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Nearshore Accumulations of Detached Macrophytes as Nursery Areas for Fish

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ABSTRACT: The feeding ecology and seasonal pattern of occurrence of the 0+ year classes of the fish *Aldrichetta forsteri, Cnidoglanis macrocephalus, Sillago bassensis*, and *Arripis georgianus* were investigated to determine relationships between these economically important species and surf-zone accumulations of detached macrophytes along the coast of Western Australia. The main prey of *A. forsteri, C. macrocephalus* and *A. georgianus* and the second most important prey of *S. bassensis* was the amphipod *Allorchestes compressa*; the distribution of *A. compressa* was restricted to detached plants in the surf-zone. The arrival in winter, of 3 of the fish species on the open coast corresponded with the period of greatest deposition of detached plants in the nearshore zone, and there appeared to be sufficient plant material, and associated amphipods, to support fish during summer. The large patches of vegatation in the surf-zone of sandy beaches support densities of *A. compressa* up to a mean of 110 g^{-1} dry wt vegetation and provide an alternative feeding habitat for these benthic feeders, one of which is restricted to estuaries in other regions of Australia. It is also likely that this vegetation provides shelter from potential predators such as diving birds and larger fish.

INTRODUCTION

Large banks of seaweed on beaches are a feature of many coastal ecosystems dominated by large kelps (e.g. ZoBell, 1971; Field et al., 1977). Several investigators have assembled data on the role of beached macrophytes in coastal food-web dynamics (e.g. Griffiths and Stenton-Dozey, 1981, Koop and Field, 1981). However, the influence of surf-zone accumulations of vegetation on ecological processes in coastal marine environments have received little attention.

Along much of the temperate coast of Western Australia there are large multispecies meadows of seagrasses fringed by limestone reefs, which support extensive beds of macroalgae, (Kirkman, 1981; McComb et al., 1981). Huge amounts of these macrophytes are detached by storms and heavy swells and accumulate along the shore forming large patches of plant material in the surf-zone and wrack banks on beaches and rocks.

Recently, by comparing the relative abundance of juvenile fish in an estuary and the nearby inshore marine habitat, Lenanton (in press) has shown that the juveniles of a number of fish species use portions of the open coast of south-western Australia (Fig. 1) as an alternative to estuaries as nursery areas. He also suggested that detached macrophyte accumulations provide a source of food and shelter for these fish. Of the fish species caught in or near macrophyte accumulations in this earlier study 4 species, the yellow-eyed mullet *Aldrichetta forsteri*, cobbler *Cnidoglanis macrocephalus*, school whiting *Sillago bassensis* and Australian herring *Arripis georgianus* were chosen for a more detailed investigation of the trophic links between juvenile fish and detached plant material. The adults of all 4 species support a significant commercial or recreational fishery in Western Australia (Anonymous, 1981).

Here we present data on the seasonal occurrence of these fish in the nearshore zone, their feeding ecology, the distribution of their major prey, and the seasonal changes in the amount of detached vegetation in the surf-zone to show the degree to which juvenile fish depend on accumulations of detached vegetation.

MATERIALS AND METHODS

During 1976 and 1977 we sampled juvenile fish from 8 protected marine shoreline stations located within the southern 165 km extremity of the lower west coast of Australia (Fig. 1). Six 2-monthly samples were taken

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from each of the 8 sampling stations, on alternate months between May 1976 and March 1977. Two consecutive seine net samples were taken during daylight at each of the 8 inshore-marine locations on each sampling occasion. The first sample was designed to provide a gross index of relative abundance for each fish species. To obtain more fish for the determination of age composition a second sample was taken approximately 30 min after an attractant (whale oil mixed with sand) had been applied to the area. In the field, each fish was measured (total length) to the nearest 1 mm and length frequency histograms were subsequently prepared for each species. Age groups were determined using this and previous (Lenanton, 1977, unpubl.) length-at-age data.

