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Utilization of seagrass habitats by juvenile groupers and snappers in Banten Bay, Banten Province, Indonesia

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Abstract Coastal development in Banten Bay, Indonesia, decreased seagrass coverage to only 1.5% of its surface area. We investigated the importance of seagrass as habitat for juvenile groupers (Serranidae) and snappers (Lutjanidae), by performing beam trawl hauls on a weekly basis in two seagrass locations and one mudflat area, and monthly trawl hauls in three different microhabitats (dense, mixed and patchy seagrass) in one of the seagrass locations. We studied the effects of location and microhabitat, as well as temporal patterns (diel, weekly and monthly) on the probability of occurrence and abundance of the most abundant grouper (Orange-spotted grouper, *Epinephelus coioides*) and snapper (Russell's snapper, *Lutjanus russellii*). We found that both species were almost exclusively found in seagrass locations, with a preference for microhabitats of high complexity (dense and mixed microhabitats). *L. russellii* had a higher probability of catch and abundance during the night, most probably because of its ability to avoid the beam trawl during daytime sampling. In addition there was an effect of week and month on the presence and abundance of both species, but patterns were unclear, probably because of high fishing pressure on juvenile groupers and snappers by push net fishermen. Groupers and snappers mainly fed on abundant shrimps, and to a lesser extent on fish. Moreover, juveniles find protection against predators in seagrass, which confirmed the critical role of quantity and quality of seagrass areas for juvenile groupers and snappers in Banten Bay.

Keywords Coral reef · Fishery · Grouper · Indonesia · Seagrass · Snapper

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Introduction

The sustainability of coastal marine fisheries greatly depends on the extent and integrity of fish habitats. Increasing pressure on coastal zones results in loss or degradation of habitats that are considered essential for a variety of species (Rubec et al., 1998). In subtropical and tropical countries areas, seagrass beds form one such habitat type (Bell & Pollard, 1989; Pinto & Punchihewa, 1996; Jenkins et al., 1997) providing its inhabitants with food, protection from predators and shelter from physical disturbances (Nojima & Mukai, 1990; Motta et al., 1995; Jordan et al., 1996). Seagrass beds provide more complex habitat structure than non-vegetated areas and are known to support higher abundance, biomass and species richness than non-vegetated areas (Bell & Pollard, 1989; Eggleston, 1995; Irlandi et al., 1995; Tolan et al., 1997). For instance, Jordan et al. (1996) found that fish abundance in seagrass beds in the northern Gulf of Mexico was significantly higher (760%) than in surrounding sand flats. Seagrass also serves as settlement substrate for fish larvae (Rooker & Holt, 1997; Rooker et al., 1998) and as important nursery areas for the juveniles of many species with a high economic or recreational value (Kikuchi, 1974; Jenkins et al., 1997; Hutomo & Sularto, 1977). Within seagrass habitats, the more densely covered meadows are considered more complex than meadows with sparse or patchy coverage (Rooker et al., 1998).

Species composition of fish and invertebrates in seagrass fluctuates during the day (Greening & Livingstone, 1982; Grey et al., 1998). The main reasons for moving from surrounding habitats into vegetated areas during the day are foraging, resting (Roblee & Zieman, 1984), or seeking refuge from predators or from tidal currents (Sogard et al., 1989). Besides diurnal, there are also seasonal patterns in the utilisation of seagrass by many species, mainly at larval and juvenile stages. These patterns are mainly influenced by currents, water temperature, salinity, habitat complexity, spawning seasons, recruitment, natural mortality and migration (Tolan et al., 1997; Rooker et al., 1998).

In Banten Bay (West Java, Indonesia) groupers (Serranidae) and snappers (Lutjanidae) are two commercially and ecologically valuable fish categories that utilise seagrass areas, especially in their juvenile stages (Heemstra & Randall, 1993; Eggleston, 1995). The populations of groupers and snappers and the fishery on these species are under pressure in Banten Bay, because of overexploitation and the use of destructive fishing methods, such as intensive fishing for juveniles by push net fishermen. Moreover, indirectly fish populations are threatened through habitat destruction due to large-scale coastal developments (Douven, 1999).

Given these coastal developments, it is essential to assess the importance of seagrass for juvenile groupers and snappers if an effective strategy for sustainable management of these fishes has to be developed. The aim of this study is therefore to analyse the importance of seagrass beds as nursery and feeding areas for juvenile groupers and snappers. Our approach for this analysis was to identify spatial and temporal variation in the abundance of juvenile groupers and snappers in Banten Bay in relation to (1) the presence or absence of seagrass, and (2) differences in structural complexity within seagrass habitats.

