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ECOLOGY OF THE ESTUARINE CATFISHES (FAM: ARIIDAE) FROM THE MATANG MANGROVE ECOSYSTEM

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ABSTRACT

This study was conducted in Sg. Selinsing to determine the distribution and abundance, and the utilization of the mangroves by the estuarine catfishes. The data showed that Arius maculatus was the most abundant ariid followed by Arius venosus, Arius utik and Arius caelatus. The combined ariid density and biomass was significantly different between diel (day and night) and phase (floods and ebbs) combinations during neap tides, being highest in the day-flood combination but was not significant during spring tides. During neap tides, the combined ariid density and biomass was significantly higher during floods (phase pattern of tides) but was not affected by day and night patterns (except for Arius truncatus). Spring tide catches did not show any significant difference of combined density and biomass during phase (floods and ebbs), and diel (day and night) patterns. The density and biomass of the ariid species was significantly higher during neap tides except for A. truncatus that had significantly higher density and biomass during spring tides. The data suggested that there was temporal separation rather than spatial separation of the ariids in Sg. Selinsing. Higher percentages of immature ariids were recorded suggesting that they utilize the mangroves as nursery grounds. Ketengus typus, Osteogeneiosus militaris and Arius venosus had reasonably high percentage of matured females and suggests that these ariids also utilize the mangroves as breeding grounds. The feeding ground function of the mangroves was also shown where a variety of diet types were recorded from stomach contents of the ariids

INTRODUCTION

The Ariidae or commonly called the fork-tailed catfishes are chiefly coastal and inhabit mangroves, estuaries or coastal lagoons with muddy or sandy bottoms of varying turbidities (Burgess, 1989). Some inhabit inland waterways beyond tidal influence as well as in freshwater streams and lagoons (*Arius gigas* in central West Africa) while some inhabit and breed in almost isolated lakes (*A. magatensis* in the Philippines; *A. acutirostris* and *A. burmanicus* in Burma).

The diversity of the catfishes varies from different marine and estuarine habitats (Weber & Beaufort, 1913; Kailola, 1990; Taylor & Menezes, 1977; Taylor & van Dyke, 1981; Jayaram, 1984). Many studies on tropical estuarine fish assemblages show that the ariids are an important part of the fish community (Sasekumar *et al.*, 1992 & 1994; Chandrasekaran & Natarajan, 1992; Chong *et al.*, 1990; Jhingran, 1991;

Khoo, 1989; Reis, 1986; UNDP/UNESCO, 1991; Blaber, 1997; Blaber *et al.*, 1990 & 1990a; Baran, 1995; Yanez-Arancibia *et al.*, 1985 & 1985a; Boujard & Rojas-Beltran, 1988; Yanez-Arancibia & Lara-Dominguez, 1988; Hayase & Fadzil, 1997; Ahmad & Hayase, 1996; Ahmad, 1997).

Studies on tropical estuarine fish assemblage generally report on species diversity and abundance (density and biomass) but lacks on temporal and spatial distribution and partitioning of fish. Fish distribution is affected by tidal patterns (neap and spring tides), phase patterns of tides (floods and ebbs), diel patterns (day and night/light and dark), seasons, gear type, depth, feeding, reproduction, interactions, etc. Blaber *et al.* (1990) showed the effect of diel, season and depth on the distribution and abundance of prawn predators in the Gulf of Carpentaria. Robertson & Duke (1990) reported on the temporal patterns of catch data from different net types. Temporal and spatial niche partitioning adaptations were important and reduced inter specific competition among three co-occuring ariid species from Terminos Lagoon, Mexico (Yanez-Arancibia & Lara-Domingiez, 1988) while spatial segregation was important for five coexisting ariid species from Sepitiba Bay, Brazil (Azevedo *et al.*, 1998).

The ariids are abundant and widely distributed within the Matang mangrove ecosystem (Khoo, 1989; Sasekumar *et al.*, 1994; Singh & Sasekumar, 1994). Besides Matang other mangroves in Selangor and Merbok (Kedah) also showed high ariid abundance (Chong, *et al.*, 1990; Ahmad & Hayase, 1996; Hayase & Fadzil, 1997). Singh & Sasekumar (1994) showed that seven ariids coexisted within Sg. Selinsing and data from exploratory trawls suggested that the ariid catches were affected by diel (day and night) and tidal phase pattern (flood and ebb) interactions. Ahmad & Akhir (1999) showed that there was spatial and not temporal utilization of the finfish community within Sg. Selinsing.

The abundance of the ariids within the mangrove ecosystem raises certain questions regarding their success. Past studies on mangrove fishes suggested that their abundance could be related to their low exploitation, low predation, and high food availability within the mangroves (Singh & Sasekumar, 1994). The above observations thus prompted this study and it was conducted in a river channel at the Matang mangrove ecosystem, Taiping, Perak. The objectives of this study are outlined below:

- To study the standing stock of the ariids within the Matang mangroves
- To determine the ariid distribution and abundance within the Matang mangroves
- To study the importance of the mangroves to the ariids as nursery, breeding and feeding grounds.

MATERIALS AND METHODS

Fishes were sampled by trawl on a twenty-four hour cycle covering tidal patterns (neap and spring), phase patterns (floods and ebbs) and diel patterns (day and night/light and dark) in Sg. Selinsing in the Matang mangrove ecosystem, Taiping (Fig. 1, area A, B & C). This gave four

possible combinations for trawling during each tidal cycle (Spring/Neap tides = Day-Flood, Day-Ebb, Night-Flood and Night-Ebb). For each of the combination 2 trawls were conducted approximately 3 hours apart. Fish abundance was converted to density and biomass [see Singh (2002) for further explanation]. Five sampling trips were conducted, three during neap tides and two during spring tides. Trawling was conducted in mid-river of Sg. Selinsing for 15 to 30 minutes duration. All samples were kept for small catches while for large catches $^1/_4$ to $^1/_2$ were taken. Ariid specimens were put in polythene bags, labeled and stored in ice and were later dissected and examined. Standard length (cm) and wet weight were measured to the nearest 0.1 unit of measurement.

Maturity was determined by an artificial maturity index (see Singh, 2002 for details). Stomach contents based on the gravimetric method of Ricker (1968) was employed to analyse ariid diets. Stomach contents were weighed (gr.) and identified to either family or genera, and where possible, to species level. The density and biomass data was transformed by using the log transformation [$\log_{10}(x + 1)$] to homogenize the variance (Sokal & Rohlf, 1998) and was then tested by one-way analysis of variance (ANOVA). Significant difference of more than two means was then tested with Newman-Keuls Multiple Range test (MRT) via Statistica (CSS: ANOVA & MANOVA) (Statsoft, 1991).

RESULTS

The most abundant ariid sampled within Sg. Selinsing was *A. maculatus* (Fig. 2a). This was followed by *A. utik* and *A. venosus* (medium abundance), and *A. caelatus, K. typus* and *O. militaris* (low abundance). *A. sagor* had the lowest abundance. *A. sagor* and *A. venosus* had higher biomass as compared to other ariids (Fig. 2b). In spite of the similarity of the biomass of the two ariids, the biomass to density ratio showed that *A. sagor* (ratio = 0.18) was a larger fish as compared to *A. venosus* (ratio = 0.028) (Table 1). The high biomass of *A. venosus* was attributed to larger numbers rather than sizes. The biomass to density ratio for *A. maculatus* was the lowest notwithstanding its large numbers.

The density of the ariids (all species combined) was higher during neap tides as compared to spring tides for all the factor combinations (Table 2, Fig. 3). Significant difference in ariid density was observed during neap tides between the factor combinations (mean, day-flood = 453.5 no/ha; mean, night-flood = 359.9 no/ha; mean, day-ebb = 143.3 no/ha; mean, night-ebb = 163 no/ha) ($p<0.0039$, Fig. 4a). Newman Keuls MRT showed that the density during day-flood combination was significantly higher to that of night-flood, day-ebb and night-ebb combination. The density between night-flood, day-ebb and night-ebb was not significantly different. The ariid density (combined) was significantly higher during floods of neap tides ($p<0.0171$, Fig. 4b) while it was not significantly different between day and night ($p>0.05$). There was no significant difference in density (combined) between the factor combinations during spring tides ($p>0.05$, $F=1.42$). The density of *A. truncatus* was significantly higher during daytime ($p<0.02$, Fig. 5a) to nighttime while that of *A. utik* was significantly higher during floods to that of ebbs ($p<0.018$, Fig. 5b) during neap tides. All other ariids did not show

significant difference in density between day and night, and flood and ebb ($p>0.05$).

The mean biomass (combined) was significantly different during neap tides between factor combinations (mean, day-flood = 11.4 kg/ha; mean, night-flood = 6.07 kg/ha; mean, day-ebb = 4.7 kg/ha; mean, night-ebb = 4.7 kg/ha) ($p<0.0021$, Fig. 6a). Newman-Keuls MRT showed that the biomass for the day-flood combination was significantly higher than that of the day-ebb, night-ebb and night-flood combinations. There was no significant difference in biomass between the day-ebb, night-ebb and night-flood combinations. The ariid biomass (combined) was significantly higher during floods of neap tides ($p<0.0136$, Fig. 6b) and not significantly different between day and night ($p>0.05$). There was no significant difference in combined density and biomass between the factor combinations during spring tides ($p>0.05$, $F=2.5$). The biomass of *A. utik* was significantly higher during floods ($p<0.019$, Fig. 5c) while that of other ariids was not significantly different between day and night, and flood and ebb ($p<0.05$) during neap tides.

Ariid species density was higher during neap tides as compared to spring tides except for *A. truncatus* ($p<0.05$) (Fig. 7a & 8, Table 3 & 4). The combined ariid density was significantly higher during neap tides than spring tides (Fig. 9a, $p<0.0001$). The density of *A. maculatus* (Fig. 9b, $p<0.0077$), *A. utik* (Fig. 9c, $p<0.0003$), *A. venosus* (Fig. 9d, $p<0.0001$), and *K. typus* (Fig. 9e, $p<0.0434$) was significantly higher during neap tides as compared to spring tides (see also Fig. 8). The density for other ariids was not significantly different between neap and spring tides ($p>0.05$). The ariid species biomass was higher during spring tides to that during neap tides for *A. caelatus, A. sagor* and *A. truncatus* (Fig. 7b & 10, Table 3 & 5). The biomass was however only significantly higher during spring tides for *A. truncatus* (Fig. 9f, $p<0.0004$). *A. utik* (Fig. 9g, $p<0.0076$) and *A. venosus* (Fig. 9h, $p<0.0125$) had significantly higher biomass during neap tides as compared to spring tides.

The density of the ariids was significantly different among the three factor combinations (tide-diel-phase) during spring and neap tides ($p<0.0001$, Fig. 11). The Newman-Keuls MRT showed that the mean density during neap-day-flood was significantly higher to that of other factor combinations while the mean density for the spring-night-ebb and spring-day-flood was significantly smaller than other factor combinations. The mean density for neap-night-flood, neap-night-ebb and neap-day-ebb were classified as medium high densities while those of spring-day-ebb and spring-night-flood as medium low densities.