Two different-sized beach seine nets were used to obtain samples. Over sandy bottoms a large seine 210 m in length with two 103.5 m wings and a 3 m pocket was used, while a small net 41 m in length having 19 m wings and a 3 m pocket was used over rocky bottoms. The wings of both nets were constructed of 25 mm stretched mesh, and had indentical pockets constructed of 9.5 mm stretched mesh. Each net fished to a depth of 2 m and swept areas of 7,018 and 267 m^2, respectively.

During 1981 at the Marmion study site (Fig. 1) we used a seine net (10 m long, 1.5 m deep, 0.5 cm mesh)

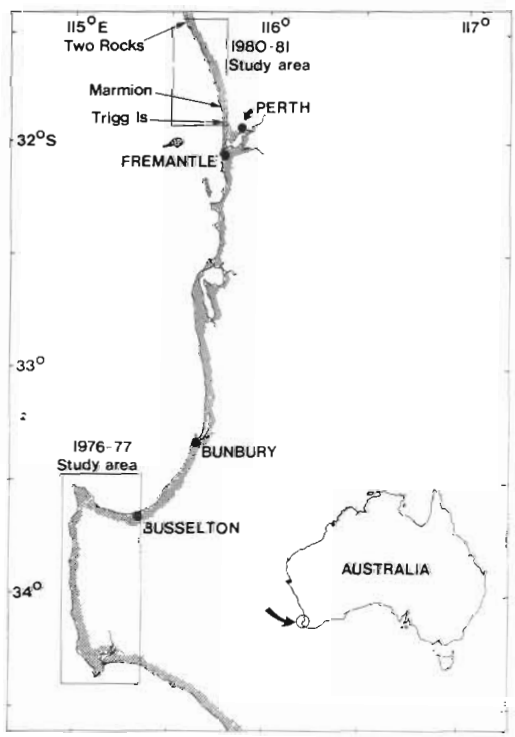

Fig. 1. Location of the 2 study areas in the south of Western Australia. Individual sampling sites are given for the more northerly area

to sample fish in and near drifting vegetation. These samples were collected to determine the diets of juvenile fishes associated with the detached macrophyte accumulations. Fish were sorted from the plants and preserved in a 10 % formalin-seawater solution. Samples were taken in April, May and July. The Australian herring *Arripis georgianus*, which is often associated with macrophyte accumulations, was not captured on these 3 occasions. However, specimens were available from the 1976–1977 sampling period.

In the laboratory each fish was measured and weighed and the stomach (or the first third of the gut for fish without stomachs) was removed and the contents transferred to a Petri dish where prey items were sorted to as low a taxonomic unit as possible. The importance of each prey in a diet was scored by measuring the volume of each prey taxon in each stomach using the method described by Hellawell and Abel (1971) and by scoring the percentage occurrence of prey in all individuals of a fish species. For each fish species we opened fresh stomachs until the graph of the cumulative number of prey taxa reached a plateau. In all cases a sample size of 20 stomachs was found to be sufficient for a description of the diet. Analyses of gut contents taken during other seasons (own unpubl. data) show that the dietary data presented here are representative of the whole year.

To determine the distribution of the invertebrates which were the major prey of the fish, we studied the diversity and abundance of the mobile epifauna associated with the nearshore detached macrophyte accumulations and the dominant macroalgae and seagrasses growing on reefs and sand substrata in the region of Marmion (Fig. 1). Attached macroalgae and seagrasses were sampled by trapping whole plants underwater in plastic bags and cutting their holdfasts and stems at the level of the substrate. The plastic bags were tied off, and returned to the laboratory within 3 h. In the surf-zone the detached macrophytes were sampled by hand, and were quickly placed in plastic bags with seawater. Between 3 and 10 samples were taken from each macrophyte habitat. Collections were taken in February and September 1981. In the laboratory, a small volume of formalin was added to each sample bag and samples were left overnight. Animals were shaken from the vegetation in each sample and the plants were then carefully checked for remaining organisms before being dried at 90 °C for 48 h. Animals were sorted and counted under a dissecting microscope and results were expressed as numbers g^{-1} dry weight of vegetation.

