

Influence of Substratum on the Comparative Food Habits of Two Species of Estuarine Stichaeoid Fishes, *Anoplarchus purpureus* (Family Stichaeidae) and *Pholis ornata* (Family Pholididae)

Abstract

Food habits of two species of co-existing northeast Pacific estuarine stichaeoid fishes, *Anoplarchus purpureus* and *Pholis ornata*, were studied by analysis of gut contents of specimens collected over two types of substrata, muddy and rocky. *A. purpureus* fed on a greater range of invertebrates and also consumed a substantial quantity of algae with macrophytes reported in over 76 percent of individuals of this species. *P. ornata* fed upon fewer kinds of prey items, consuming chiefly amphipods over rock substrata and siphon tips of bivalves over muddy substrata. Cropping of exposed parts of macroinvertebrates appears to be an important feeding strategy for both species. Differences in diet between the two species and the capacity to shift food preferences based on substrate-related prey availability may serve to accommodate the coexistence of these two morphologically and ecologically similar species.

Introduction

Intertidal fishes of North Pacific shores may exhibit specific substratum preferences and the range of microhabitats and associated feeding opportunities that are available may be significant in structuring the intertidal ichthyofaunal community. In his comprehensive reviews of intertidal fish biology, Gibson (1969, 1982) concluded that rocky shores with highly irregular topography provide the greatest amount of cover and hence display the greatest diversity of species. Studies by Nakamura (1976) have revealed differing substratum preferences in sympatric species of sculpins of the family Cottidae. Marliave (1977) demonstrated that settling larvae of several species of North Pacific intertidal fishes exhibit specific substratum preferences usually selecting substrata that are representative of adult microhabitats.

Stichaeoid fishes of the families Stichaeidae and Pholididae are especially intriguing owing to their amphibious nature. Stichaeoids have been shown to occur in greater frequency over substrata that are periodically exposed during low tide (Yoshiyama 1981). Two species of amphibious stichaeoids, *Anoplarchus purpureus* and *Pholis ornata*, broadly overlap in distribution and microhabitat preferences in Yaquina Bay, a small Oregon estuary with both muddy and rock substrata (Barton 1982a). *A. purpureus* has been found in rocky and muddy substrata in both open coastal waters and sheltered embayments (Schultz and Delacy 1932;

Yoshiyama 1981; Barton 1982a,b). Fishes of the family Pholididae are associated with rocky microhabitats (Quasim 1957, Sawyer 1967) but also demonstrate a pronounced affinity for vegetation (Burgess 1978). *P. ornata* constitutes a significant component of the intertidal ichthyofauna associated with eelgrass in Yaquina Bay (Bayer 1981).

The question of competitive interaction based on available food resources is a difficult one to assess. In North Pacific intertidal ichthyofaunal communities, possible competition for food, measured as dietary overlap, has been implicated in tidepool cottids (Yoshiyama 1980). An absence of resource partitioning among cottids may also reflect an ample abundance of food in the intertidal zone such that competitive interactions do not exist in sympatric species (Nakamura 1971). Studies of the comparative food habits of several species of stichaeoids suggest mechanisms of resource allocation among sympatric species (Barton 1982b). Differential allocation of food resources may facilitate the observed overlap in substratum and microhabitat preferences exhibited by *A. purpureus* and *P. ornata* in Yaquina Bay. Although these two species are frequently found co-existing beneath the same rock or clump of vegetation at low tide, they may possess decidedly different food preferences and foraging strategies which may vary over different substrata at high tide. The purpose of this study was to compare the food habits of these two species so that an evaluation of the influence

of inhabited substratum and its impact on competitive interactions might be possible.