The mean biomass was significantly different between the factor combinations during neap and spring tides ($p<0.0061$, Fig. 12). Newman-Keuls MRT showed that the mean biomass during the neap-day-flood combination was significantly higher to other factor combinations while the spring-day-flood and spring-night-ebb combinations had significantly smaller biomass. The mean biomass during neap-day-ebb, neap-night-ebb, neap-night-flood, spring-night-flood and spring-day-ebb combinations were not significantly different and were classified as medium biomass. Overall the mean biomass between neap tides and

spring tides were generally mixed except for the biomass for neap-day-flood combination.

The maturity index (Fig. 13) showed that the ariids were largely juveniles with higher percentage being immature and maturing (index 1, 2, 3 & 4) (Table 6). Males of the ariids showed higher percentage of immaturity except for *A. utik, K. typus* and *O. militaris*. Only males of *A. utik* were sampled. *A. venosus, A. caelatus, A. maculatus* and *O. militaris* had higher percentage of females that were matured or spawning within the mangroves. Only *O. militaris* had high percentage of both matured males and females in Sg. Selinsing. The data above suggests that *A. venosus, A. caelatus,, O. militaris,* and *K.typus* utilize the mangroves as breeding as well as nursery grounds while *A. sagor, A. maculatus* and *A. truncatus* utilize the mangroves mainly as nursery grounds. The utilization of the mangroves by *A. utik* was uncertain because only males were sampled. Since the percentage maturity was high this species probably also utilizes the mangroves as breeding grounds.

The ariids feed on a variety of food that is found within the mangroves as well as within Sg. Selinsing. A list of the food types recorded from the stomach contents of the ariid catfishes is given in Table 7. The ariids consume larger amounts of crustacea (*Acetes* sp., penaeid prawns, *Alpheus* sp.), animal matter, Onchidiums, fish and polychaetes (Fig. 14). There was considerable diet overlap within the *Arius* sp. (Table 8). *K. typus* (4 diet types) and *O. militaris* (5 diet types) fed only on very few diet types while the *Arius* sp. fed on a variety of diets (9 to 18 diet types). The common diets among the *Arius* sp was *Acetes* sp, penaeid prawns, Onchidiums, polychaetes, fishes, *Alpheus* sp., organic matter and crustaceans parts.

K. typus mainly fed on crustacean parts and bivalves; *O. militaris* fed on crustacean parts, bivalves, and fish; *A. maculatus* fed mainly on *Acetes* sp., penaeids, *Alpheus* sp., onchidiums, fish and polychaetes; *A. caelatus* fed mainly on *Acetes* sp., penaeids, crustacean parts, organic matter, fish and polychaetes; *A. truncatus* fed mainly on polychaetes; *A. venosus* and *A. utik* fed mainly on *Acetes* sp., penaeid prawns, organic matter, fish and polychaetes; and *A. sagor* fed mainly on crustacean parts, brachyura parts, organic matter, *Alpheus* sp., onchidiums, fish, grapsid crabs, polychaetes and sipunculids. Among the *Arius* sp., the diet of *A. sagor* was the most diverse with 18 diet types. Octopus, a mangrove snake and a juvenile of a plotosid catfish were recorded from the diets of *A. sagor.*

DISCUSSION

The ariid catfishes have a circumtropical distribution between 35° North and 35° South of the equator (Fig. 15, from Kailola, 1990). They are distributed along continental margins of the western and eastern coasts of north, central and south America; west, south and east Africa (including Madagascar); the Red Sea and the northwestern Indian Ocean; and the Indo-Pacific region (Kailola, 1990). Past studies from Matang has shown that the ariids are widely distributed and abundant within the mangroves as compared to inshore waters and mudflats (Table 9). The ariid abundance was reported higher from mangrove channels/rivers (6.2

%), followed by mudflats (2 %) and inshore waters (2 %) (Sasekumar *et al.*,1994). (Chong *et al.* (1990) however, showed that the ariid abundance in Selangor (south of Matang) was higher from intertidal (19.3%) and subtidal (9%) areas of mudflats as compared to near inshore and far inshore waters while mangrove inlets and creeks did not record any catches. Yap (1995) showed that the ariid catches in Matang comprised 8.3 % in terms of abundance while their wet weight comprised 17.6 % of the total fish catch, second only to the sciaenids. Yap *et al.* (1994) showed that in trawls, the abundant sciaenid, *Johnius carouna* had a biomass of 15.2 kg/ha but this value was lower than that reported for *A. caelatus* (22.6 kg/ha) by Singh & Sasekumar (1994).

Besides spatial distribution between habitat types the ariids also have depth distribution. Abundance data from inshore waters of Matang (Sasekumar *et al,* 1994) and inshore, and far inshore waters of Selangor (Chong *et al,* (1990) suggested that the ariids were less abundant from the coastal shallow waters as compared to mangrove areas. The low and lack of abundance from the shallow coastal habitats of Matang and Selangor respectively was either related to net selectivity and/or ariid preference for deeper waters as well as mangrove areas. The preference for different habitats was probably related to their different life history stages. The depth during trawling in the shallow coastal waters of Matang (Singh & Sasekumar, 1994; Sasekumar *et al.,* 1994*)* and Selangor (Chong *et al.,* 1990) was between 3 to 10 meters. Fish trawl surveys off the west coast of Peninsular Malaysia showed that ariid distribution was in deeper coastal waters between 31 to 50 metres. Mohsin & Ambak (1996) showed that larger ariid species were found in deeper coastal waters. Sekharan (1973) and Tobor (1978) stated that ariid sizes increase as depth increases.

The relative temporal abundance of the ariids in the Matang mangroves has generally remained the same with *A. maculatus, A. venosus* and *A. caelatus* being the abundant ariids with *A. sagor* being the least abundant (Singh & Sasekumar, 1994; Hayase & Fadzil, 1999). Singh & Sasekumar (1994) however showed low abundance of *K. typus* from gill net catches in Sg. Selinsing. Eight species cohabit within Sg. Selinsing (this study); 5 species in the Selangor coast (Chong *et al.,* 1990); 7 species in Sg. Selinsing (Singh & Sasekumar, 1994); 7 species in Sg. Selinsing, Matang and 5 species in Merbok (Hayase & Fadzil, 1999); 5 species in Matang and 6 species in Merbok (Khoo, 1989) and 2 species in Sg. Pulai (Sasekumar *et al.,* 1989) (Table 10)

The density to biomass ratio is a simple index that can be used to assess sizes of the ariids that were sampled in Sg. Selinsing. The high biomass to density ratio for *A. sagor* showed that this species was the largest ariid sampled. The low biomass to density ratio of *A. maculatus* showed that there were larger numbers but smaller sizes of this ariid being caught (Table 11), from Singh, 2000). The general pattern for the distribution of the ariids in Sg. Selinsing was higher density and biomass during neap tides. The neap combinations had significantly higher density and biomass as compared to spring combinations with the neap-day-flood combination having the highest density and biomass. The larger biomass and density during floods at neap tides was probably related to larger sizes or that during floods larger volumes of water would bring in larger

numbers of fish. The abundance of *A. truncatus* during daytime and *A. utik* during floods of neap tides suggests temporal partitioning of the ariids within Sg. Selinsing. Ahmad (1997) showed that the ariid abundance from mangrove channels in Matang was not affected by tidal height (flood and ebbs) and turbidity. Sasekumar *et al.* (1994) showed that fish catch from push nets and trawls in Sg. Selinsing was generally not influenced by tides (flood and ebbs) and light (day and night).

The significantly higher density of the ariids during neap tides was probably related to dissolved oxygen and turbidity. Dissolved oxygen at the bottom of Sg. Selinsing is lower during spring tides as compared to neap tides [see Singh (2002), chapter 4]. Turbidity in Sg. Selinsing is also higher during spring tides (Singh, 2002). High turbidity affects vision as well as oxygen absorption (Bruton, 1985) and this may have depressed the density and biomass of the ariids during spring tides. The higher biomass of *A. truncatus* during spring tides suggested that larger specimens of this species probably tolerated higher turbidities. Other ariids were less tolerant to higher turbidities and were more abundant and had higher biomass during neap tides (*A. maculatus, A. venosus,A. utik* and *K. typus* for density; *A. venosus* and *A. utik* for biomass).

Cyrus & Blaber (1992) showed that there was a clear relationship between turbidity and fish distribution. They found that the catch per unit effort (CPUE) of *A. macrocephalus* and *A. mastersi* increased with increasing turbidity, that of *A. graeffei* decreased with increase in turbidity while the CPUE of *Arius* sp. 2 increased with higher turbidity and salinity. Cyrus (cited in Bruton, 1985) showed that different species of fish have different turbidity preference and that suspensoids that cause turbidity can affect fish in different ways (Bruton, 1985). Larger density of ariids during neap tides suggests that the ariids in Sg. Selinsing have preference for lower turbidity. Abou-Seedo *et al.* (1990) showed that fish numbers and biomass from seine catches in shallow waters from Kuwait Bay were higher in clearer waters as compared to turbid waters.

The higher percentage of immature individuals of the ariids strengthens further the hypothesis that mangroves are important nursery areas. In the case of the ariids, the mangroves were also utlised as breeding grounds especially for *A. venosus, K. typus, A. caelatus* and *O. militaris.* Chong *et al.* (1990) showed that fishes utlised the near inshore and mangrove areas as nursey grounds while Grey (1986) showed that the sea bass (barramundi – siakap) spawns in the coastal waters and their juveniles move into mangrove areas before maturing in fresh water. Hill *et al.* (1982) showed that the mud crab, *Scylla serrata* spawns in the deeper coastal waters and the larvae are later transported by tides into the mangroves where they grow and mature. Robertson & Blaber (1992) stated that mangroves harbor higher densities of juvenile fishes and that most fish species which use mangroves as juveniles, spawn outside estuaries.

I postulate four possible reasons for the abundance and the success of the ariids in the mangroves. Firstly, the predation of the ariids in the mangroves is relatively unknown. In a study of the diet analysis of marine snakes in the coastal waters of Malaysia, Voris & Voris (1983)

showed that the snakes *Enhydrina schistosa* and *Lapemis hardwickii* predated on the ariids. 80-100% of the former and 0-25% of the latter consisted of ariid catfishes. In a similar study, Jayne *et al.* (1988) reported that the marine snake, *Cerberus rynchops* also predated on ariid catfishes. The populations of the above marine snakes are not known and hence no conclusion can be drawn on the predation rates of marine snakes on the ariid catfishes. During sampling the author seldom came across the marine snakes.

Secondly, the adult males mouth brood the eggs. The larvae are retained until yolk absorption is complete (Rimmer, 1985). This enhances the survival of the catfishes and reduces predation of the larvae and hence reduces larval mortalities. Thirdly, there is a diverse food source available for the catfishes in the mangroves. This study showed that the ariid fed on a variety of food types and also that there was a considerable food overlap among the ariids. Competition for food can be reduced either by utlising a large or a diverse food resource. The mangroves seem to supply both. Fourthly, there is a lack of interest in the catfish as a protein source and this has prevented its exploitation. This is reflected by the low economic returns and fishing interest in the catfish landings. Fisheries statistics show that the economic value of the catfish is low making up only 5.5% of the total artisanal and 0.64% of the total commercial catch for the state of Perak (Singh & Sasekumar, 1994).