Materials and methods

Study area

Our study was performed in the seagrass area of Banten Bay (5° S–106° E), a shallow bay located on the northern coast of West Java, Indonesia (Fig. 1), which is undergoing accelerated economic development with industrial estates being established along its western shores. Industrial and port developments cause reclamation activity and stone mining, which decline the seagrass coverage and coral reef through changes in water current and circulation. The total area of seagrass beds in the bay is about 330 ha, which is approximately 1.5% of the total surface. The largest and densest seagrass beds are located along the western part of the bay and comprise 145 ha (Douven et al, 2003). Three sampling sites were selected, two seagrass beds, Kepuh (ca. 90 ha) and Kuala Pasar (ca. 55 ha), and one non-vegetated area, Teratai, situated closely to the mouth of a small river (Fig. 1). In the bay, 7 seagrass species are present: *Cymodocea rotundata, C. serrulata, Enhalus acoroides, Halophila ovalis,*

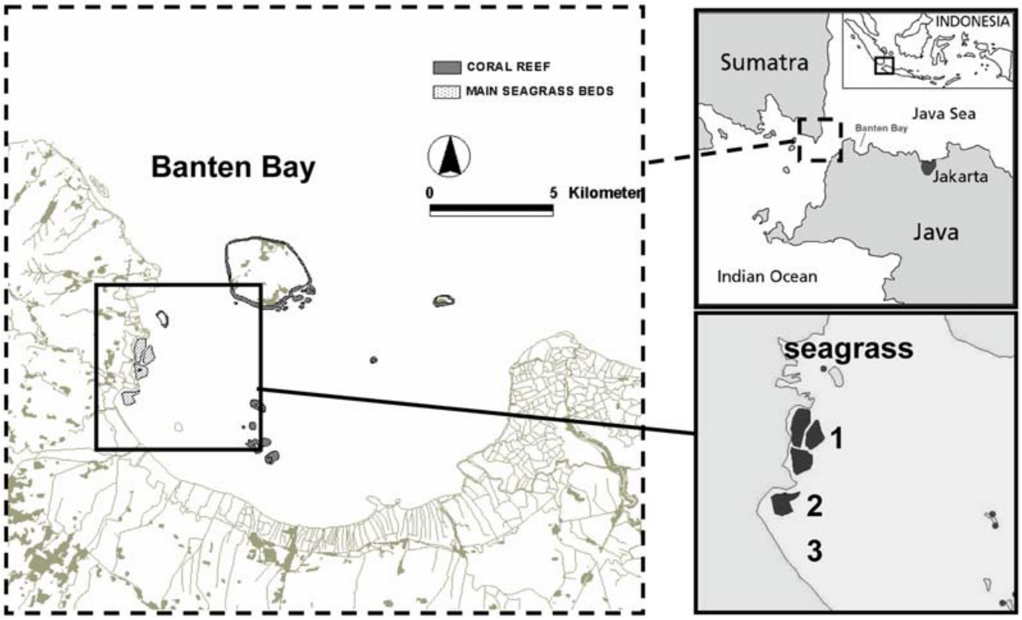

Fig. 1 Location of the study area in Banten Bay, Banten Province, West Java, Indonesia. 1 = Kepuh (seagrass), 2 = Kuala Pasar (seagrass), 3 = Teratai (non-vegetated, muddy area)

Halodule uninervis, Syringodium isoetifolium, and *Thalassia hemprichii* (Kiswara, 1999). Within the seagrass of both areas mainly mono-specific populations (*E. accoroides*) are found, but also mixed populations of *E. acoroides* and *S. isoetifolium* and *T. hemprichii*.

Within the seagrass, three habitat categories were distinguished: mixed, dense, and patchy. The mixed area encompassed several species of seagrass mingled with soft coral, sponges and macroalgae, resulting in a high level of complexity. The dense area consisted mainly of *E. acoroides* in high densities, and the patchy area consisted of patches of seagrass of 1–2 m in diameter, separated from each other by approximately 1–2 m of bare substrate. The patchy habitat comprised approximately 50% of the total seagrass habitat in Kepuh and Kuala Pasar (Douven et al., 2003) In Kepuh, the dense, mixed and patchy areas were 35, 22 and 33 ha, respectively.

Fish abundance sampling

We sampled juvenile grouper and snapper with a small beam trawl (opening width of 1 m, opening height of 0.3 m, 1 cm stretched mesh size), which was made heavier with an iron chain attached to the bottom rope in order to increase the efficiency of sampling in seagrass. The trawl was hauled by one person on foot during 2 min, covering a mean distance of 69 m. The fishes caught were kept alive in plastic bags filled with water, and transported to the laboratory, where they were identified to the lowest taxonomic level possible after Munro (1967), Tarp & Kailola (1985), Allen (1985) and Heemstra & Randall (1993). The number of individuals and the total weight per species were recorded for each haul. From each grouper and snapper total and standard length (cm) and weight (g) were measured.

We performed weekly and monthly sampling. Weekly sampling aimed at determining the effect of the presence of seagrass on the abundance of juvenile grouper and snapper. It was conducted at Kepuh, Kuala Pasar and Teratai (Fig. 1) from 23 February until 2 June 1999. Five replicates were performed during daylight at each location. At Teratai, no sampling was performed in the last four weeks, because of the total absence of grouper or snapper in the previous sampling period.

Monthly sampling aimed at determining the effect of microhabitat types on the abundance of juvenile grouper and snapper. This study was carried out at Kepuh within the 3 microhabitat types during the high tidal phase from June 1998 to August 1999, both during day and night. Five to seven replicate hauls were performed each time.