Materials and Methods

Fishes were collected for analysis of stomach contents from three sites within Yaquina Bay (44°37'N; 124°02'W), a small tidal estuary on the central Oregon coast. The estuary consists of a narrow channel bordered with mudflats and cobble beaches. Fishes were collected at each of three stations within the Bay (Figure 1) and the nature of the substratum (rocky or muddy) recorded for each collection. While both bottom types could be observed at each station, stations 1 and 3 consisted predominantly of a hard mudstone substratum with patches of loose cobble while station 2 was chiefly broad mudflats

with a seasonal cover of eelgrass (*Zostera*) or sea lettuce (*Ulva*) and patches of loose cobble scattered throughout.

All fishes were collected during mid-morning low tides in the spring and summer 1976-1977. Fishes were captured beneath loose boulders and in vegetation with the aid of aquarium dipnets and were immediately preserved in a buffered solution of 10 percent formalin in seawater. Preservation of gut contents was facilitated in larger (>60 mm) individuals by injection of the formalin solution into the gut cavity. Digestive tracts were later removed and contents identified to the lowest possible taxon. Food overlap was measured as the percentage of similarity (PS) (Whittaker 1967, McEachran *et al.* 1976). This value was calculated from the number of individual food items constituting the diet of each

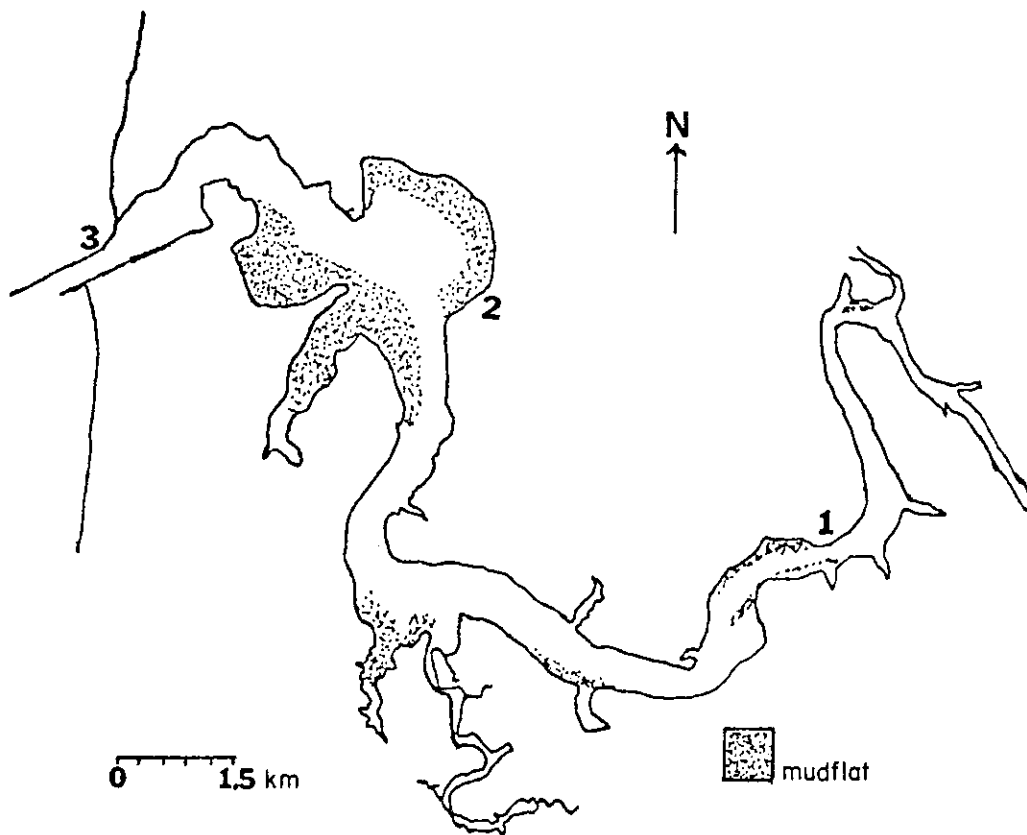


Figure 1. Map of Yaquina Bay, Oregon, showing collection sites.

species and each substratum type. Values less than 50 percent were judged to be significant (McEachern *et al.* 1976).