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Figure 1 : Water parameter and fish sampling sites in Sg. Selinsing (area A, B & C), Matang Mangroves (see Singh 2002 for details)

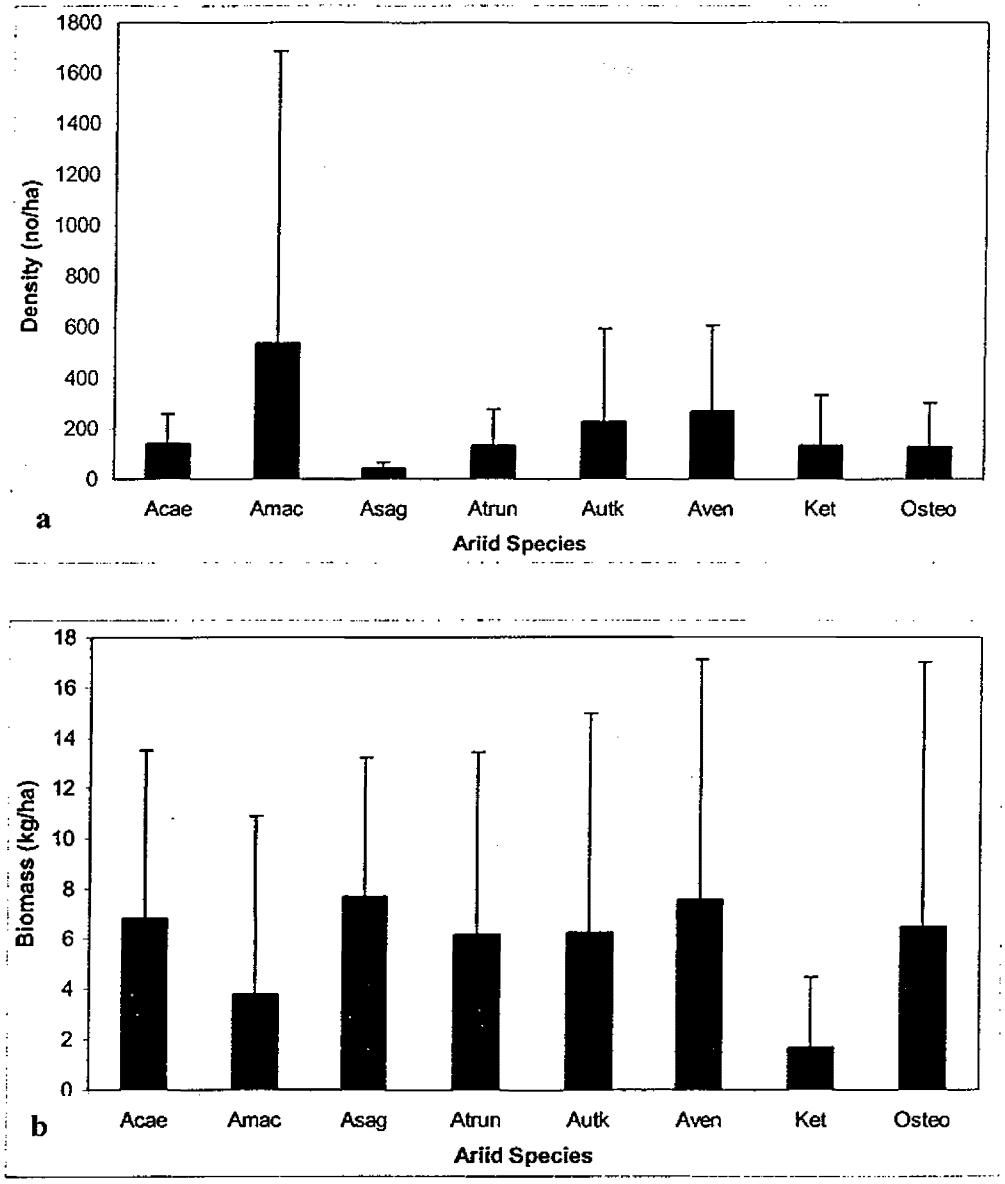


Figure 2 : Mean density (a) and biomass (b) of ariids in trawls in Sg. Selinsing (Acae -A. caelatus; Amac - A. maculatus; Asag - A. sagor; Atrun - A. truncatus; Autk - A. utik; Aven - A. venosus; Ket - K. typus; Osteo - O. militaris)

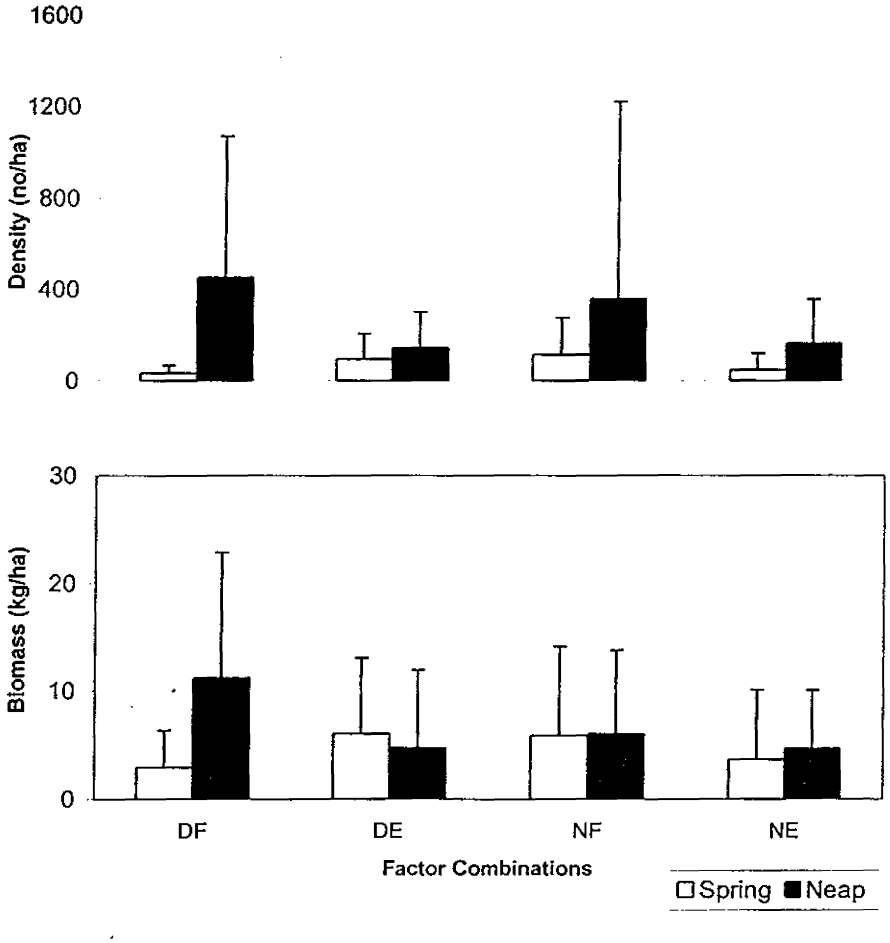
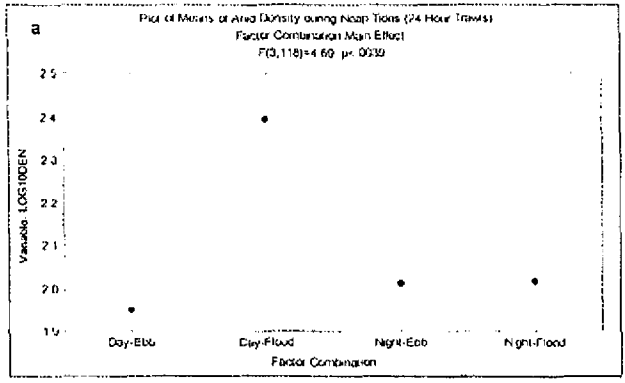
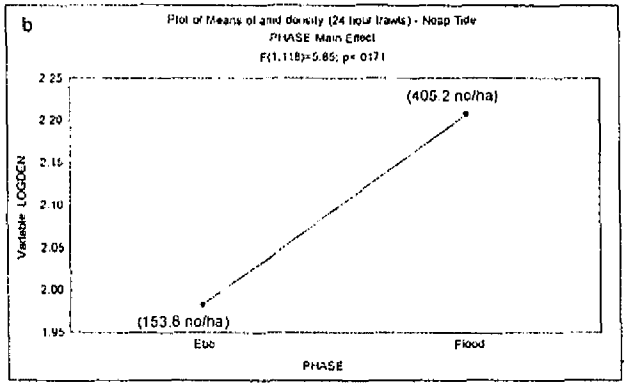


Figure 3 : Mean density and Biomass of ariids from trawls during spring and neap tides in Sg. Selinsing (DF = Day-Flood; DE = Day-Ebb; NF= Night-Flood; NE = Night-Ebb)


a
Plot of Means of Grid Density during Neap Tides (24 Hour Trawls)
Factor Combination Main Effect
F(3,118)=4.60; p< .0039
Variable LOG10DEN
2.5
2.4
2.3
2.2
2.1
2.0
1.9
Day-Ebb
Day-Flood
Night-Ebb
Night-Flood
Factor Combination

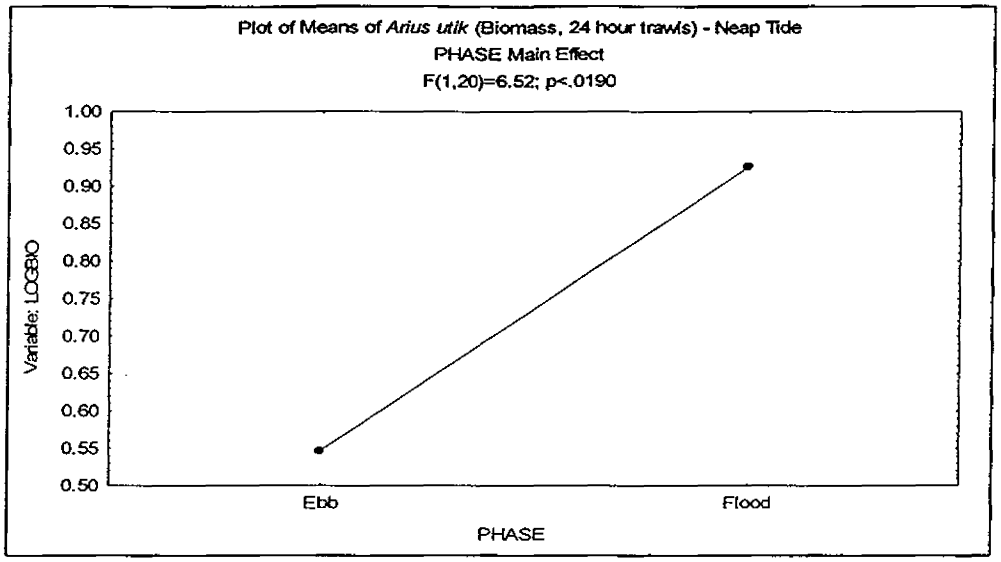

b
Plot of Means of grid density (24 hour trawls) - Neap Tide
PHASE Main Effect
F(1,118)=5.85; p< .0171
Variable LOGDEN
2.25
2.20
2.15
2.10
2.05
2.00
1.95
(405.2 no/ha)
(153.8 no/ha)
Ebb
Flood
PHASE