Food composition sampling

The stomach content of juveniles of the two most abundant grouper and snapper species, Orange-spotted grouper, *Epinephelus coioides*, and Russell's snapper, *Lutjanus russellii*, were studied. Fish were collected from the seagrass of Kepuh in April to June 1998 using beach seines, push nets and beam trawls. Specimens were immediately preserved, using a 4% buffered formaldehyde solution. In the laboratory, total length of the specimens was measured to the nearest 0.1 cm, and weight to the nearest 0.1 g. Stomachs were removed, blotted and weighed with and without stomach content. Food items were removed from the stomach and identified to the lowest taxonomic level possible. Then organisms were grouped in four categories, i.e., shrimps, fish, molluscs, others. Each category was weighed to the nearest 0.1 g.

Data handling and analysis

To compare fish catches in hauls of different lengths, fish catches per haul had to be corrected for the towed distance. We did this by investigating the relationship between combined catch weight of groupers and snappers and the distance towed. All catches per haul were then standardised to catch per unit of effort (CpUE) for a haul of mean length (69 m), using the equation:

$$\mathrm{CpUE} = \mathrm{C} \cdot \left(\frac{69}{d}\right)^{0.68}$$

where CpUE is the catch per unit of effort, standardised for a haul of mean length (g haul^{-1}), C the raw catch of groupers and snappers per haul (g haul^{-1}) and d the towed distance per haul (m).

Total catches during the sampling period (numbers and weight) and average CpUE were recorded for *E. coioides* and *L. russellii*. Because of the strongly left-skewed distribution of CpUE data we $\log_{10}$-transformed weights and numbers in the catch to obtain geometric means. The effects of location/micro-habitat and week/month on the CpUE were tested in two steps. First an absence-presence analysis was performed, followed by an analysis of the non-zero catches. Absence-presence analysis was necessary because of the high number of zero-catches (>50%) for both species. Zero-values cannot be log-transformed and therefore cannot be included in an analysis of variance (ANOVA).

Presence-absence analysis

In the presence-absence analysis the effect of location and week/month on the response variable, i.e., catch probability was examined. Catch probability (p_{ij}) was defined as the fraction of non-zero catches:

$$p_{ij} = \frac{n_{ij}(\mathrm{non-zero})}{n_{ij}(\mathrm{zero}) + n_{ij}(\mathrm{non-zero})}$$

where n is the number of trips, i the location (in case of weekly sampling)/micro-habitat (in case of monthly sampling) (i = 1–3), and j the week/month (j = 1–15).

The response variable p_{ij} is binomially distributed, which means that the least-squares method cannot be used to estimate the model parameters. Instead a logit-regression (Ter Braak & Looman, 1995) was applied, to link the expected value of the response variable to a linear predictor g(m), which was analysed by an analysis of deviance, using the model:

$$g(m) = \log_e\left(\frac{p_{ij}}{1 - p_{ij}}\right) = m + l_i + t_j + l_i \times t_j$$

where m is the overall probability, l_i the effect of ith location/micro-habitat (i = 1–3), t_j the effect of jth week/month (j = 1–15), and $l_i \times t_j$ the interaction term. Non-significant terms were eliminated from the model. In case of significant effects the approximate 95% approximate confidence limits of predictions were estimated to compare group means.

Analysis of non-zero catches

To further analyse the effects of location/micro-habitat and week/month on variations in catch per haul (CpUE), the non-zero catches were analysed by ANOVA. The CpUE data were log-normally distributed and we used the following model:

$$Y_{ij} = \mu + l_i + t_j + d_k + l_i \times t_j + l_i \times d_k + t_j \times d_k + l_i \times t_j \times d_k + \varepsilon_{ijk},$$

where Y_{ij} is $\log_{10}$ (CpUE), μ the overall mean CpUE, l_i the effect of ith location/micro-habitat (i = 1–3), t_j the effect of jth week/month (j = 1–3), d_k the effect of time of day (only in case of monthly sampling: k = 1–2, day or night)), $l_i \times t_j$, $l_i \times d_k$, $t_j \times d_k$, $l_i \times t_j \times d_k$ the interaction terms, and ε_{ijk} the error term. Non-significant terms were removed from the model. Residuals were tested for normality and 95% confidence limits were calculated to compare group means in case of significant effects.

Length distribution analysis

Effects of location (Kepuh or Kuala Pasar), micro-habitat, and time of day (day or night) on the length of juvenile *E. coioides* and *L. russelli* were tested by means of a χ^2-test (Sokal & Rohlf, 1995).

Food composition analysis

Frequency of occurrence (FO), percentage composition by number (NO) and by weight (WT) were calculated. Because all these measures show biases when used individually (e.g., percentages by number tend to over-emphasize small food items, such as small shrimps that are eaten in large numbers, but amount little to the total weight of the food, and under-estimate large items like fish eaten in small numbers), the relative importance index was developed:

$$\mathrm{RI_a} = \frac{100 \times \mathrm{AI_a}}{\sum_{a=1}^{n} \mathrm{AI_a}} = \frac{100 \times (\mathrm{FO_a} + \mathrm{NO_a} + \mathrm{WT_a})}{\sum_{a=1}^{n} (\mathrm{FO_a} + \mathrm{NO_a} + \mathrm{WT_a})},$$

where $\mathrm{RI_a}$ is the relative importance index for food item a, $\mathrm{AI_a}$ the absolute importance index for food item a, $\mathrm{FO_a}$ the % frequency of occurrence of food item a, $\mathrm{NO_a}$ the % of total numbers of food item a, and $\mathrm{WT_a}$ the % of total weight of food item a.