Results

A total of 511 stomachs, representing both species over both types of substrata, was examined. Of the two species, *A. purpurescens* appears to select from a broader range of food items (Table 1, Figure 2). Among the most noteworthy differences in the diets of the two species is the substantial quantity of macroalgae found in the stomachs of *A. purpurescens*. Nemerteans and polychaetes also appear in greater numbers in this species, especially over rocky substrata (Table 2, Figure 2). *P. ornata* exhibited a greater specificity in diet and substratum appears to have an impact upon food preferences in this species. Amphipods constitute the chief food source for *P. ornata* over rocky surfaces but this species shifts to a bivalve siphon nipping strategy when

foraging over muddy surfaces (Figure 2). Cropping of exposed parts of benthic infauna appears to be an important strategy employed by both species. Barnacle cirri, heads and tentacle crowns of polychaetes, and the aforementioned siphons were observed in the stomachs of both *A. purpurescens* and *P. ornata*. Only an incidental consumption of algae was observed in *P. ornata*, however.

Calculations of PS values were based on the five most frequently recovered animal food items which constituted the bulk of the stomach content (Table 2). The PS value for *A. purpurescens* in rocky vs. muddy substratum was 61.8 percent; for *P. ornata* in rocky vs. muddy substratum, 41.5 percent. Overall PS value for *A. purpurescens* vs. *P. ornata* was 75.1 percent. Although constituting a substantial quantity of the stomach volume in *A. purpurescens*, algae was not included because of the impossibility of enumerating individual organisms. Both species emphasize the consumption of small crustacea, mainly amphipods. The

TABLE 1. Food preferences of *Anoplarchus purpurescens* and *Pholis ornata* measured as total number and percent occurrence of individuals from different substrata with specified food items in stomach contents.

Food Item	Anoplarchus purpurescens				Pholis ornata			
	total number		percent occurrence		total number		percent occurrence	
	rocky	muddy	rocky	muddy	rocky	muddy	rocky	muddy
Algae	84	88	76.4	76.5	7	13	7.4	8.8
Nematoda	5	3	4.5	2.6	0	1	0	.7
Nemertinea	40	3	36.4	2.6	1	4	1.1	2.7
Polychaeta	40	23	36.4	20.0	4	13	4.3	8.8
Bivalva (siphons)	13	21	11.8	17.4	1	109	1.1	74.2
Gastropoda	0	1	0	.9	0	0	0	0
Amphineura	1	0	.9	0	0	0	0	0
Cirripedia	1	5	.9	4.3	12	1	12.8	.7
Copepoda	9	2	8.2	1.7	1	17	1.1	11.6
Ostracoda	0	0	0	0	2	0	1.4	0
Cumacea	1	4	.9	3.5	5	0	5.3	0
Amphipoda	38	82	34.5	71.3	73	34	77.7	23.1
Isopoda	6	17	5.5	14.8	15	2	16.0	1.4
Decapoda	9	13	8.1	11.3	8	41	8.5	27.9
Pycnogonida	7	4	6.4	3.5	0	0	0	0
Insecta	8	2	7.3	1.7	3	0	3.2	0
Number with empty stomachs	4	16	—	—	12	13	—	—
Total number of sample	114	131			106	160		