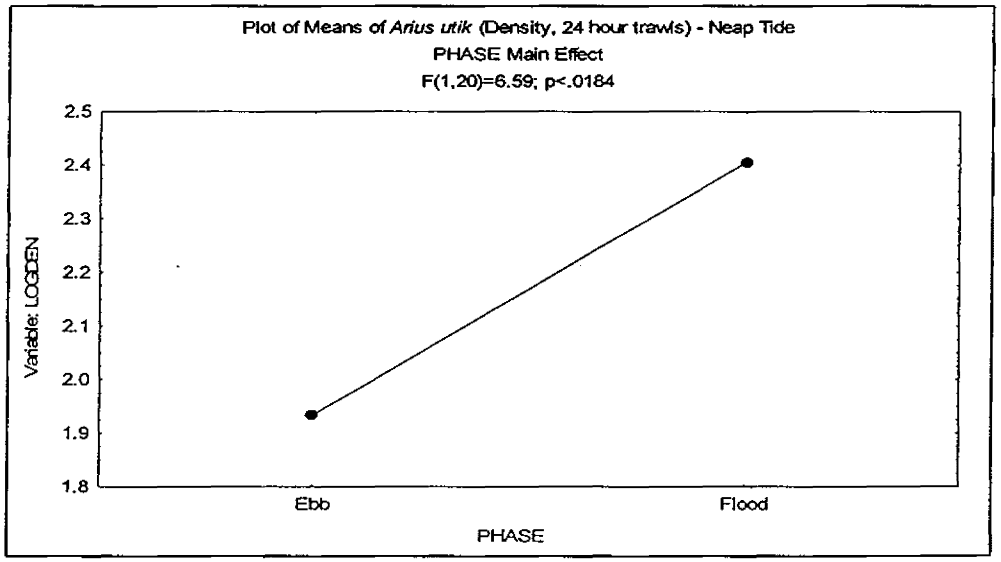
Newman-Keuls MRT: LOGDEN (2 way ANOVA) - Neap Tide

Homogeneous Groups, alpha=.05 INTERACTION: Diel X Phase				
	Mean Density		Homogeneous Groups	
Factor Combination	(no/ha)	N	1	2
Day Ebb	143.6	28	xxxx	
Night Ebb	163	32	xxxx	
Night Flood	359.9	32	xxxx	
Day Flood	453.5	30		xxxx

Figure 4a One way ANOVA of ariid density by factor combination from trawls during Neap Tides (Day-Ebb; Day-Flood; Night-Ebb; Night-Flood)

Figure 4b One way ANOVA of ariid density with Phase as main effect during Neap Tides from trawls





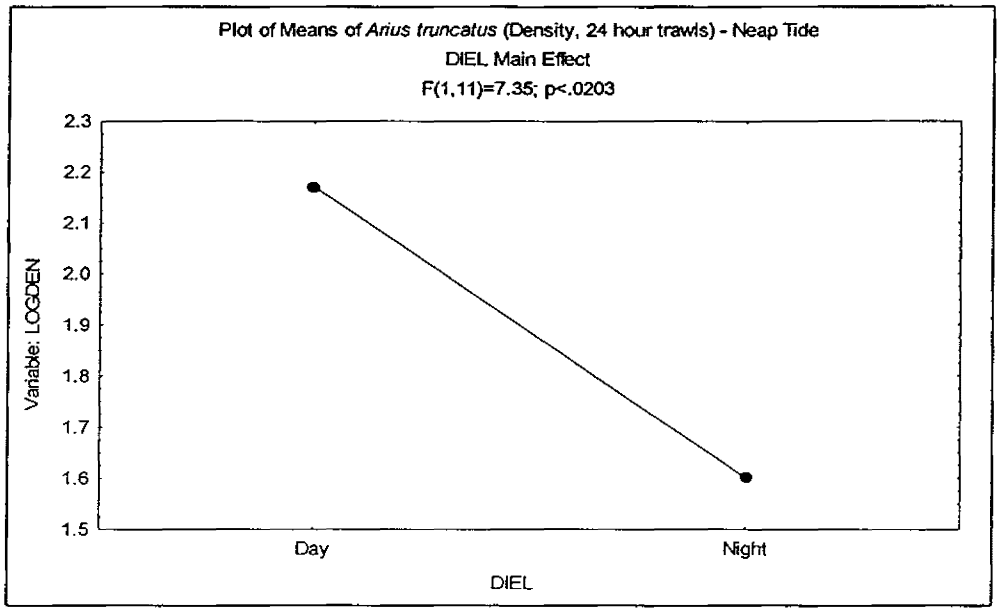


Figure 5 : One way ANOVA of ariid density and biomass by Diel and Phase from trawls during Neap Tides

Newman-Keuls MR1 variable LnBB(12) way ANOVA) - Neap Tide
Homogeneous Groups, alpha= 05
INTERACTION, Del v Phase

Factor Combination		Mean Biomass (kg/ha)	N	Homogeneous groups	
Day	Ebb	4.27	28	XXXX	
Night	Ebb	4.7	32	XXXX	
Night	Flood	6.7	32	XXXX	
Day	Flood	11.23	30		XXXX

Figure 6a One way ANOVA of arid biomass by factor combination from tracks during Neap Tides (Day-Ebb, Day-Flood, Night-Ebb, Night-Flood)

Figure 6b One way ANOVA of arid biomass with Phase as main effect for trans tracks during Neap Tides

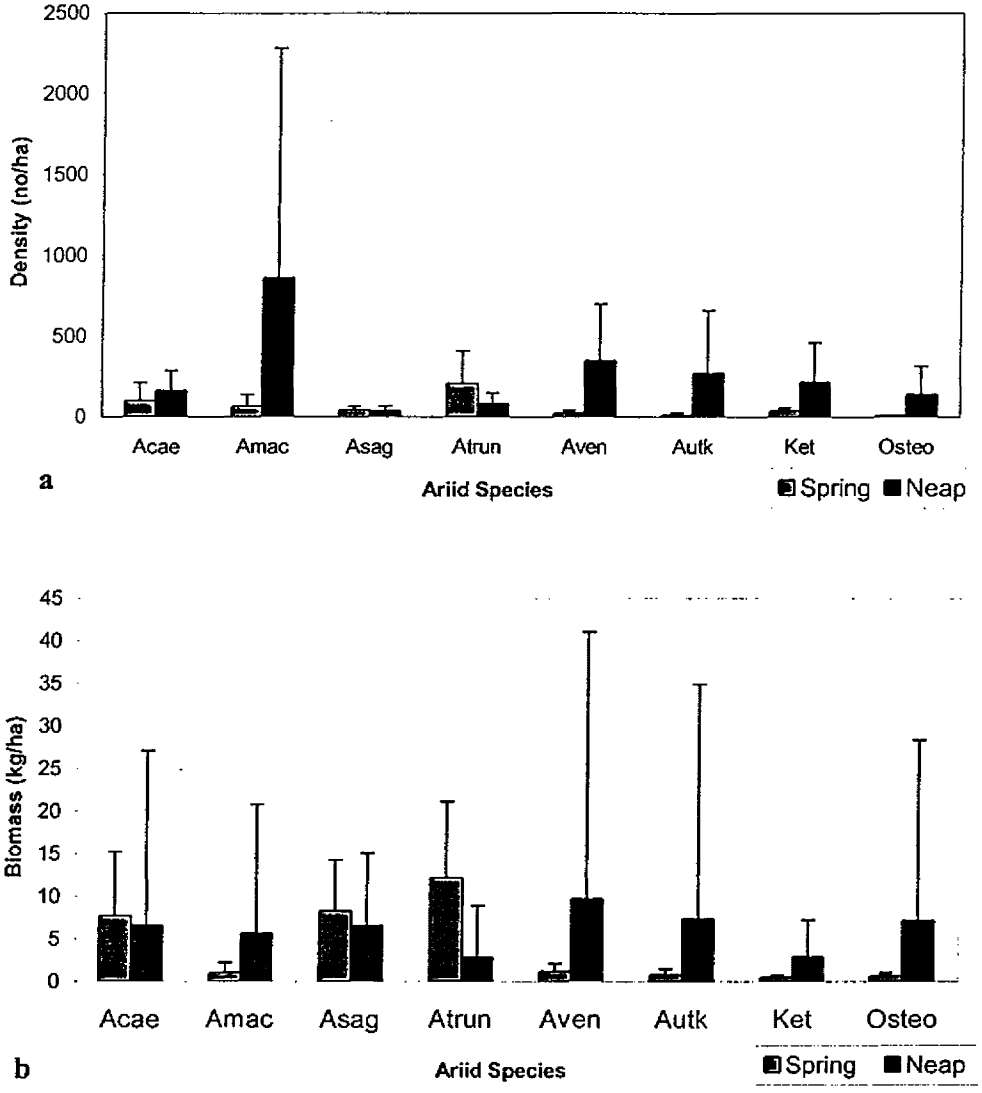


Figure : 7 Mean density (a) and biomass (b) of ariids during spring and neap tides in trawls (Acae - A. caelatus; Amac - A. maculatus; Asag - A. sagor; Atrun - A. truncatus; Aven - A. venosus; Autk - A. utik; Ket - K. typus; Osteo - O. militaris)