Results

Variation in juvenile grouper and snapper abundance between habitats

A total of 11,912 specimens, representing 77 species and 38 families were collected during the fifteen sampling weeks. The total catch weight was 30.8 kg, with a mean CpUE of 150 g haul^{-1}, on average consisting of 58 individuals per haul (Table 1). The most abundant species in terms of weight (18.3%) was Orange-spotted grouper, *E. coioides*, followed by shrimps (17.8%), crabs (14.1%), Grey eel-catfish, *Plotosus canius* (10.4%), and Banded frogfish, *Halophryne diemensis* (6.2%). Seven species of grouper contributed 20% to the total catch weight. Snapper species only contributed 0.6%. *E. coioides* was the most abundant grouper species with a frequency of occurrence in all the hauls of 56%. Russell's snapper, *L. russellii*, was the most abundant snapper species in the catches, but its frequency of occurrence was only 13% (Table 1).

There was a significant effect of sampling week and location on the presence of *E. coioides* and *L. russellii* (Table 2, Fig. 2), and a significant interaction between these two factors for *E. coioides*. The probability of catch was significantly higher in locations with seagrass (Kepuh and Kuala Pasar) than in the non-vegetated area (Teratai). In the non-vegetated area the probability of catch of groupers and snappers was all but zero (from the grouper only one of the 300 specimens was caught in Teratai, while none of the snapper specimens were caught here. The differences in average probability of catch between the seagrass locations were not significant for either grouper (Kepuh: P = 0.87; Kuala Pasar: P = 0.64) or snapper (Kepuh: P = 0.15; Kuala Pasar: P = 0.21).

Within the seagrass habitat, there was a significant effect of week on CpUE of *E. coioides* and of location on CpUE of *L. russellii* (Table 3). The geometric mean of non-zero CpUE was 18 g haul^{-1} for *E. coioides* (monthly means varying from 4 to 63 g haul^{-1}) and 1.3 g haul^{-1} for *L. russellii* (means of 0.5 g haul^{-1} at Kepuh, and 2.8 g haul^{-1} at Kuala Pasar) (Fig. 3).

Table 1 Catch composition of the weekly sampling, showing frequency of occurrence in the hauls (total number of hauls $n = 205$), percentage of non-zero catches, total number and total weight, mean number per haul, mean CpUE (arithmetic and geometric mean) and 95%-confidence intervals (expressed as geometric mean x $F^{\pm 1}$)

Species	Frequency	% Non-zero catches	Total number	Total weight (kg)	Mean number per haul	Mean CpUE (g haul^{-1})		Confidence interval factor, *F*
						Arithmetic mean	Geometric mean	
Total catch	205	100	11912	30.8	58	150	91.1	9.8
Shrimps	202	99	6265	5.49	31	26.8	16.9	7.3
Crab	139	68	410	4.35	3.0	21.2	12.8	27
Plotosus canius	24	12	28	3.21	1.2	15.7	83.6	8.6
Halophryne diemensis	28	14	38	1.92	1.4	9.40	9.3	86
Overall groupers	125	61	392	6.19	3.1	30.2	17.5	29
Epinephelus. coioides	114	56	301	5.65	2.6	27.5	18.1	27
E. sexfasciatus	30	15	38	0.173	1.3	0.9	2.9	13
E. bleekeri	18	9	28	0.122	1.6	0.6	3.6	13
Other groupers*	15	7	16	0.241	1.1	1.2	1.6	50
Overall snappers	46	22	64	0.189	1.4	0.9	1.9	12
Lutjanus russellii	27	13	31	0.103	1.2	0.5	1.3	18
L. johnii	17	8	20	0.037	1.2	0.2	1.1	8.5
Other snappers**	11	5	12	0.046	1.1	0.2	2.4	12

* E. malabaricus, E. caeruleopunctatus and unidentified groupers

** L. carponotatus, L. fulviflamma

Table 2 Presence-absence analysis of weekly sampling

Source	df	Deviance	
		E. coioides	*L. russellii*
Intercept	160	281	117
Location	2	167**	104**
Week	14	135**	77**
Location × Week	28	107*	NS

Asterisks denote statistically significant differences (* $P < 0.05$; ** $P < 0.01$). Location represents seagrass habitats of Kepuh and Kuala Pasar and non-vegetated habitat of Teratai. Non-significant (NS) factors were removed from the model

Variation in juvenile grouper and snapper abundance between seagrass microhabitats

In fifteen months of sampling, a total of 16,126 fishes from 116 species and 44 families were collected from the seagrass area of Kepuh. Total biomass was 62.6 kg; with a mean CpUE of 157 g haul^{-1}, on average consisting of 40 individuals per haul (Table 4). The most abundant species in terms of weight (19.7%) was Orange-spotted grouper, *E. coioides*, followed by shrimps (10.4%), White-spotted spinefoot, *Siganus canaliculatus* (9.9%), Banded frogfish, *Halophryne diemensis* (7.7%), and Fourline terapon, *Pelates quadrilineatus* (6.0%). Nine species of grouper contributed 20% to the total catch weight. Snapper species only contributed 3.3%. *E. coioides* was the most abundant grouper species with a frequency of occurrence in all the hauls of 37%. Russell's snapper, *L. russellii*, was the most abundant snapper species in the catches, with a frequency of occurrence of 29% (Table 4).

