

Update of the Fishes of Mangrove and Coastal Waters of Northeastern Langkawi

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ABSTRACT Two fish surveys in the waters of Langkawi's northeastern mangroves and adjacent nearshore waters were carried out in August 2003 and April 2004, to provide further information of the fish diversity that was first reported in the Langkawi Scientific and Heritage Expedition, April 2003. To date, there are 91 species of fish belonging to 42 families recorded inside mangrove-fringed estuaries and coastal inlets. Five new families, the Belonidae, Elopidae, Lobotidae, Pristigasteridae and Ostraciidae, have been added to the previous record of 37 families. In the open nearshore waters, from Pulau Peluru Strait to off Gua Cherita, 50 fish species were recorded. Cluster analysis indicates that the fish communities of Sg. Kisap, Sg. Kilim and coastal inlets were more similar to each other, than to Sg. Ayer Hangat or the open nearshore waters. However, half of the fish species present in the open nearshore waters also occur inside the mangrove-fringed estuaries and waterways. It is proposed that ecological linkages between the inshore waters, mangroves and coral reefs exist, involving fish movements for maturation/ spawning, feeding and utilization of the coastal habitats as nursery areas.

ABSTRAK Dua tinjauan fauna ikan telah dijalankan di perairan paya bakau dan pesisiran pantai Langkawi Timur Laut pada Ogos 2003 dan April 2004 untuk mendapat maklumat lanjut mengenai diversiti ikan yang telah dilaporkan pada kali pertamanya di Ekspedisi Saintifik dan Warisan Langkawi, April 2003. Sehingga kini, sejumlah 91 spesies ikan daripada 42 famili telah dilaporkan dari muara sungai dan perairan di pinggir hutan bakau. Lima famili baru iaitu Belonidae, Elopidae, Lobotidae, Pristigasteridae dan Ostraciidae telah ditambah ke dalam rekod yang sebelumnya adalah 37 famili. Di perairan terbuka pesisiran pantai, di antara Selat Pulau Peluru dan sekitar Gua Cherita, sejumlah 50 spesies ikan telah dilaporkan. 'Analisis Berkelompok' menunjukkan bahawa komuniti ikan di Sg. Kisap, Sg. Kilim dan saluran air pesisiran pantai adalah lebih menyerupai antara satu sama lain berbanding dengan Sg. Ayer Hangat atau perairan terbuka pesisir. Walau bagaimanapun, sebahagian daripada spesies ikan yang terdapat di kawasan berdekatan pantai juga didapati di muara dan cabang-cabang sungai yang berpinggiran hutan bakau. Kajian ini mencadangkan bahawa terdapat perhubungan ekologi di antara kawasan yang menghampiri pantai, paya bakau dan terumbu karang dari aspek pergerakan ikan untuk tujuan kematangan/pembiakan, pemakanan dan penggunaan habitat kawasan pantai sebagai kawasan nurseri.

(fish community, mangroves, inshore waters, Langkawi)

INTRODUCTION

Langkawi's northeast mangroves cover 1,987 ha, representing 64% of the total mangrove area of Langkawi island. These island mangroves are unique representing Malaysia's only type of mangroves growing on limestone platforms, or Type VI mangrove setting (*sensu* Thom [1]). The northeast mangroves of Langkawi are drained by three main interconnected river systems,

comprising that of Sungai Ayer Hangat, Sungai Kilim and Sungai Kisap. The mangroves are characterized by high salinity (27 – 33.5 ppt) and relatively clear waters [2].

A previous survey of the fish and invertebrate fauna by the same authors recorded 67 species of fish (37 families) and 31 species of invertebrates of mainly crab fauna. The same survey recorded two important findings, first, the star snapper,

Lutjanus stellatus, a new record for the region, and second, the box crab, *Calappa bilineata*, a first record for Malaysia. An interesting finding from this work is the occurrence of reefal fish species, such as sparids, labrids, haemulids and monacanthids, in the mangrove estuaries. Apparently, these species make use of the mangrove-fringed rivers as their habitats and possibly as feeding areas.

