1953; Miller, 1967). Orcutt (1950) occasionally found the digestive tract of starry flounders filled with the brittle star, *Ophiura lütkeni* (disc diameter 12–25 mm), and Miller (1967) observed the brittle star, *Amphiodia* sp., among the gut contents.

Small clams, particularly thin-shelled species, are reported to be a main food of starry flounders elsewhere (Villadolid, 1927; Orcutt, 1950; Moiseev, 1953; Miller, 1967; Jewett and Feder, 1976). *Yoldia hyperborea,* in addition to other bivalve molluscs, i.e., *Serripes groenlandicus* and *Musculus niger,* were important food items in Norton Sound and Port Clarence. All bivalves were usually swallowed whole.

The proboscis of *Echiurus echiurus alaskensis* and the caudal appendage of *Priapulus caudatus* occur at or near the sediment surface (Chamberlin, 1920; Meglitsch, 1972) and are therefore, readily accessible to active bottom-feeding fishes such as *P. stellatus. Priapulus caudatus* has previously been reported as food for starry flounders (Chamberlin, 1920; Miller, 1967 (*Priapulus* sp.)).

Fishes are not commonly consumed by *P. stellatus*; however, *Lumpenus fabricii* was an important food in the Chukchi Sea. Starry flounders from the San Juan Archipelago did not contain fishes (Miller, 1967), although small fishes such as *Sardinops, Citharichthys, Cymatogaster* and *Lycodopsis* have been listed as uncommon food for this species elsewhere (Villadolid, 1927; Orcutt, 1950; Clemens and Wilby, 1961).

Food differences between study areas presumably reflect differential prey availability (density and/or selectivity). The biological interactions of *P. stellatus* with its prey can better be understood in conjunction with quantitative infaunal and epifaunal sampling.

Infaunal food benthos in the southeastern Bering Sea exceeds 50% of the total benthos, and consists predominantly of polychaete worms, small clams, and brittle stars. The western Bering Sea lacks a developed food benthos, but is exceedingly rich in epibenthic animals such as sponges, sea anemones, and sand dollars, (Alton, 1974). Neiman (1963) found that the density of the benthos reached a maximum of 905 g/m^2 in the Chirikov Basin (between St. Lawrence Island and Bering Strait). The amount of food benthos in the northeastern Bering Sea and southeastern Chukchi Sea is not known, but appears to be relatively high (Feder and Jewett, 1978). The present study revealed that asteroids (sea stars) made up 69 and 48% of the benthic invertebrate biomass from the northeastern Bering Sea and southeastern Chukchi Sea respectively (Feder and Jewett, 1978). Subsequent feeding observations on the dominant sea star species indicated prey preferences similar to those of the starry flounders i.e., polychaete worms, clams, and sand dollars.

Neiman (1963) suggests that annual fluctuation in water temperature, rather than availability of food, may be the determining factor responsible for the maximum northerly distribution of many benthophagic flatfishes. Pruter and Alverson (1962) found only one starry flounder while conducting a demersal trawl investigation in the southeastern Chukchi Sea during August, 1959; the bottom water temperature ranged between 2·2° and 8·9°C ($\bar{X}$ = 5·1°C). As noted in a report on fish (mainly postlarvae and juveniles) collected on an ecological trawl (mainly Isaacs-Kidd) survey in the eastern Chukchi Sea, starry flounders were absent from the catches (Quast, 1972). During that collection period, 25 September – 17 October 1970, bottom water temperatures ranged between –1·5° and 3·5°C. However, in the present study, during September and October when the bottom water temperature ranged from 2·0° to 8·0°C ($\bar{X}$ = 6·3°C), the estimated starry flounder population in the southeastern Chukchi Sea and Kotzebue Sound region was 1·5 million fish (Wolotira et al., 1977). Neiman's supposition that low temperatures restrict far northern movement of flatfishes is presumably correct. However, owing to the paucity of data on temperature, food benthos, and flatfishes, further study is strongly encouraged.

Acknowledgements

We thank the crew of the NOAA ship "Miller Freeman" for logistic support; University of Alaska, Institute of Marine Science personnel: Max Hoberg for shipboard and taxonomic assistance; George Mueller and Nora Foster for taxonomic assistance; Dr. Ronald Smith, Alan Paulson, and Shirley Liss for assistance with data processing; and Ana Lea Vincent for drafting assistance. Robert Wolotira, National Marine Fisheries Service, Kodiak, Alaska, assisted with logistic support.

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