There was a significant effect of microhabitat on the probability of catch of *E. coioides*, which was significantly higher in dense ($P = 0.18$) and mixed ($P = 0.24$) microhabitats than in patchy microhabitat ($P = 0.08$) (Table 5, Fig. 4). For *L. russellii* there was a significant effect of month and time of day on the probability of catch, which was on average higher during the night ($P = 0.15$ at night vs. $P = 0.08$ during the day) (Table 5, Fig. 4).

The analysis of the non-zero CpUE showed analogous results to the presence-absence analysis, in the sense that CpUE of *E. coioides* was significantly higher in mixed (27 g haul^{-1}) and dense (34 g haul^{-1}) microhabitats than in patchy habitat (13 g haul^{-1}), and that CpUE of *L. russellii* was higher at night (6 g haul^{-1}) than during the day (2 g haul^{-1}) (Table 6, Fig. 5). For both *E. coioides* and *L. russellii*, a significant effect of month on CpUE was observed (Table 5, Fig. 5), with the lowest values for *E. coioides* in November 1998 to April 1999, and from May to August 1999 for *L. russellii*. Neither species showed clear seasonal patterns.

Size distribution of *E. coioides* and *L. russellii*

Total length of *E. coioides* varied from 1.6 cm to 29 cm ($n = 156$) with a peak in the 3–4 cm interval. Location had a significant effect on the

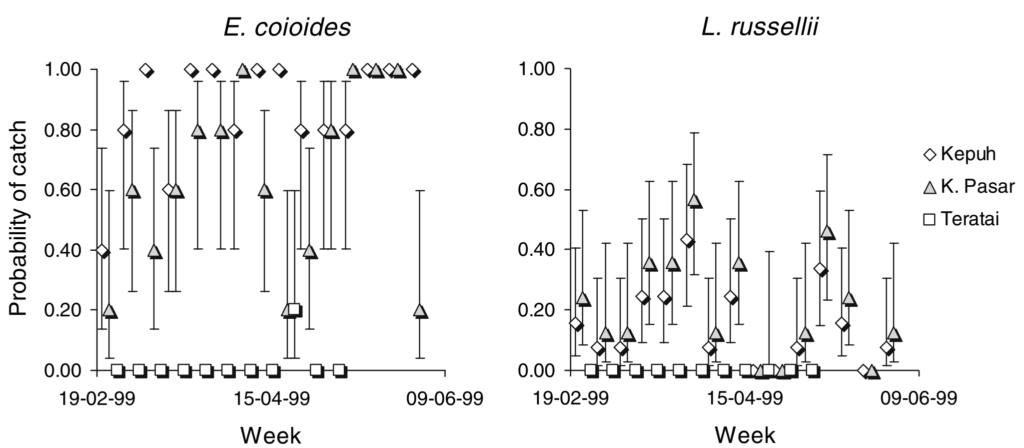

Fig. 2 Effect of week and location on the probability of catch of orange-spotted grouper, *Epinephelus coioides* (left) and of Russell's snapper, *Lutjanus russellii* (right) in the weekly samples. Error bars represent 95% confidence limits

Table 3 ANOVA table for the model of catch per unit of effort on non-zero catches in the weekly samples

Source	*E. coioides*		*L. russellii*	
	df	MS	Df	MS
Location	–	NS	1	3.66**
Week	14	0.89*	–	NS
Location × Week	–	NS	–	NS
Error	98	38	25	0.28

Asterisks denote significant difference (* $P < 0.05$; ** $P < 0.01$). Non-significant (NS) factors were removed from the model

length distribution ($\chi^2 = 66$, df = 2; $P < 0.0001$), with a mean length of 3.2 ± 0.8 cm (mean ± standard deviation) in Kepuh and of 5.1 ± 2.8 cm in Kuala Pasar. *L. russellii* ranged from 2 cm to 16 cm ($n = 137$), with a peak in the 4–5 cm interval. There was no significant effect of location on the length of *L. russellii*, which had a mean length of 6.1 ± 2.5 cm. The effects of microhabitat and time of day could not be significantly shown.

Food composition and relative importance of food items

The percentage of investigated stomachs that was empty was 35% in *E. coioides* and 37% in *L. russellii*. Shrimps were by far the most dominant food item in the diet of both species (Table 7). Most shrimp belonged to the families Sergestidae and Penaeidea, while also some Amphipoda and Decapoda were found. Fish was the second most important food item. Juveniles of both species start consuming fish at a length of ca. 4 cm, and fish becomes increasingly important with size. In the length class 12–14 cm, more than 50% of the juveniles contained fish. Fish species that were consumed were *Ambassis* sp. (Glassfish), *Apogon* sp. (Cardinalfish), *Gerres oyena* (Common silver-biddy), *Lethrinus lentjan* (Pink ear emperor), *Lethrinus genivittatus* (Longspine emperor), *Pelates quadrilineatus* (Fourline terapon), *Siganus canaliculatus* (White-spotted spinefoot), and *Stolephorus* sp. (Anchovy).