The present study aimed to provide further information on the diversity of fishes and invertebrates of northeast Langkawi, as well as to address the following question: to what extent are the coastal fishes dependent on the mangroves as habitats or feeding areas? To answer this question, we carried out comparative species analysis and trophic analysis of mangrove as well as coastal water species. The paper provides an update of the fish biodiversity, but reports only the results of the comparative species analysis.

MATERIALS AND METHODS

Study area and sampling stations

The mangrove forest reserves of Langkawi, namely Ayer Hangat (402 ha), Gua Cherita (208 ha), Kisap (1336 ha), Tanjung Dagu (27 ha), Pulau Langgun (14 ha) fall in the northeastern region of Langkawi [3]. Sungai (Sg.) Ayer Hangat drains the Kuala Ayer Hangat and Gua Cherita mangrove reserves; Sg. Kilim drains the Sg. Pinang and Kilim mangrove and limestone-type forests, while Sg. Kisap drains the Kisap mangrove and Tanjung Dagu reserves.

In the previous survey in April 2003, Chong *et al.* [2] sampled from a total of 16 established stations, all of which were located inside the estuaries. In the present study, 9 different stations were sampled in August 2003, and a further 7 stations were sampled in April 2004. A total of 28 stations were sampled from mangrove-fringed waterways during the three surveys of northeastern Langkawi (Fig. 1). All except 3 stations are estuarine mangrove habitats, while the three are short coastal inlets also fringed by mangroves. A further 4 stations were sampled in the inshore waters located 0.5- 1 km off the eastern coast of Gua Cherita and in Selat Peluru (Figure 1).

Water parameter measurements and fish sampling

At selected stations, only salinity (ppt) and temperature (°C) were recorded using a Salinity-Conductivity-Temperature (SCT) meter during the last two surveys. Geographical Positioning System (GPS) readings were recorded at each station. Fish and invertebrates were sampled using a combination of gill nets (1.5"- and 5"-mesh sizes) of 120-300m length and cast net (2.3- cm mesh size). Gill netting was carried out during the night and day. Night fishing was done by deploying the gill nets at between 8-10 pm, and retrieving the nets the next morning. Day fishing was carried out by deploying the same nets at stations and allowing the nets to fish for approximately 1 hr before net retrieval. For the fine (1.5") gill net, the method of sampling was first to deploy the net and then driving the fish shoal into it by beating the sea surface using a long pole, alternating from each side of the moving, hand-paddled boat. In between gill netting, the cast net was operated. The cast nettings (varying from 5 -13 casts) were also made in shallow water at the bank. Positions of net deployment and retrieval in terms of latitudes and longitudes were recorded using a GPS unit. The beam trawl which was used during the first survey was not used as a sampling gear during the second and third surveys.

All fish catches were immediately placed on ice during sampling. Back at the base camp in Kuah, the fish catches were immediately processed. Fish (and invertebrates) were identified to the species level using standard identification keys [4, 5, 6, 7, 8 and 9]. After identification, all specimens belonging to the same species were enumerated and weighed together. Minimum and maximum standard lengths (SL) were recorded. All species were photographed using a high-resolution digital camera. Unidentified specimens were measured, tagged and preserved in 10% formalin, before they were brought back to the laboratory in the University of Malaya, for further examination and identification to the species level. Representative specimens after identification were deposited in the Institute of Biological Sciences, University of Malaya. To avoid the problem of synonyms, the valid species name as given in Fishbase [10] was followed.

Statistical Analysis

All data including from those from the first survey were pooled together to build a checklist of presence and absence data for fish and invertebrate species, according to the following habitats: Sg. Ayer Hangat, Sg. Kilim, Sg. Kisap, Coastal Inlets and Inshore Waters. Only the first four habitats are considered as mangrove habitats (i.e. fringed by mangrove forests). For comparative species analysis among the various habitats, a distance measure based on percentage difference (ignoring double zeros) was used to compute distances among the habitats. Based on the distances obtained, agglomerative, single-linkage cluster analysis was then performed to construct a dendrogram.