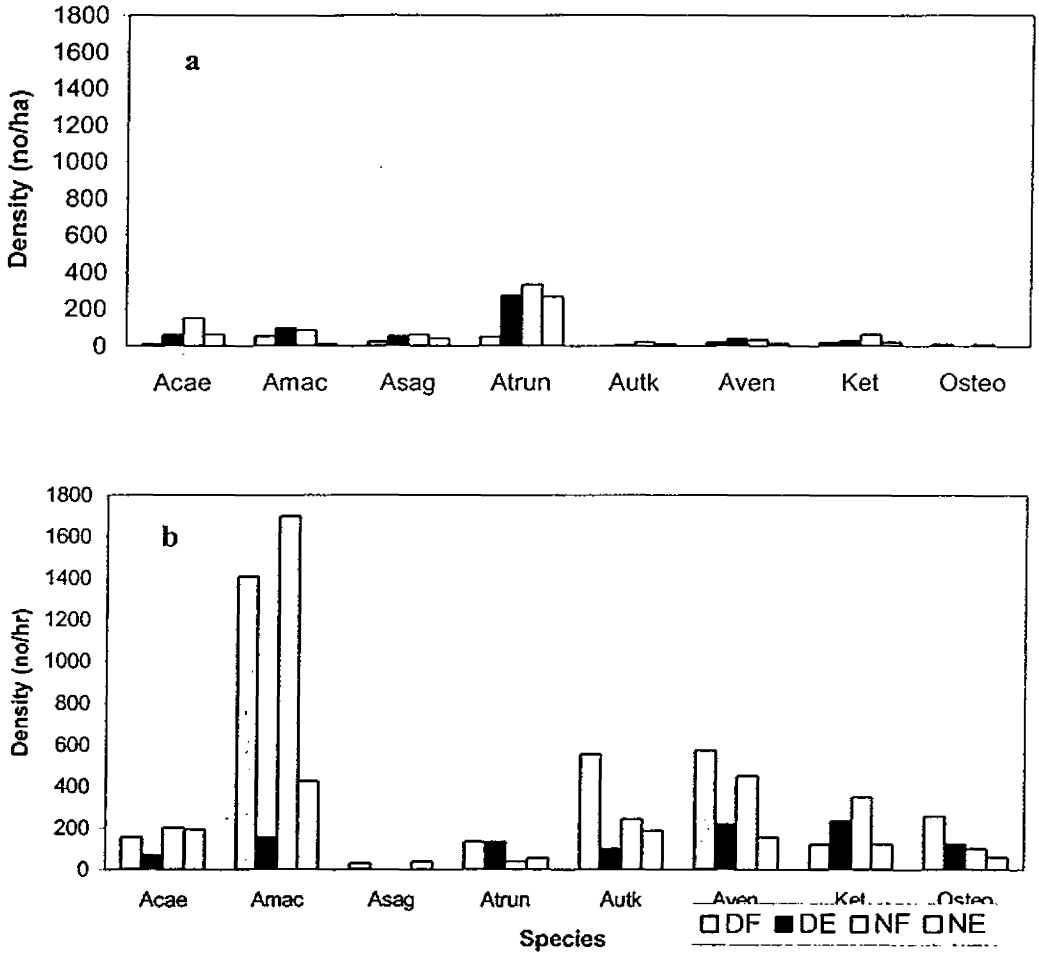


Figure : 8 Mean density of ariid species during different factor combinations (a - spring tides, b - neap tides)
(Acae - A. caelatus; Amac - A. maculatus; Asag - A. sagor; Atrun - A. truncatus; Autk - A. utik; Aven - A. venosus; Ket - K. typus; Osteo - O. militaris)
(DF - Day Flood; DE - Day Ebb; NF - Night Flood; NE - Night Ebb)

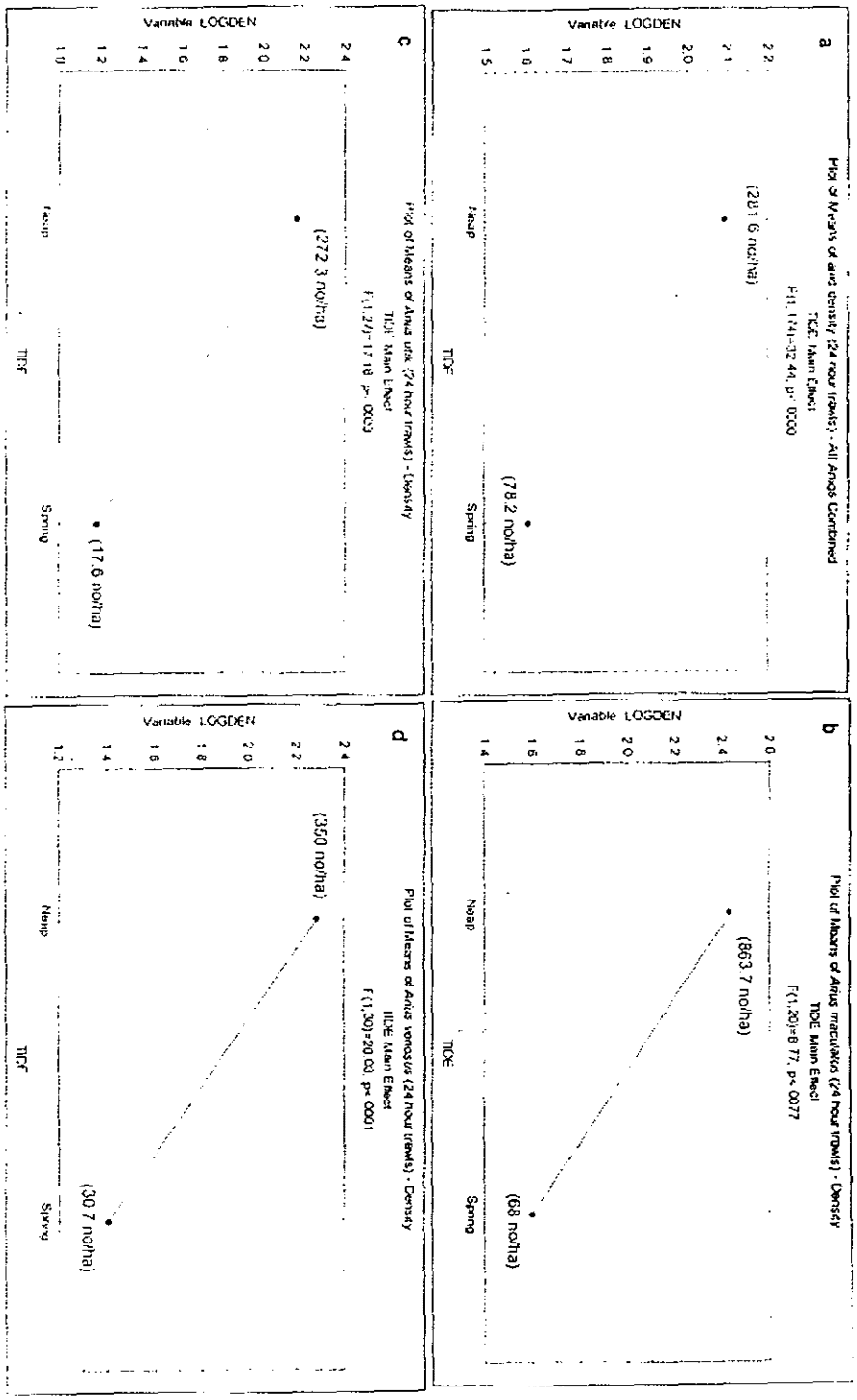


Figure 4 One-way ANOVA of mud density and biomass during Neap and Spring Tides (values in parentheses are means)