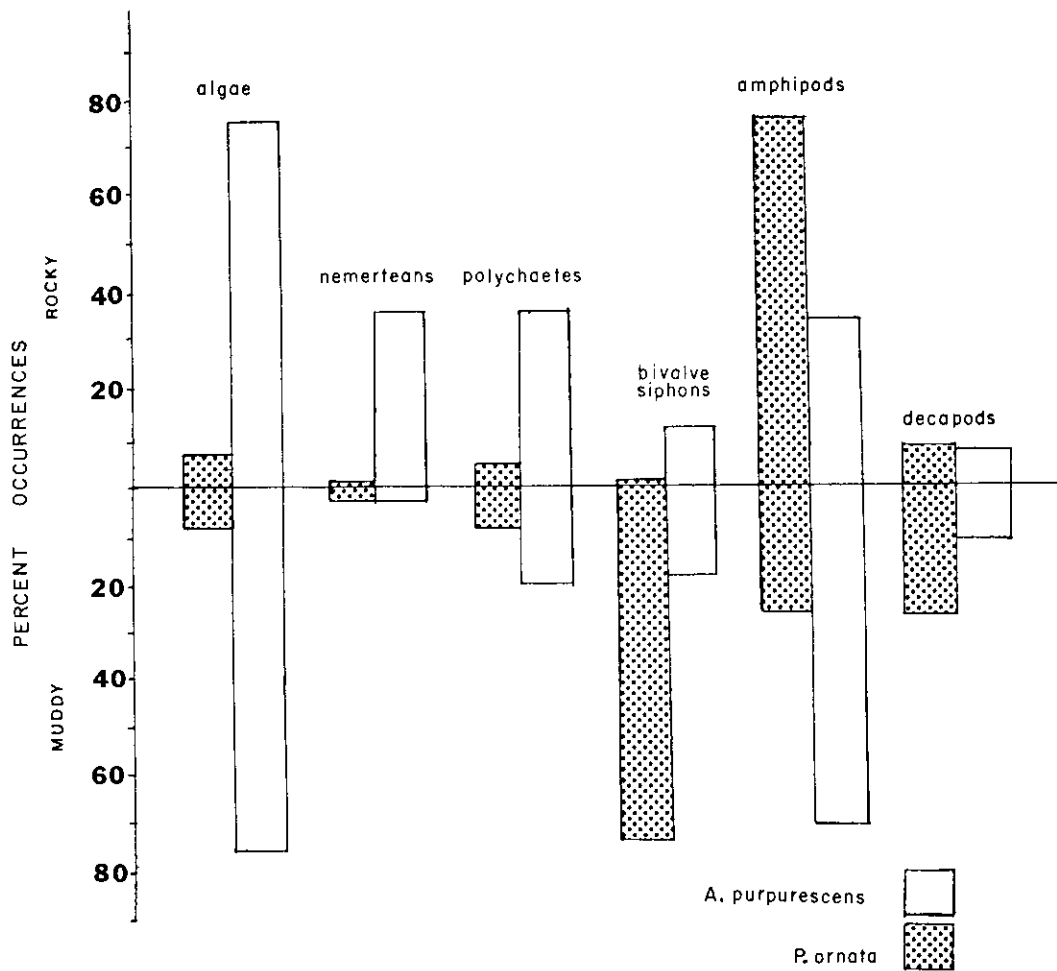


Figure 2. Percent occurrences of the most frequently observed food items in the guts of *A. purpurescens* and *P. ornata* feeding over rocky vs. muddy substrata.

significance of substratum type is apparent in *P. ornata* with a low PS value of 41.5 percent calculated from a comparison of the animal components of diets from individuals collected over rocky versus muddy surfaces.

Discussion

The extent to which coexisting species allocate resources or, in absence of such allocation, have resource-impacted ranges of distribution is difficult to assess. Gibson (1969, 1982) has summarized some of the strategies that alleviate competition for available food resources among sympatric intertidal fish species. Substratum related types of foraging patterns may facilitate coex-

istence in estuaries by emphasizing different components of overlapping diets. This may be interpreted as a response to changes in feeding opportunities in the intertidal zone of estuaries. The high dietary overlap reported for *A. purpurescens* and *P. ornata* in this study is largely a consequence of a heavy dependence upon small amphipods by both species. This value also does not reflect the significance of herbivory in the foraging strategy of *A. purpurescens*. An analysis of dietary overlap that relies upon enumeration of individual prey items in the gut contents is not without its limitations. Numerical methods may over-emphasize small prey items taken in large numbers (for example, amphipods) yet such

TABLE 2. Number of individual animal food items in stomachs of *A. purpurescens* and *P. ornata* inhabiting different substrata.