We also measured the standing crop of detached macrophytes on 46 km of coast between Two Rocks, Yanchep Beach and Trigg Beach north of Fremantle (Fig. 1) by determining the volumes of accumulations

both in the surf zone and in wrack banks on the beaches. Length and width of each beach deposit was measured and depth transects through each wrack bank were made by pushing a measuring pole through the seagrass and seaweed deposits until the beach surface was reached. In the surf-zone on steeply sloping beaches the depths of macrophyte accumulations were determined by dropping a weighted line from a boat at the seaward edge of the accumulations. On lower energy beaches depth could be determined by swimming through the macrophyte accumulations and using a weighted line to determine the depth profile. The volume of surf-zone macrophytes was calculated knowing the length of beach occupied by plants and assuming they formed a triangular wedge with the beach.

RESULTS

Distribution and Size Composition of Nearshore Fishes

The seasonal abundance and size composition of *Aldrichetta forsteri, Arripis georgianus, Cnidoglanis macrocephalus* and *Sillago bassensis* taken in 1976 and 1977 at the more southerly study site, together with the size composition of representatives of all except the second of the above species taken recently in the Marmion area are presented in Fig. 2a–d. Most fish were taken in or near accumulations of detached macrophytes, and the catches from both these study sites consisted predominantly of 0+ year classes. 0+ *A. forsteri, S. bassensis*, and *A. georgianus* were first