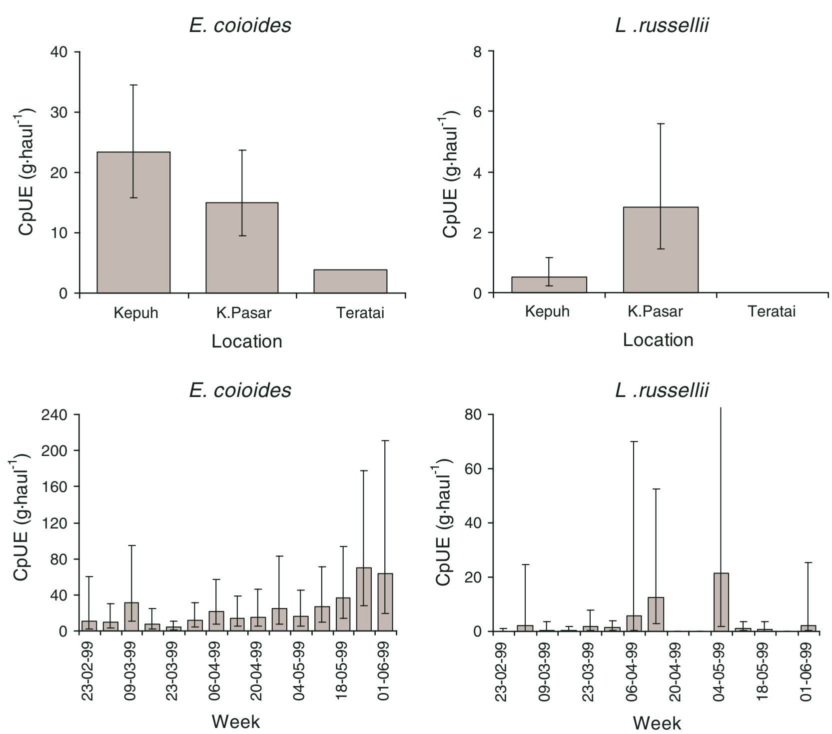

Fig. 3 Effect of location (top) and week (bottom) on CpUE of orange-spotted grouper, *Epinephelus coioides* (left) and of Russell's snapper, *Lutjanus russellii* (right) in the weekly samples. Error bars represent 95% confidence limits

Table 4 Catch composition of the monthly sampling in seagrass of Kepuh, showing frequency of occurrence in the hauls (total number of hauls n = 399), percentage of non-zero catches, total number and total weight, mean number per haul, mean CpUE (arithmetic and geometric mean) and 95%-confidence intervals (expressed as geometric mean x $F^{\pm 1}$)

Species	Frequency	% Non-zero catches	Total number	Total weight (kg)	Mean number per haul	Mean CpUE (g $haul^{-1}$)		Confidence interval factor, *F*
						Arithmetic mean	Geometric mean	
Total catch	399	100	16126	62.6	40	157	92	10
Shrimps	289	72	65	6.53	0.2	16.0	11	10
Siganus canaliculatus	153	38	197	6.17	0.5	16.0	13	28
Halophryne diemensis	49	12	25	4.81	0.1	12	27	92
Pilates quadrilineatus	276	69	13	3.77	<0.1	10.0	5	19
Centrogenys vaigiensis	11	3	35	0.27	0.1	0.70	11	18
Overall groupers	208	52	1987	12.7	8.7	33	22.9	35
Epinephelus coioides	148	37	318	12.3	0.8	31	25.6	29
E. sexfasciatus	17	4	266	0.170	0.7	0.4	4.9	22
Other groupers*	25	6	1403	0.243	3.5	0.6	3	25
Overall snappers	152	38	266	2.06	4.7	5.2	5.1	19
Lutjanus johnii	30	8	35	0.369	0.1	0.9	6.1	11
L. russellii	117	29	197	1.18	0,5	3	4.6	16
Other snappers**	27	7	34	0.509	1	1.3	4	40

* E. bleekeri, E. coeruleopunctatus, E. malabaricus, E. quoyanus and unidentified groupers

** L. argentimaculatus, L. carponotatus, L. fulviflamma, and L. vitta

Table 5 Presence-absence analysis of weekly sampling

Source	df	Deviance	
		E. coioides	*L. russellii*
Intercept	381	551.8	213
Microhabitat	2	542.2*	NS
Month	14	NS	185.9**
Diel	1	NS	171.8**
Microhabitat × Month	–	NS	NS
Microhabitat × Diel	–	NS	NS
Month × Diel	–	NS	NS
Microhabitat × Month × Diel	–	NS	NS

Asterisks denote statistically significant differences (* $P < 0.05$; ** $P < 0.01$). Microhabitat represents dense, mixed and patchy parts of seagrass in Kepuh from June 1998 to August 1999. Diel represents time of day (day or night). Non-significant (NS) factors were removed from the model