Food Item	<i>A. purpurescens</i>		<i>P. ornata</i>	
	rocky	muddy	rocky	muddy
Nematoda	5	5	0	0
Nemertinea	114	9	0	4
Polychaeta	70	22	10	18
Bivalva (siphons)	20	27	8	595
Gastropoda	0	1	0	0
Amphineura	2	0	0	0
Cirripedia	1	5	11	4
Copepoda	22	2	3	29
Ostracoda	0	0	0	2
Cumacea	1	6	4	0
Amphipoda	86	483	460	116
Isopoda	6	76	28	2
Decapoda	9	17	5	65
Pycnogonida	8	5	0	0
Insecta	19	3	4	0

methods may give a better indication of feeding effort (Hyslop 1980). Small organisms may also be of enhanced significance because of their greater speed of digestion (Sikora *et al.* 1972 in Hyslop 1980).

Soft bodied invertebrates appear in greater quantities in the diet of *A. purpurescens*, especially in rocky substrata. The cirratulid polychaete tentacles observed in the guts of *A. purpurescens* in this and other studies (Barton 1982b, Yoshiyama and Darling 1982) suggest an unusual dietary adaptation that may facilitate coexistence with sympatric species. Yoshiyama and Darling (1982) have demonstrated that cirratulid polychaetes are distasteful to other fish species.

The most noteworthy difference in the diets of *A. purpurescens* and *P. ornata* was in the consumption of large quantities of macroalgae by the former. Macrophytes can provide significant nutrition for fishes (Montgomery and Gerking 1980) and their utilization has been demonstrated to be an ecologically and energetically feasible strategy for north temperate fishes, including some species of stichaeoids (Wells *et al.* 1973; Edwards and Horn 1982; Horn, Murray, and Ed-

wards 1982; Horn 1983). In related studies, Barton (1982b) demonstrated food resource partitioning in central California intertidal stichaeoid communities that included *A. purpurescens*, and Hughes (1983) has shown a reduction in the dietary overlap in two species of *Pholis*, including *P. ornata*, that coexist in a shallow inlet of Puget Sound.

Since both species are basically predators upon the epifaunal and infaunal components of benthic communities, substratum-related variation in foraging strategies might be expected. This was most apparent with *P. ornata* that switched from a chiefly amphipod diet in rocky areas to one consisting mainly of bivalve siphon tips in muddy areas. Hughes (1983) also reported siphon nipping in *P. ornata* in Puget Sound and suggested that this species possesses dentition that facilitates this mode of feeding. Peterson and Quammen (1982) have observed siphon nipping to be an important component in the diet of three inshore fish species and have demonstrated significant decreases in growth rates of bivalve populations exposed to siphon cropping by small fishes. The dependence upon siphons by *P. ornata* reflects its preference for muddy, protected embayments whereas the greatest diversity in stichaeoid communities is seen in rocky shores in more exposed locales (Hart 1973, Miller and Lea 1972, Yoshiyama 1981).

The relationship between substratum and feeding strategy has been documented in a number of benthic fish species including skates (McEachran *et al.* 1976) and flatfishes (Percy and Hancock 1978). The present study demonstrates that the coexistence of *Anoplarchus purpurescens* and *Pholis ornata* may be facilitated by differences in feeding preferences with *A. purpurescens* consuming a greater variety of food items, including substantial quantities of algae, while *P. ornata*, with a more restricted dietary regime, demonstrates a shift in dietary preferences based on the nature of the substratum over which it is feeding.

Acknowledgments

The author wishes to thank Kate Myers and Range Bayer for assistance in collection of specimens. Funds for preparation of this manuscript were made available from the Centre College Faculty Development Fund.

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Received 7 May 1985

Accepted for publication 14 June 1985