RESULTS AND DISCUSSION

Water parameters

For all stations during the two surveys in August 2003 and April 2004, surface water temperatures ranged between 28.3°C to 31.8°C, lower temperatures being recorded in the early morning (0900 hr). Surface salinity readings ranged from 27 – 33 ppt in August 2003, whereas in April 2004 they ranged from 21-30 ppt. However, except for Station 21 located at the upstream of a coastal inlet (Figure 1) which recorded the lowest salinity (21 ppt), the minimum salinity recorded in April 2004, was 27 ppt. During the two surveys, the range of salinities recorded for Sg. Ayer Hangat, Sg. Kilim, Sg. Kisap, coastal inlets and open nearshore waters were 29.7 – 30.9, 31.1 – 33.0, 28.0 – 33.0, 21.0 – 33.0 and 30.4 – 30.9, respectively. In comparison, the previous survey in April 2003 recorded surface salinities ranging from 28.0-30.0 ppt in Sg. Ayer Hangat, 27.0-33.5 ppt for Sg. Kilim, and 27.0-30.0 ppt for Sg. Kisap [2].

Species composition

Mangrove estuaries

An additional 24 species of fish were recorded, apart from the 67 species already reported in the first Langkawi survey [2]. Thus far, a total of 91 species of fishes belonging to 42 families has been recorded from the estuaries of Langkawi's northeastern mangroves (Table 1). The total number of fish species recorded from Sg. Ayer Hangat, Sg. Kilim, Sg. Kisap and the coastal inlets, were 39, 34, 32 and 26 species, respectively.

The newly recorded families were Belontiidae, Elopidae, Lobotidae, Pristigasteridae and Ostraciidae. The horn-nosed boxfish, *Ostracion rhinorhynchus*, and fan-bellied leatherjacket, *Monacanthus chinensis*, represent yet another two reefal fish recorded inside the mangrove estuary [2]. Two juvenile tripletail, *Lobotes surinamensis*, were caught at a mangrove-fringed coastal inlet (station 20). Young juveniles of the species have been reported to hide among floating mangrove leaves and *Sargassum* mats; their mottle coloration of yellow, brown and black mimics that of senescent mangrove leaves [9]. Except Merbok [11], it has never being recorded before in mainland mangroves in the peninsula despite extensive mangrove studies done in Klang [12], Matang [13] and Johor [14]. Another interesting observation is the tenpounder, *Elops machnata*, a species that reportedly reaches 10 kg in body weight. This inshore piscivore is also becoming infrequently encountered in many of the peninsular's mangrove ecosystems where their larvae and juveniles enter estuaries to feed. Four additional grey mullet species, *Chelon macrolepis*, *Liza tade*, *Valamugil cunnesius* and *Liza subviridis* have been recorded from the Sg. Kisap area. Thus far, the three Langkawi surveys have established six species of grey mullets from the same general area, making the northeastern Langkawi mangroves perhaps one of the richest in mullet diversity. The Pristigasteridae was represented by an identified *Ilisha* species.

Inshore Waters

The total number of fish species recorded from open nearshore waters was 50 species (Table 1). Exclusively marine species that were not recorded from mangroves numbered 20 species.

Off the eastern coast of Gua Cherita, the open water fishes were dominated by pelagic fishes comprising scombrids, clupeids, carangids and engraulids, and demersal species especially from the Leiognathidae. The major species occurring in large numbers were Indian mackerel (*Rastrelliger kanagurta*), gizzard shad (*Anodontostoma chacunda*), yellowtail scad (*Atule mate*), trevallies (*Carangoides praeustus*, *C. malabaricus*) and anchovies (*Thryssa* and *Stolephorus* spp.). Three additional leiognathids not previously recorded were *Leiognathus leuciscus*, *L. splendens* and *Secutor ruconius*. Large carnivores include the bigeye snapper, *Lutjanus lutjanus*, pickhandle barracuda,

Sphryaena jello, and Dorab wolf-herring, *Chirocentrus dorab*.

In Selat Peluru waters, reefal fishes generally dominated. These include the Indian threadfish, *Alectis indicus*, spadefish, *Ephippus orbis*, hotlips *Plectorhynchus gibbosus*, and large predators like the white spotted eagle ray, *Aetomylaeus maculatus*, and the grey bamboo shark, *Chiloscyllium griseus*.