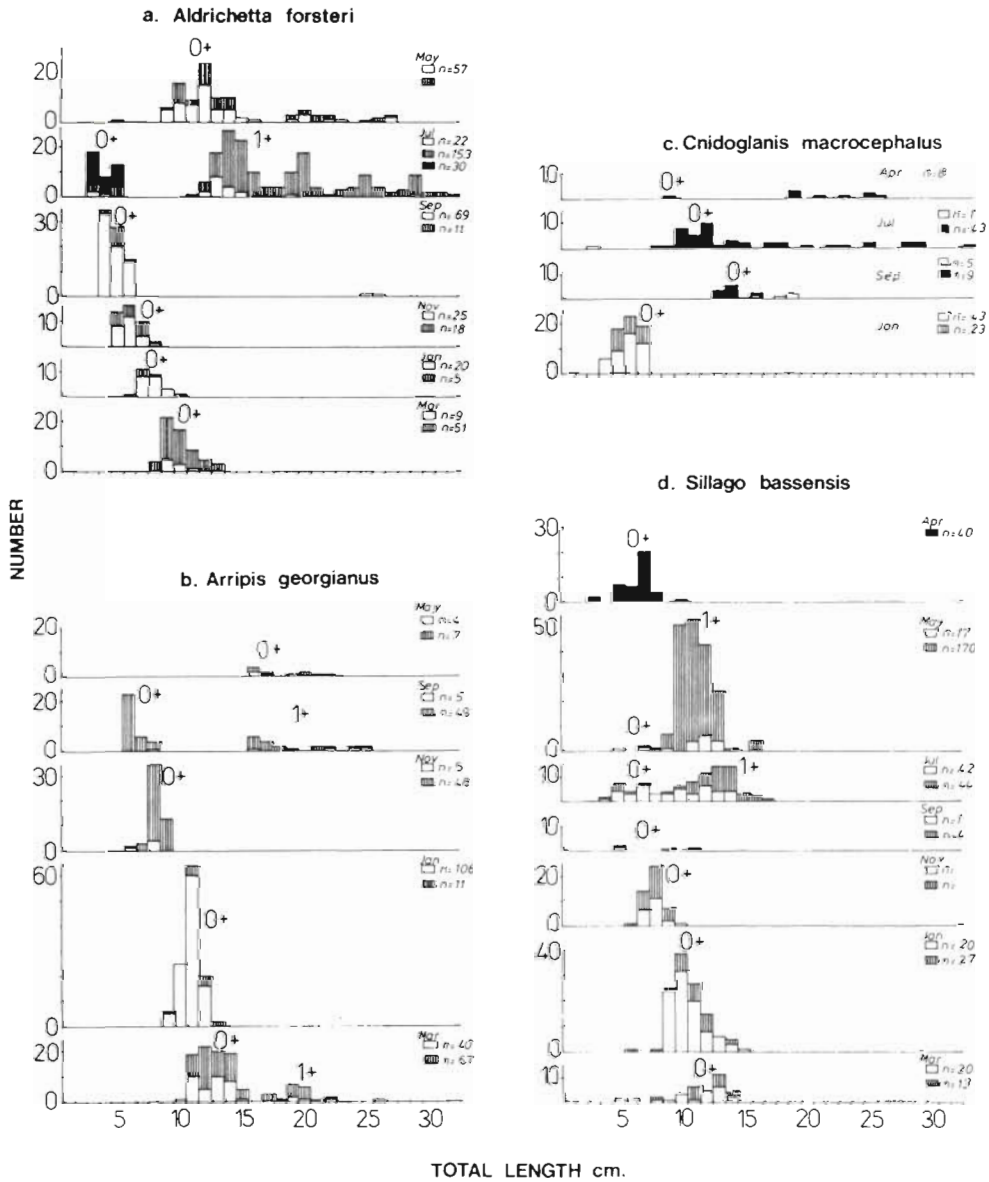

Fig. 2. Relative seasonal abundance and size and age composition of *Aldrichetta forsteri* (a), *Arripis georgianus* (b), *Cnidoglanis macrocephalus* (c), *Sillago bassensis* (d), captured at both study sites. Solid bars: fish captured during 1981; open and hatched bars: fish taken with the first and second hauls, respectively, during 1976 and 1977

Table 1. Diets of the juveniles of *Aldrichetta forsteri, Cnidoglanis macrocephalus, Sillago bassensis* and *Arripis georgianus* associated with nearshore detached macrophyte accumulations. The importance of prey in the diets is expressed as percentage occurrence and percentage volume. Sample size and range of total lengths (cm) of fish examined are given. + = less than 1 % of the total volume of prey

Prey groups	Fish species							
	Aldrichetta (20)[2] (2.9–5.2)		*Cnidoglanis* (20)[2] (9.0–12.6)		*Sillago* (20)[1] (3.2–9.7)		*Arripis* (9)[3] (6.5–8.0)	
	O	V	O	V	O	V	O	V
Fam. Nereidae	5.0	3.1	5.0	1.2	50.0	31.7		
Other polychaetes			5.0	+	10.0	3.3	44.4	1.4
Bivalves							55.5	14.4
Allorchestes compressa	85.0	73.8	100.0	75.5	50.0	19.9	66.6	49.4
Amphipod sp. 8	20.0	+	80.0	11.6	20.0	2.7	77.7	8.9
Other amphipods	10.0	+	5.0	+	40.0	4.5	44.4	1.7
Isopods			25.0	4.9	5.0	+	33.3	+
Tanaidaceans	15.0	+	5.0	+	50.0	3.7	33.3	1.1
Harpacticoid copepods	30.0	19.1	35.0	+	10.0	+		
Halicarcinus sp.			5.0	3.2	15.0	1.9		
Other brachyurans			5.0	+			66.6	13.3
Natantians					30.0	15.4	27.2	2.8
Insects	15.0	+			5.0	+	33.3	2.2
Detritus			45.0	1.2			33.3	+
Other	25.0	1.2	10.0	+	35.0	15.6	44.4	2.5

[1] Captured 16th April 1981 [2] Captured 27th July 1981 [3] Captured 16th November 1976

caught in the nearshore environment during late winter and early spring Fig. 2a, b, d. Although the first record of 0+ *C. macrocephalus* was also made during winter (July, Fig. 2c), the largest catches of small 0+ were taken in January, as was to be expected from a September to December spawning period (Kowarsky, 1975). The 0+ year classes of all 4 species persisted in association with detached macrophytes in the nearshore areas throughout summer (Fig. 2a–d). There was very good agreement between the size of 0+ fish taken in the Marmion area with those taken 5 yr earlier from the shoreline waters of the more southerly site. A comparison of a number of protected marine shoreline stations in the more southerly study area revealed that those with greater amounts of detached macrophytes yielded greater numbers of 0+ fish of these four species (Lenanton, in press).