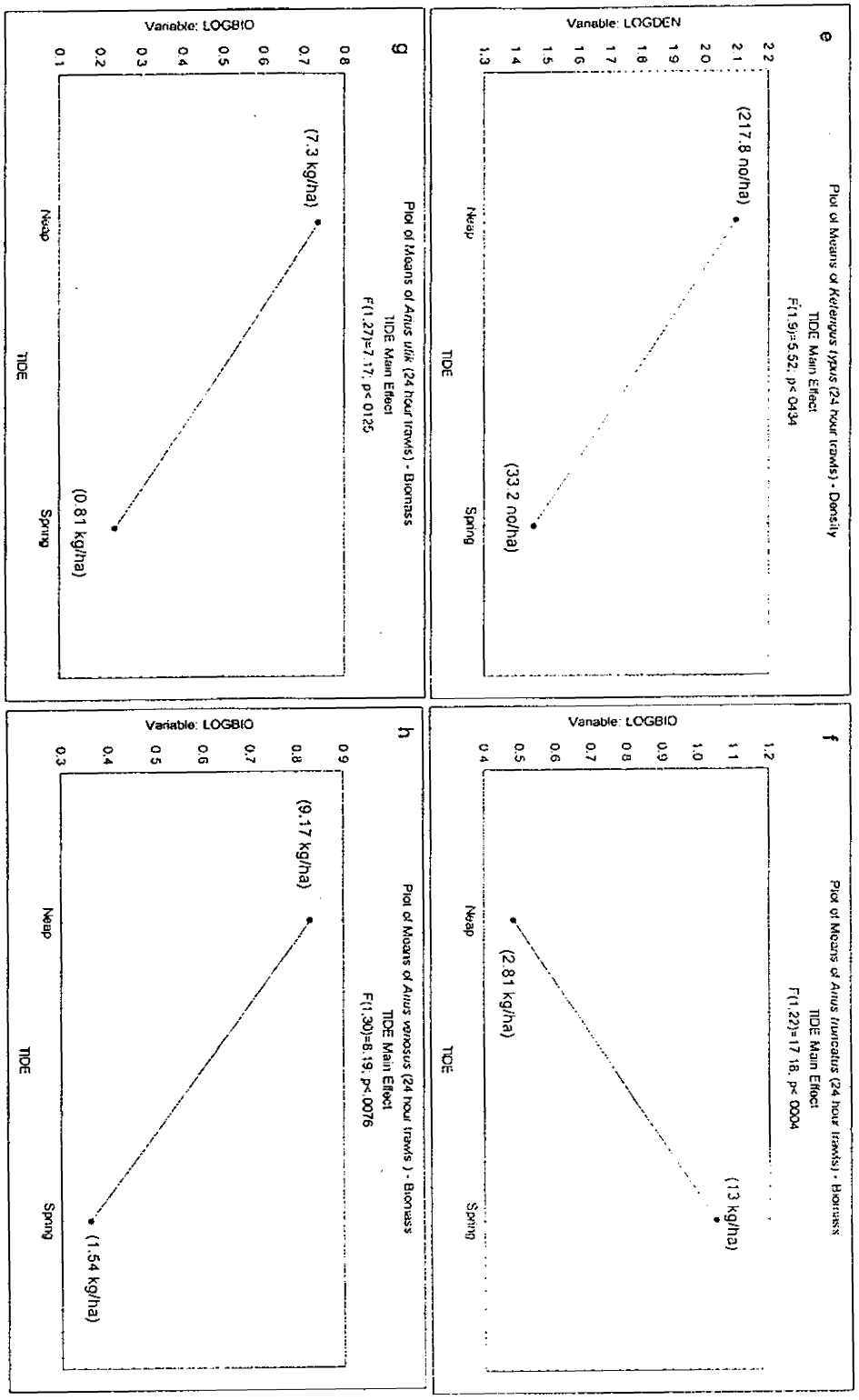


Figure 9 Continued

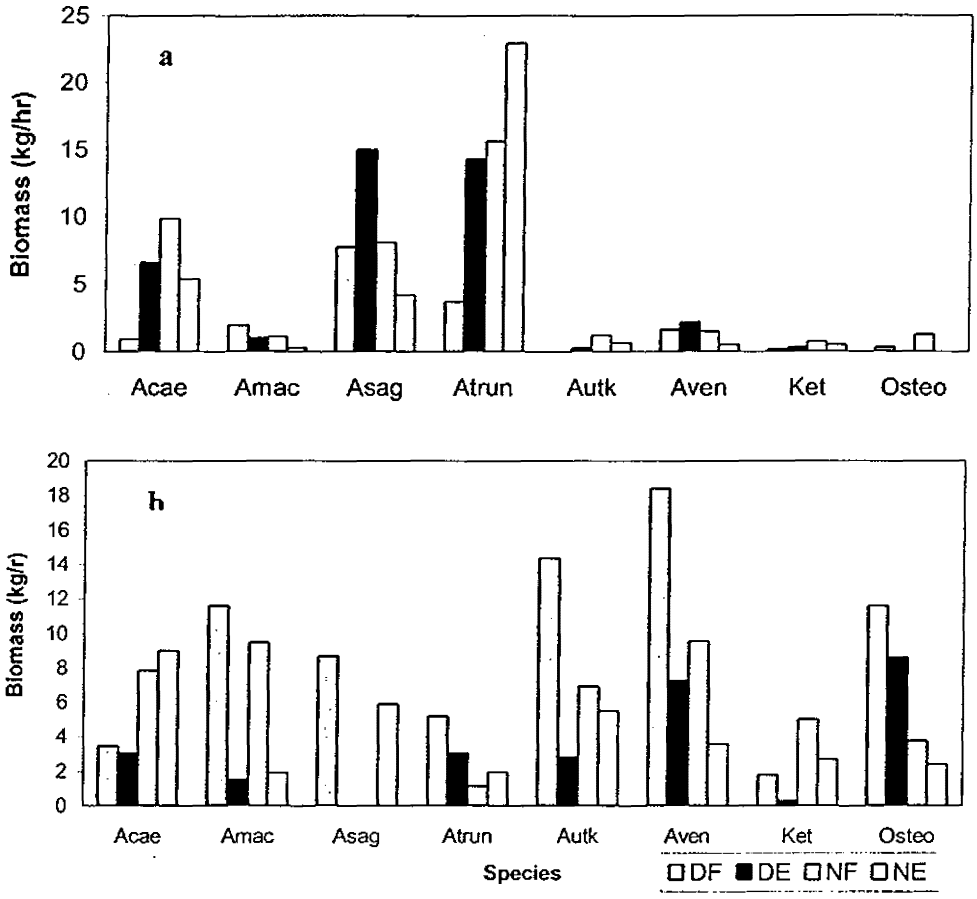


Figure 10 : Mean biomass of ariids during different factor combinations (a - Spring Tide, b - Neap Tide) (Acae - A. caelatus; Amac - A. maculatus; Asag - A. sagor; Atrun - A. truncatus; ven - A. venosus; Autk - A. utik; Ket - K. typus; Osteo - O. militaris) (DF - Day Flood; DE - Day Ebb; NF - Night Flood; NE - Night Ebb)

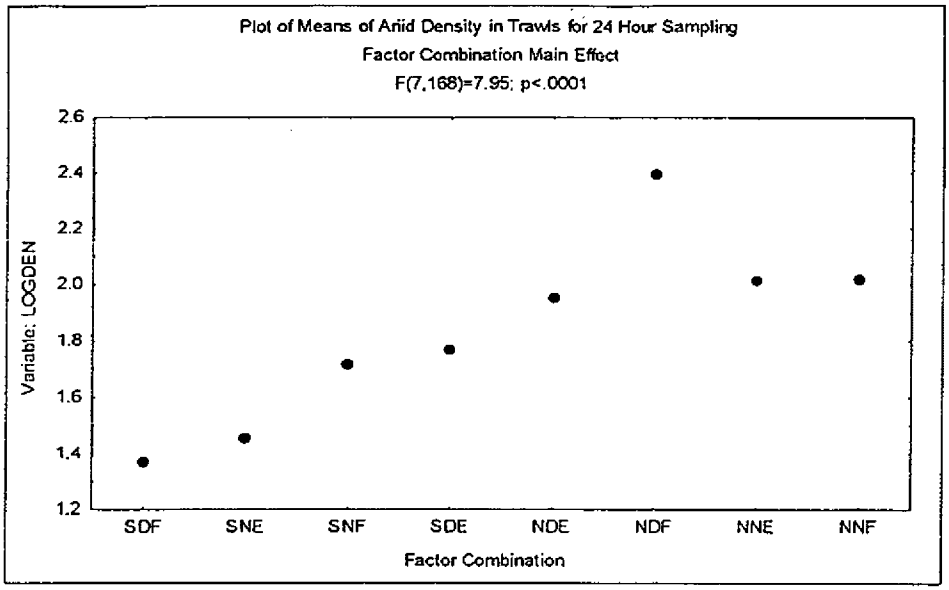


Figure 11 Plot of means of one way ANOVA of ariid density during different factor combinations for 24 hour trawls in Sg. Selinsing
(SDF - Spring Day Flood; SNE - Spring Night Ebb; SNF - Spring Night Flood; SDE - Spring Day Ebb; NDE - Neap Day Ebb; NNE - Neap Night Ebb; NNF - Neap Night Flood; NDF - Neap Day Flood)

Newman-Keuls Multiple Range test; 24 Hour Trawl Sampling for both Neap and Spring Tides (Density)

Homogeneous Groups, alpha=.05 MAIN EFFECT: Factor Combination				
	Mean Density	Homogeneous Groups		
Factor Combination	(no/ha)	1	2	3
Spring Day Flood	32.9	XXXX		
Spring Night Ebb	47.1	XXXX		
Spring Night Flood	113.9	XXXX	XXXX	
Spring Day Ebb	95.5	XXXX	XXXX	
Neap Day Ebb	143.3		XXXX	
Neap Night Ebb	163		XXXX	XXXX
Neap Night Flood	359.9		XXXX	XXXX
Neap Day Flood	453.5			XXXX

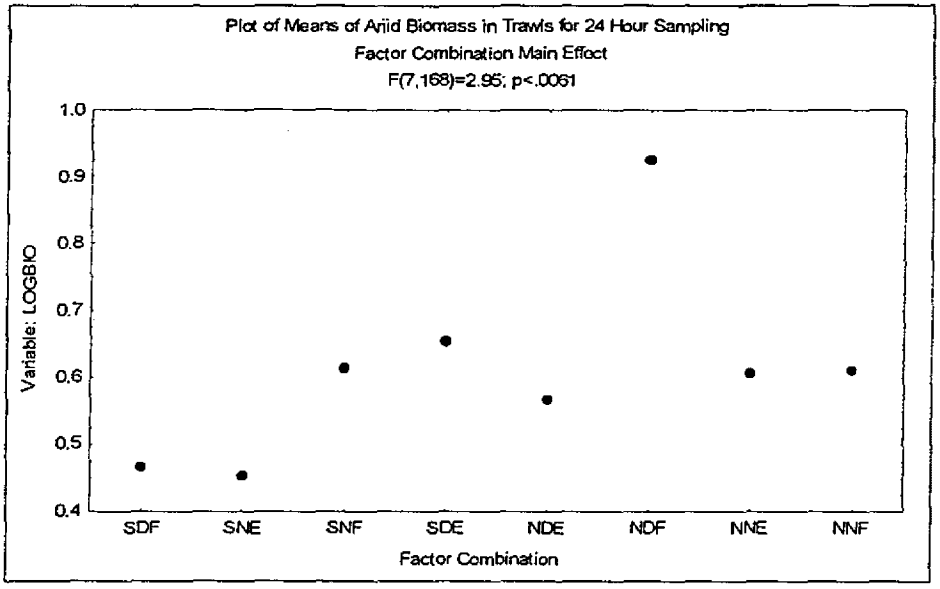


Figure 12 Plot of means of one way ANOVA of ariid biomass during different factor combinationsfor 24 hour trawls in Sg. Selinsing
(SDF - Spring Day Flood; SNE - Spring Night Ebb; SNF - Spring Night Flood;
SDE - Spring Day Ebb; NDE - Neap Day Ebb; NNE - Neap Night Ebb;
NNF - Neap Night Flood; NDF - Neap Day Flood)

Newman-Keuls Multiple Range test; 24 Hour Trawl Sampling for both Neap and Spring Tides (Biomass)

Homogeneous Groups, alpha=.05 MAIN EFFECT: COMB			
	Mean Biomass	Homogeneous Groups	
Factor Combinations	(kg/ha)	1	2
Spring Night Ebb	3.69	xxxx	
Spring Day Flood	2.95	xxxx	
Neap Day Ebb	4.77	xxxx	xxxx
Neap Night Ebb	4.7	xxxx	xxxx
Neap Night Flood	6.07	xxxx	xxxx
Spring Night Flood	5.91	xxxx	xxxx
Spring Day Ebb	6.09	xxxx	xxxx
Neap Day Flood	11.2		xxxx

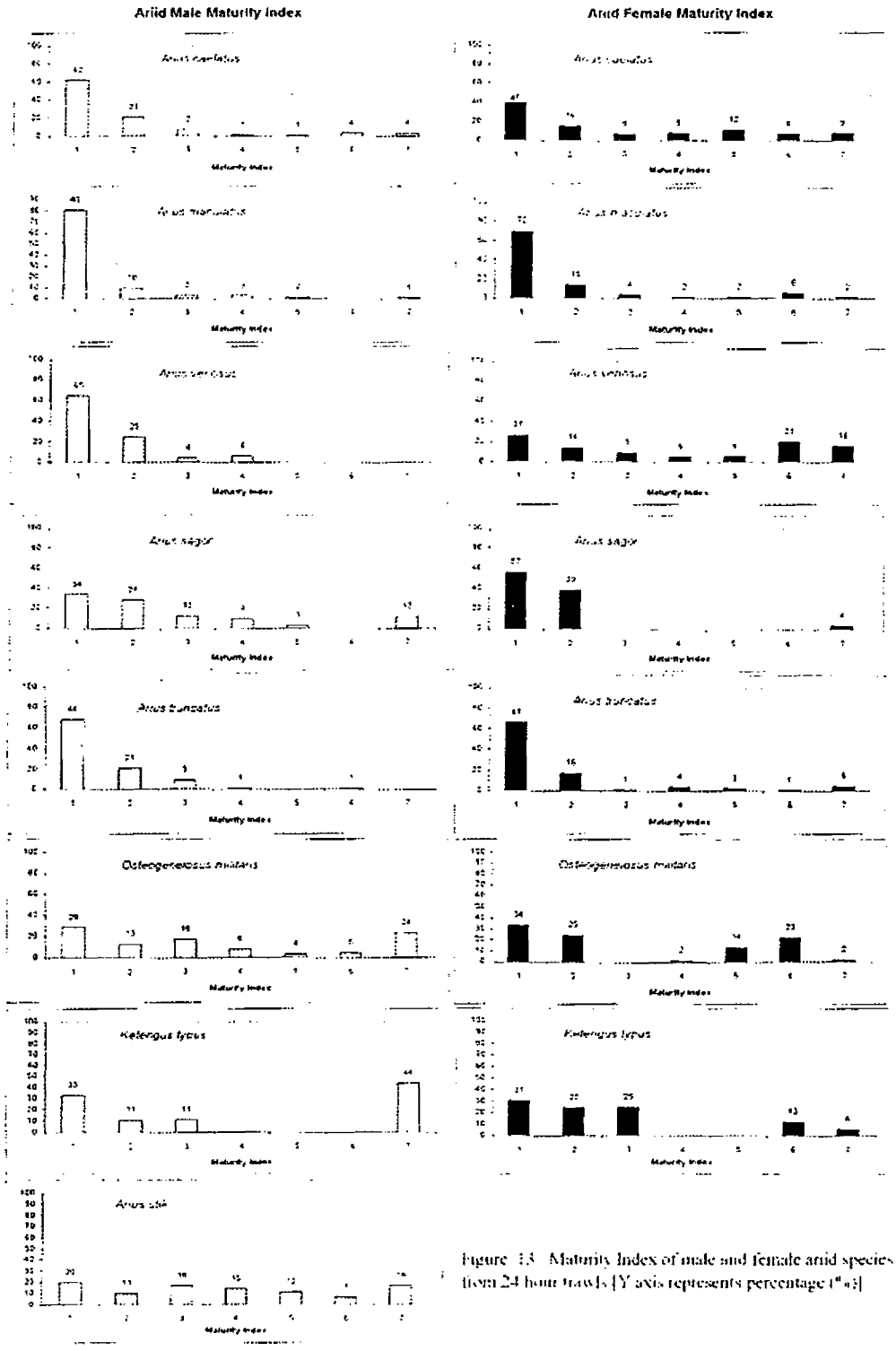


Figure 13 Maturity Index of male and female ariid species from 24 hour trawls (Y axis represents percentage (%))