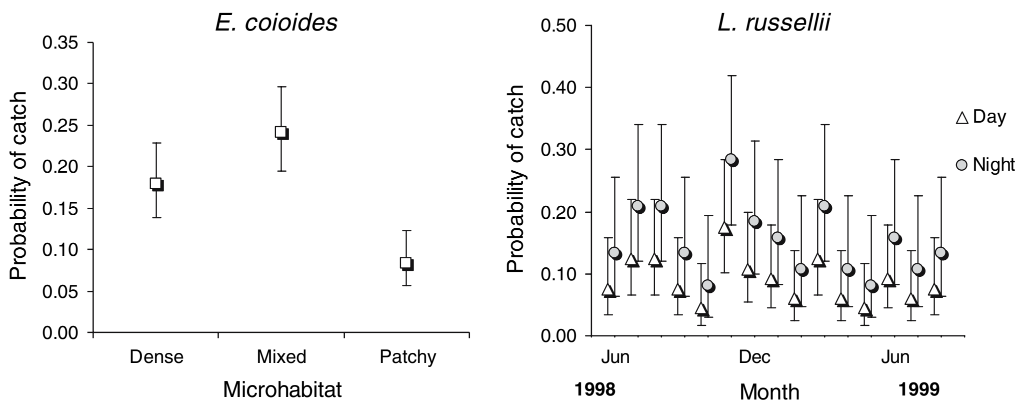

Fig. 4 Effect of microhabitat on the probability of catch of orange-spotted grouper, *Epinephelus coioides* (left) and the effect of month and time of day on the probability of catch of Russell's snapper, *Lutjanus russellii* (right) in the monthly samples. Error bars represent 95% confidence limits

Discussion

Seagrass as a nursery and feeding habitat

We found that juvenile Orange-spotted grouper *E. coioides* and Russell's snapper, *L. russellii*, were almost exclusively found in the seagrass areas of Banten Bay and not in adjacent non-vegetated areas (Fig. 2). This finding is in accordance with literature indicating the importance of vegetated areas, such as seagrass beds, for settlement and nursery of several species of grouper and snapper (Allen, 1985; Bell & Westoby, 1986; Bell et al., 1987; Bell & Pollard, 1989; Jory & Iversen, 1989; Chester & Thayer, 1990; Heemstra & Randall, 1993; Jenkins et al., 1997; Tolan et al., 1997). A reason for the seagrass preference of juvenile groupers and snappers is the diverse and abundant invertebrate fauna in this habitat, which is supported by the plants. The constant growth of epiphytes on the leaves and the production of large amounts of detritus provide rich food sources for organisms at all tropic levels (Connolly, 1994a; Edgar et al., 1994). The main food of juvenile groupers and snappers were shrimps, followed by fish (Table 7), which is in accordance with results reported on feeding habits of groupers in the same type of area (Sugama & Eda, 1986) in Curacao and other Caribbean islands (Randall, 1967; Brule et al., 1994). On average the CpUE of shrimps were 10–18% of the total CpUE, forming an abundant food source. As body size of the juveniles increases, the importance of larger prey, such as fish, in their diet increases, which is mostly associated with a change of habitat, e.g., towards coral reefs

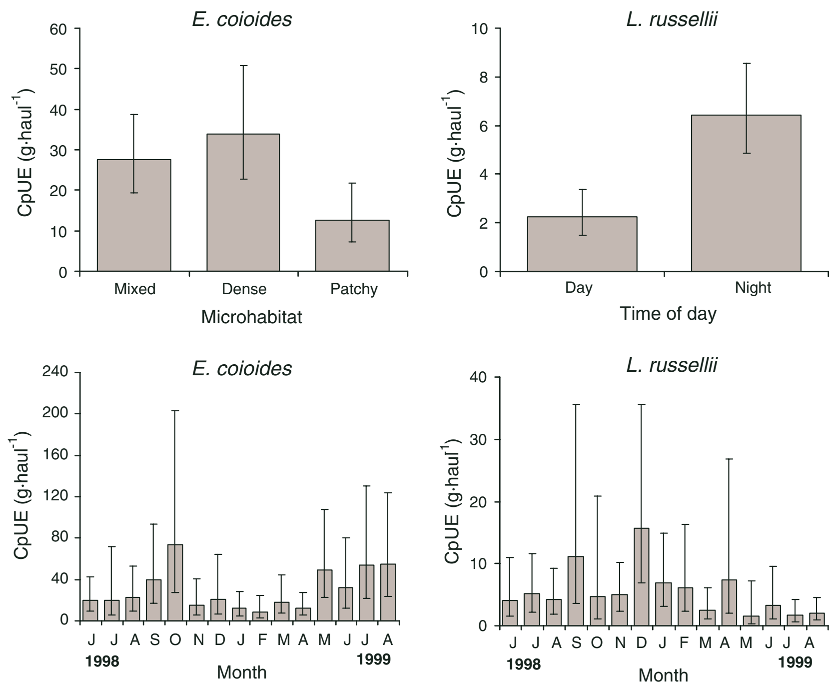

Fig. 5 Effect of microhabitat (top left) and month (bottom left) on CpUE of orange-spotted grouper, *Epinephelus coioides*, (left) and effect of time of day (top right) and month (bottom right) on CpUE of Russell's snapper, *Lutjanus russellii* in the monthly samples. Error bars represent 95% confidence limits

Table 6 ANOVA table for the model of catch per unit of effort on non-zero catches in the monthly samples

Source	*E. coioides*		*L. russellii*	
	df	MS	df	MS
Microhabitat	2	2.163*	–	n.s.
Month	14	0.862*	14	0.605*
Diel	–	NS	1	5.354**
Microhabitat × Month	–	NS	–	NS
Microhabitat × Diel	–	NS	–	NS
Month × Diel	–	NS	–	NS
Microhabitat × Month × Diel	–	NS	–	NS
Error	131	0.48	101	0.27

Asterisks denote significant difference (* $P < 0.05$; ** $P < 0.01$). Non-significant (NS) factors were removed from the model

(Eggleston, 1995). The fact that the maximum length of *E. coioides* found in the seagrass was only 29 cm (while the maximum reported length is ca. 120 cm: Froese & Pauly, 2006) and 16 cm for *L. russellii* (maximum reported length 50 cm: Froese & Pauly, 2006) is an indication that seagrass is more important for juveniles of these species than for adults. Seagrass might also be advantageous because it provides shelter from predators. An indication for this is that the amount of shrimp at the non-vegetated Teratai location was not significantly different from the amounts at the two seagrass locations, but here only one grouper and no snappers were caught.