Diets of Juvenile Fish

The amphipod *Allorchestes compressa* was the major prey consumed by juveniles of *Aldrichetta forsteri, Cnidoglanis macrocephalus* and *Arripis georgianus*; it was the second most important prey of *Sillago bassensis* (Table 1). For *A. georgianus* another amphipod occurred in a greater percentage of the fish but *A. compressa* composed about half of the total volume of all prey. Other important food items included nereid polychaetes and natantian crustaceans for *S. bassensis*, bivalves and brachyurans for *A. georgianus* and harpacticoid copepods for *A. forsteri*.

Distribution of *Allorchestes compressa*

Data on the density of mobile macro-invertebrates associated with major macrophytes of the inshore zone (Fig. 3) show that the amphipod *Allorchestes compressa* is found almost exclusively associated with detached plant accumulations (DPA) in the surf-zone in summer and early spring. *A. compressa* is only rarely associated with detached plants on beaches (authors unpubl. data). In both seasons the mean density of *A. compressa* in the surf-zone was about 110 individuals g^{-1} of vegetation. At both sampling times other amphipod species dominated the fauna associated with attached plant species, and gastropods were abundant on *Sargassum* and *Hypnea* (Fig. 3). In summer, the highest total faunal density was found on *Sargassum*, but in early spring *Hypnea* and the detached macrophytes harboured the highest total numbers of animals.

Standing Crops of Detached Macrophytes

The volumes of detached vegetation in the surf-zone and on beaches in the whole Marmion study site varied seasonally and were often extremely high, up to

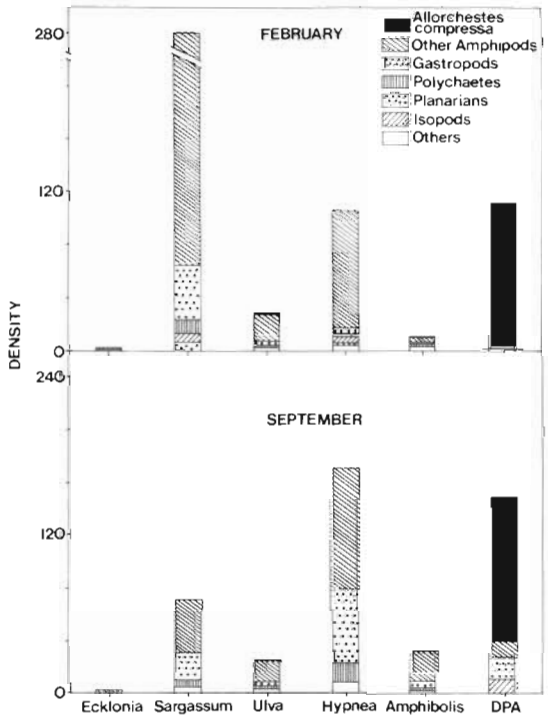

Fig. 3. Mean densities (N g^{-1} dry wt of vegetation) of mobile macro-invertebrate taxa associated with the major macrophytes growing on nearshore reefs and detached plant accumulations (DPA) in the surf-zone near Marmion in late summer and early spring 1981

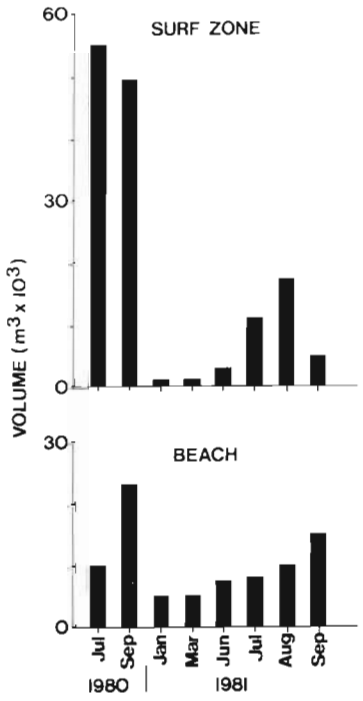

Fig. 4. Volumes of detached plant material in the surf-zone and stranded on beaches along 46 km of coast near Marmion during 1980 and 1981. Because beached material is more compacted, comparisons of volumes between zones are not valid