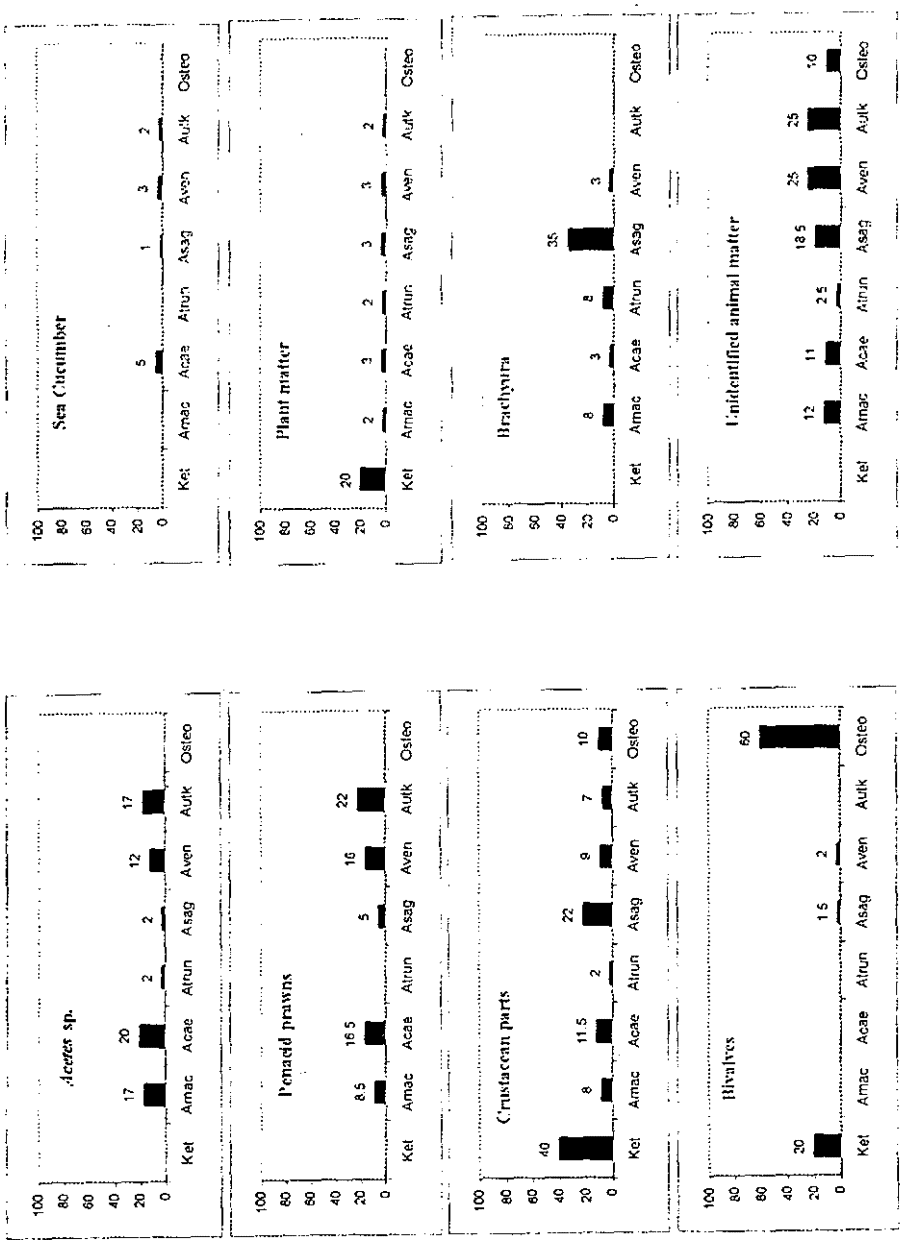


Figure 14 Percentage wet weight of food types eaten by ariids from the Matang mangroves (Ket - *Ketengus typus*; Amac - *Arius maculatus*; Acae - *Arius caelatus*; Atrun - *Arius truncatus*; Asag - *Arius sagor*; Aven - *Arius venosus*; Autk - *Arius utik*; Osteo - *Osteogeneiosus militaris*)

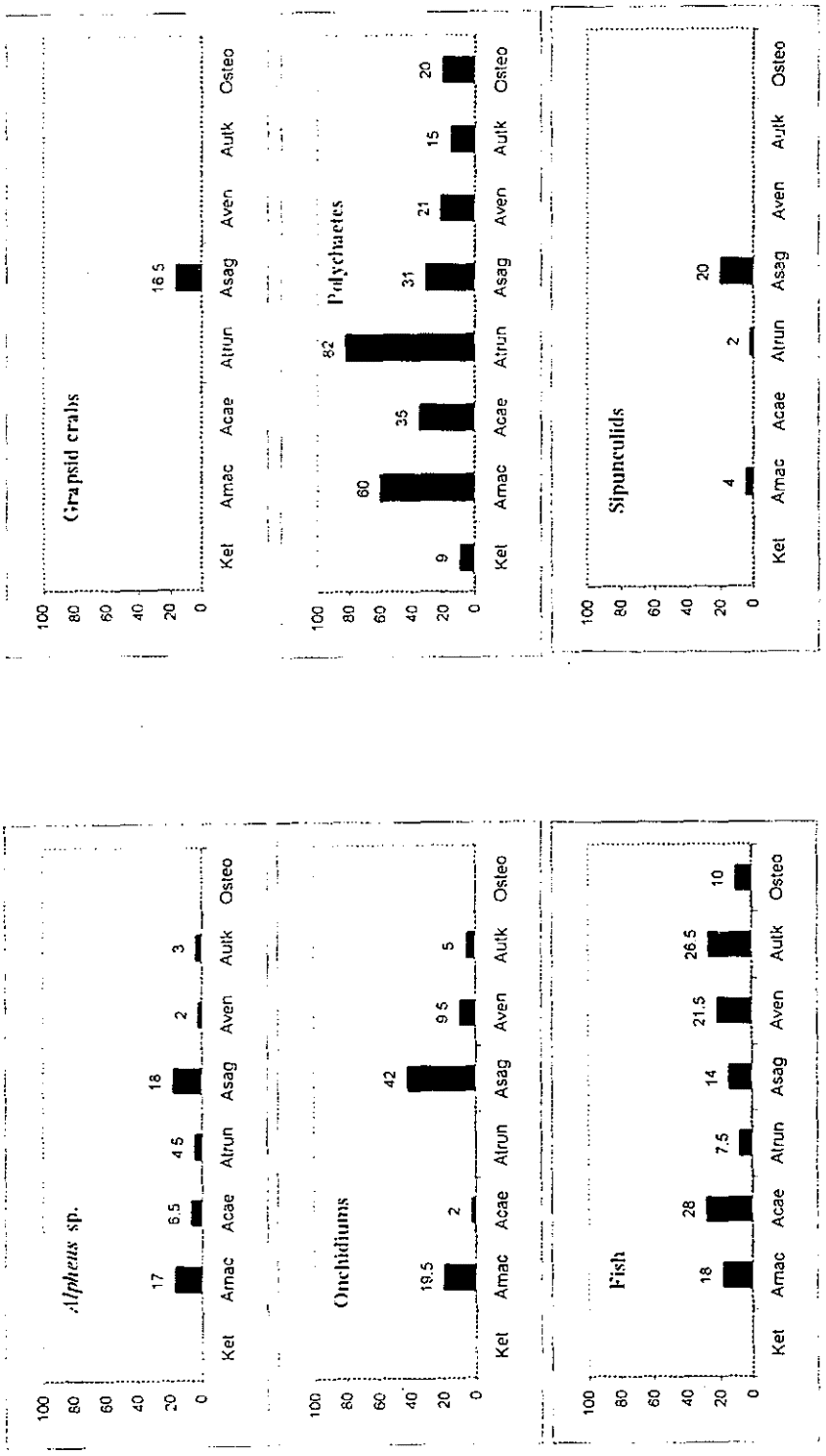


Figure 14 Continued



Figure 15 World distribution of the Ariidae (from Kailola, 1990)

Table 1 Mean density and biomass of ariids from trawls in Sg. Selinsing

Species	Density (no/ha)	Biomass (kg/ha)	Biomass/Density Ratio
Arius caelatus	141.1 ± 117.4	6.8 ± 6.7	0.048
Arius maculatus	538.2 ± 1147.4	3.8 ± 7.1	0.0071
Arius sagor	41.9 ± 23.8	7.7 ± 5.5	0.18
Arius truncatus	134.2 ± 142.2	6.2 ± 7.2	0.046
Arius utik	228.4 ± 365.5	6.2 ± 8.7	0.027
Arius venosus	270.7 ± 334.3	7.6 ± 9.5	0.028
Ketengus typus	133.9 ± 196.8	1.7 ± 2.8	0.012
Osteogeneiosus militaris	129.8 ± 170.1	6.5 ± 10.5	0.05

Table 2 Mean density and mean biomass ariids from trawl surveys during spring and neap tides in Sg. Selinsing

Factor Combination	Tide	Density (± sd) (no/ha)	Biomass (± sd) (kg/ha)
Day - Flood	Spring	33 ± 35	3 ± 3.4
	Neap	453.5 ± 614.41	11.24 ± 11.63
Day - Ebb	Spring	96 ± 109.6	6.1 ± 6.69
	Neap	143.3 ± 156	4.7 ± 7.2
Night - Flood	Spring	114 ± 161	6 ± 8.2
	Neap	359.9 ± 858.5	6.07 ± 7.710.6
Night - Ebb	Spring	47 ± 72	3.69 ± 6.46
	Neap	163 ± 193	4.7 ± 5.42

Table 3 Mean density (no/ha) and biomass (kg/ha) of ariid species during neap and spring tides from trawls in Sg. Selinsing

	Density (no/ha)		Biomass (kg/ha)	
Ariid Species	Neap Tide	Spring Tide	Neap Tide	Spring Tide
Arius caelatus	165.9 ± 120	103.3 ± 109.3	6.5 ± 6.6	7.6 ± 7.5
Arius maculatus	863.7 ± 1421.3	65.4 ± 71.3	5.7 ± 8.8	1 ± 1.1
Arius sagor	38.5 ± 29.5	43.5 ± 22.6	6.5 ± 5.2	8.2 ± 5.9
Arius truncatus	84.2 ± 65.4	208.5 ± 201.8	2.8 ± 2.7	12.2 ± 8.9
Arius utik	272 ± 388.5	17.6 ± 14.2	7.3 ± 9.2	0.8 ± 0.7
Arius venosus	350 ± 351.8	24.8 ± 17.6	9.7 ± 10.2	1.2 ± 0.87
Ketengus typus	217 ± 241.8	38.5 ± 21.2	2.9 ± 3.6	0.5 ± 0.22
Osteogeneiosus militaris	142.4 ± 174.3	10.9	7.1 ± 10.9	0.7 ± 0.31