The differences in CpUE of *E. coioides* between the two seagrass locations, Kepuh and Kuala Pasar were not statistically significant, but the abundance differences of *L. russellii* were (Fig. 3). It is not clear what causes this difference, but it could partly be an artefact of the very low

Table 7 Relative importance of common food items in the diets of the *E. coioides*, and *L. russellii* at length class 2–17 cm, expressed as percentage frequency of occurrence (FO), weight percentage (WT), number percentage (NO), and relative importance index (RI_a)

	FO (%)	WT (%)	NO (%)	RI_a (%)
E. coioides				
Shrimp	95.5	79.8	93.9	89.0
Fish	3.4	19.4	7.1	9.9
Crab	0.4	0.7	1.4	0.8
Other	0.4	0.4	0.5	0.3
L. russellii				
Shrimp	83.2	67.3	90.9	80.7
Fish	13.9	30.0	7.1	17.1
Crab	1.0	2.7	1.1	1.7
Other	1.0	0.0	0.6	0.5

CpUE values for *L. russellii*. These low CpUE values do not reflect realistic biomass estimates, because of the relatively low catch efficiency (catchability) of snappers when using a beam trawl. Snappers are able to swim fast, and therefore they can avoid the trawl, resulting in lower abundance estimates. Groupers, however, tend to stay motionless, hiding among the vegetation and are therefore easily caught by trawl. Connolly (1994b) pointed out that described differences in fish assemblages could, in some cases, be more dependent on the gear used than on actual differences between locations. This difference in catchability is one of the reasons for the much lower CpUE of snappers when compared with groupers. It is probably also the reason why both the probability of catch and the CpUE estimates of *L. russellii* are higher at night than during the day (Fig. 4, 5), because in the dark snappers are less likely to avoid the trawl.

Within the seagrass locations we found that juvenile *E. coioides* were more abundant in dense and mixed than in patchy microhabitat (Fig. 4, 5), which is in accordance with the selection by pelagic larvae of structurally complex microhabitats for their first settlement. Redistribution of juveniles only takes place within the selected seagrass bed, because crossing bare substrate increases the risk of predation (Bell & Westoby, 1986; Bell et al., 1997). Irlandi et al. (1995) argue that rates of predation increase with increased fragmentation of the seagrass habitat. They suggest that bare substrate surrounding the patches of vegetation may function as corridors that facilitate the movement of large mobile organisms into and among the patches. Tolan et al. (1997) found that post-larvae stages and young juveniles of several species were strongly associated with specific seagrass habitats with the areas of highest complexity generally holding the highest fish densities.

Seasonality in the occurrence and abundance of juvenile groupers and snappers

Spawning in both *E. coioides* and *L. russellii* is continuous, with two peaks along the year. Larvae of both species are transported into Banten Bay by currents from the Indian Ocean through the Sunda Strait during the wet season and by currents from the Java Sea during the dry months. Accordingly we expected to find seasonality in the abundance of juveniles of both species in the catches. We did indeed find temporal patterns in probability of catch and mean CpUE in both *E. coioides* and *L. russellii* (Fig. 2–5), which probably were caused by the appearance of two cohorts, the first in November to December 1998 (after the wet season) and the second in February to June 1999 (after the dry season). However, the patterns were confounded by heavy fishing on juveniles by push net fishermen, who removed up to 80% of the juveniles in a matter of weeks (Nuraini, unpublished), thereby strongly influencing the CpUE values.

Conclusion

From this study we can conclude that for the juvenile stages of *E. coioides* and *L. russellii* in Banten Bay seagrass habitats are of great importance. Because the extent and quality of the seagrass areas is under pressure due to human activities there is less habitat available for the species to grow up and subsequently migrate to their adult habitats. Moreover, since the likelihood of larvae to encounter suitable habitat is strongly dependent on habitat abundance (Carr, 1991) and habitat distribution (Hannan & Williams, 1998) the probability of larvae reaching the few remaining seagrass beds in Banten Bay could be diminishing fast.

Seagrass areas are of critical importance for the settlement and nursery of early juveniles of groupers and snappers in Banten Bay, Indonesia. Juvenile Orange-spotted grouper, *Epinephelus coioides*, and Russell's snapper, *Lutjanus russellii*, were found almost exclusively in seagrass habitats, with a preference for seagrass of high structural complexity. The importance of seagrass was closely related to the abundance of shrimps, the most important food for juvenile groupers and snappers and the presence of cover against predators. The importance of the seagrass fields in Banten Bay justifies protection of the already small extent of this habitat (330 ha), which is also under increasing pressure from coastal development.

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