55,400 m^3 (Fig. 4). We present data on beached plants because although this material contains few amphipods it is nevertheless a potential habitat for *Allorchestes compressa* if resuspended in the surf-zone. The measured volumes of macrophytes in the 2 zones are not comparable because beached vegetation was more compacted than surf-zone material (1 m^3 of beached plants will yield approximately 12 m^3 of material in the surf-zone). Maximum volumes of material in the surf-zone occurred about 1 mo earlier (July–August) than on beaches (September). There was year to year variation in the winter volumes of plant material, particularly in the surf-zone where the 1980 accumulations were 3 times the volume of those in 1981.

DISCUSSION

Although the earlier study by Lenanton (in press) suggested that amphipods were important in the diets of fish found associated with accumulations of detached seaweed along the open coast of south-western Australia, the exact nature of the link between these areas and fish was not clear because the identity and the source of the amphipods was not resolved.

The results of the present study have established the high degree to which 0+ age group fish are dependent upon the large patches of detached plants. *Allorchestes compressa* is a major prey item for juveniles of the 4 fish species considered; because the distribution of *A. compressa* is restricted to detached plants and the fish are all shallow water species (Lenanton, 1977; Dybdahl, 1979) these large accumulations of detached seaweeds and seagrasses provide important feeding sites for the fishes.

The juvenile fish and detached plant material association is probably a widespread phenomenon along the temperate west and south-west coast of Western Australia. Large accumulations of decomposing macrophytes are a feature of many open sandy beaches and sheltered bays in this region and *Allorchestes compressa* is always present amongst the vegetation (own obs.). That fish in regions other than the Marmion study site use the accumulations as feeding areas is borne out by the diet of the Australian herring *Arripis georgianus* which were obtained from the earlier, more southerly study site. The main prey of these fish was *Allorchestes compressa*.

The accumulations of plant material probably also confer great protection for fish from larger predatory fish and diving birds, which would feed less efficiently amongst dense patches of plants in the shallow waters

of the surf-zone. The known piscivorous pied cormorant *Phalacrocorax varins* (Serventy, 1938) feeds in greater numbers around patches of detached plants than on open sandy beaches and rocky reefs in the Marmion study area but birds have never been observed to feed within these dense accumulations (own unpubl. data).

The initial arrival of juvenile fish on the open coast may also be timed to correspond with the period of greatest deposition of detached macrophytes in the surf-zone. Our data show that the first captures of 0+ *Aldrichetta forsteri, Sillago bassensis* and *Arripis georgianus* in the nearshore zone occur in late winter and early spring when the volumes of detached plants were highest, and there were high densities of the fishes preferred prey *Allorchestes compressa*.

Large clumps of drift algae are a common feature of a number of coastal communities (e.g. Cowper, 1978; Charner Benz et al., 1979) and several macroinvertebrate (Hooks et al., 1976; Gore et al., 1981) and fish species (Stoner and Livingston, 1980) have been reported to be intimately associated with these algae. The study which describes a relationship most similar to that presented here is that of Stoner and Livingston (1980) which presents a clear example of a blenny being dependent on red algal clumps for shelter, food and possibly dispersal of young. The association which we describe between fish and detached macrophytes differs from previous studies as we are dealing with economically important species in a high-energy, open coast, surf-zone system where plants are usually deposited over sandy beaches.

Mid-water feeding planktivorous fish often dominate open surf-zone areas where there are no macrophytes present (Modde and Ross, 1981). However, accumulations of detached vegetation support a more sedentary food source for benthic feeding fishes such as the 4 species we have examined. The response of fish to this new feeding habitat is best illustrated in this study by the yellow-eyed mullet *Aldrichetta forsteri*. This species is a benthic feeder (Robertson, 1980); throughout its range in southern and eastern Australia 0+ and 1+ individuals of *A. forsteri* are restricted to shallow estuaries or sheltered embayments (Harris, 1968; Robertson, 1980). This is also the case in Western Australia (Chubb et al., 1981), except when accumulations of detached plant material provide an alternative shallow-water feeding area.

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