Table 4 Mean density (no/ha) of ariid species during factor combinations during neap and spring tides from trawls in Sg. Selinsing

Factor Combination	Tides	Ariid Species							
		A. caelatus	*A. maculatus*	*A. sagor*	*A. truncatus*	*A. utik*	*A. venosus*	*K. typus*	*O. militaris*
Day-Flood	Neap	157.8 ± 92.8	1410 ± 1310.3	30.8	135.8 ± 70.7	557.5 ± 681.4	572.9 ± 387.6	123.5	257.3 ± 255.4
	Spring	10.2	56.5 ± 65.5	25.7 ± 7.2	51.4 ± 58.2	-	20.5	20.5	10.2
Day-Ebb	Neap	72 ± 44.8	156.9 ± 168.2	-	133.8 ± 72.7	101.2 ± 120.9	221.2 ± 252	236.7	121.7 ± 139.6
	Spring	64 ± 17.5	97 ± 73	55.9 ± 37.3	277.9 ± 152.2	5.9	40.3 ± 26.8	31.6 ± 28	-
Night-Ebb	Neap	192.1 ± 81.9	425.4 ± 523.8	41.1 ± 35.6	54.8 ± 11.8	186.9 ± 159.5	157.8 ± 140.7	123.5 ± 136.4	61.7 ± 20.8
	Spring	61.7	15.4 ± 7.2	41.1 ± 20.5	267.6	15.4 ± 7.2	15.4 ± 7.4	20.5	-
Night-Flood	Neap	203.2 ± 204.8	1698 ± 2703.4	-	39.4 ± 34	243.5 ± 218.1	451.6 ± 446.9	349.9 ± 465.7	108.8 ± 150.9
	Spring	151.8 ± 143.6	87.4 ± 109.1	61.7	334.5 ± 371.1	25.7 ± 21.8	36 ± 36.3	61.7	10.2

Table 5 Mean biomass (kg/ha) of ariid species during factor combinations during neap and spring tides from trawls in Sg. Selinsing

Factor Combination	Tides	Ariid Species							
		A. caelatus	*A. maculatus*	*A. sagor*	*A. truncatus*	*A. utik*	*A. venosus*	*K. typus*	*O. militaris*
Day-Flood	Neap	3.4 ± 0.55	11.6 ± 9.7	8.7	5.2 ± 3.6	14.6 ± 14.2	18.4 ± 13.8	1.8	11.6 ± 14.8
	Spring	0.92	1.69 ± 2.1	7.7 ± 4.1	3.7 ± 3.2	-	1.6	0.18	0.31
Day-Ebb	Neap	3.0 ± 2.2	1.5 ± 0.98	-	3.1 ± 1.8	2.8 ± 2.5	7.2 ± 7.2	0.31	8.6 ± 13.5
	Spring	6.6 ± 2.2	1 ± 0.81	15 ± 8.6	14.3 ± 4.4	0.3	2.2 ± 1.5	0.34 ± 0.28	-
Night-Ebb	Neap	9.0 ± 7.6	1.9 ± 2	5.8 ± 6.1	1.9 ± 1.3	5.4 ± 7.3	3.5 ± 3	2.7 ± 2.9	2.4 ± 2.1
	Spring	5.3	0.28 ± 0.019	4.1 ± 2.7	22.9	0.6 ± 0.2	0.5 ± 0.05	0.53	-
Night-Flood	Neap	7.8 ± 9	9.4 ± 15.3	-	1.1 ± 1	6.9 ± 6.2	9.5 ± 9.1	5 ± 6.3	3.7 ± 6.3
	Spring	9.8 ± 10.5	1.1 ± 1.3	8.1	15.6 ± 13.2	1.2 ± 1.1	1.4 ± 1.6	0.73	1.25

Table 6 Percent mature and immature male and female ariids in Sg. Selinsing

	Male		Female	
Ariid Species	**Immature**	**Mature**	**Immature**	**Mature**
A. caelatus	91	9	74	26
A. maculatus	96	9	73	27
A. venosus	100	-	56	44
A. sagor	84	16	96	4
A. truncatus	99	1	90	10
A. utik	64	36	-	-
K. typus	56	44	81	19
O. militaris	68	32	61	39

Table 7 Food types consumed by ariids in the Matang mangrove ecosystem

Crustacea		Fishes
Acetes sp.		Fish rays
Penaeid prawns		Fish scales
	Metapenaeus sp.	*Platycephalus* sp.
	Metapenaeus brevicornis	*Ilisha* sp.
	M. lysianassa	*Thryssa kamalensis*
	Parapenaeopsis sp.	*Anodontostoma chacunda*
	P. coromandelica	*Liza* sp.
	Penaeus merguiensis	*Leiognathus* sp.
Sphaeroma sp.		*Johnius* sp.
Thalassina anomala		*Johneops* sp.
Tachypleus sp.		*Johneops vogleri*
Stomatopoda		*Johnius carouna*
Cirolana sp.		*Arius* sp. – juvenile
Sergestid and penaeid larvae		*Cynoglossu s* sp.
Amphipods		Engraulidae
Alpheus sp.		Clupeidae
Macrobrachium sp.		Gobiidae
Paguridae		
Grapsidae (*Sesarma*)		
Ocypodidae		Polychaetes
		Marphysa sp.
		Nereis sp.
Bivalvia		
Placuna sp.		
Pelecyora trigona		Gastropods
Naculana sp.		Onchididae
		Nassarius sp.
Insecta		
Chilopoda		Sipunculida
Insect parts		*Phascolosoma arcuatum*
Reptilia		CephalopodaU
		Octopus sp.
Plant matter		
		Unidentified organic mass

Table 8 Diets of ariids sampled from Selinsing River (* denotes presence of food type)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ketengus typus				*						*			*		*		*			
Arius maculatus	*		*	*	*	*	*	*	*	*				*	*	*	*	*		
A. caelatus	*	*	*	*	*	*	*		*	*				*	*	*	*	*		
A. truncatus	*			*		*	*	*	*					*	*	*				
A. sagor	*	*	*	*	*	*	*	*	*			*	*	*	*	*	*	*	*	*
A. venosus	*	*	*	*	*	*	*		*	*	*		*	*	*	*	*			
A. utik	*	*	*	*	*	*	*		*	*	*			*	*		*	*		
Osteogeneosus militaris						*	*						*	*	*					

1- Acetes sp; 2- sea cucumber; 3- penaeid prawns; 4-plant matter; 5-Onchidium sp; 6-polychaetes; 7-fishes; 8-sipunculids; 9-Alpheus sp.; 10-fish scales; 11-fish rays; 12-Grapsidae; 13-bivalves; 14-organic matter; 15-crustacean parts; 16-brachyura; 17-eggs; 18-insects; 19-reptile; 20-cephalopoda

Table 9 Distribution of catfishes in the inshore waters, mudflats and mangrove channels of Matang (from Singh & sasekumar, 1994)

Ariid Species	Sampling Sites					
	IN	MF	SL	SSB	SSK	SJ
Arius caelatus	+	+	+	+	+	+
Arius sp.	-	-	+	+	-	-
Arius maculatus	-	-	+	+	+	+
Arius sagor	-	+	+	+	+	+
Arius venosus	-	-	+	+	+	+
Ketengus typus	-	-	+	+	+	+
Oeteogeneiosus militaris	+	+	+	+	+	+

(IN - Inshore waters; SL - Sg. Selinsing; SSB - Sg. Sangga Besar; SSK - Sg. Sangga Kecil; SJ - Sg. Jaha; MF - Subtidal mudflats)

(+= present; - = absent)

Table 10 List of ariids sampled by various gear types (bagnets, trawls, gill nets, beam trawls, cast nets, enclosure traps) from different studies in Peninsular Malaysia

Khoo (1989)	Sasekumar *et al.* (1989)	Chong *et al.* (1990)	Sasekumar *et al.* (1992)	Sasekumar (1994)	Singh & Sasekumar	Havase & Fadzil (1999)
Matang	Sg. Pulai	Selangor coastal waters	Selangor coastal waters		Matang	Matang
Arius sagor	*Arius sagor*	*Arius caelatus*	*Arius caelatus*		*Arius caelatus*	*Arius maculatus*
Arius venosus	*Arius venosus*	*Arius sagor*	*Arius maculatus*		*Arius sagor*	*Arius venosus*
Arius caelatus		*Arius tonggol*	*Arius sagor*		*Arius maculatus*	*Arius sagor*
Arius macrocephalus		*Arius venosus*	*Arius tonggol*		*Arius venosus*	*Arius caelatus*
Arius sp.		*Osteogeneiosus militaris*	*Arius venosus*		*Arius* sp.	*Arius* sp.
			Arius sp. A		*Ketengus typus*	*Ketengus typus*
Merbok			*Osteogeneiosus militaris*		*Osteogeneiosus militaris*	*Osteogeneiosus militaris*
Arius maculatus			*Ostogeneiosus*			
Arius sagor						Merbok
Arius venosus						*Arius caelatus*
Arius caelatus						*Arius maculatus*
Arius macrocephalus						*Arius venosus*
Arius sp						*Arius* sp.
						Ketengus typus
Sasekumar (1999)	Chong (1998)	Sarus (1997)	Salem (2000)			
Sg. Pulai	Sg. Johor and Tributaries	Sg. Pulai	Klang Coastal Waters			
Arius venosus	*Arius caelatus*	*Arius venosus*	*Arius caelatus*			
Arius maculatus	*Arius venosus*		*Arius sagor*			
Arius sagor	*Arius sagor*		*Osteogeneiosus militaris*			
	Arius maculatus		*Arius maculatus*			
	Osteogeneiosus militaris		*Arius venosus*			
	Batrocephalus mino					

Table 11 Mean standard length (SL) and mean weight (Wt) of ariid species landed by trawls in Selinsing River (from Singh, 2000)

	SL (± sd)	Range	Wt (± sd)	Range
Arius caelatus	13.8 ± 4.2	(4 - 27.4)	62.5 ± 55.6	(0.7 - 383.5)
Arius maculatus	7.5 ± 2.9	(3.85 - 21.9)	13.2 ± 26.4	(0.5 - 176.5)
Arius sagor	20.5 ± 4.8	(11.5 - 37.7)	185.1 ± 143.8	(25.7 - 669.5)
Arius truncatus	14.9 ± 4.7	(2.6 - 31.2)	52.2 ± 52.7	(1.9 - 322.5)
Arius venosus	11.8 ± 1.9	(1.24 - 17)	29.5 ± 12.5	(0.8 - 69.5)
Arius utik	10.9 ± 3.1	(3.85 - 17.7)	27 ± 21.3	(0.2 - 101.4)
Ketengus typus	8.2 ± 2.4	(3.7 - 13.1)	12.1 ± 9.4	(0.4 - 35.5)
Osteogeneosus militaris	13.3 ± 5.3	(3.75 - 23.2)	57.6 ± 45.8	(0.6 - 203.7)