Comparison between Mangrove and Open Inshore Waters

Distance measures based on species diversity among the five sites, namely, Sg. Ayer Hangat, Sg. Kilim, Sg. Kisap, coastal inlets and inshore open waters, are summarized in Table 2. Since these are distance measures, the most similar sites are those with the lowest distance measures, for instance, between Sg. Kisap and coastal inlets that drain into the Pulau Peluru Strait ($D = 0.33$).

Cluster analysis indicates closer similarity of fish fauna among Sg. Kisap, coastal inlets and Sg.

Kilim (Figure 2). As expected the open waters off the coast had fish fauna that were least similar to the estuarine fish fauna. Nevertheless, about half of the fish species that occurred in open waters off the coast were also found inside the estuaries.

From the findings of Chong *et al.* [2] who suggested the use of the estuarine mangrove habitats by offshore reefal species as feeding areas, the present study provides further evidence of the ecological linkages among the three habitats as depicted in Figure 3.

Broad arrow indicates movements of fishes between mangrove and coral reef habitats for feeding; solid narrow arrows indicate movements of fishes to inshore and probably offshore marine waters for maturation and spawning (commercial fishery occurs here); broken narrow arrows indicate movement of larval or postlarval fishes to coastal habitats that serve as nursery areas.

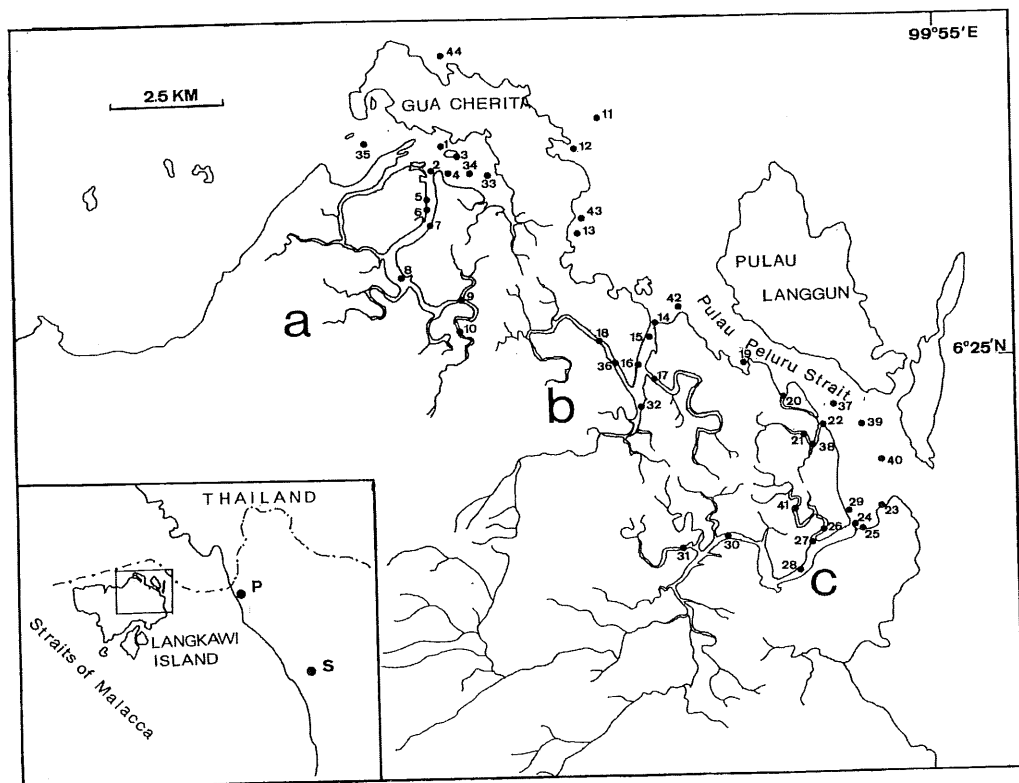


Figure 1. Map of study area in northeast Langkawi. Inset shows marked study area (square) in Langkawi Island in relation to Kuala Perlis (P) and Alor Star (S) on the mainland of Peninsular Malaysia; numerals indicate sampling stations in Sg. Ayer Hangat (a), Sg. Kilim (b), Sg. Kisap (c), coastal inlets and open near shore waters.

Table 1. Checklist of recorded fishes (including invertebrates) in mangrove estuaries, coastal inlets and open near shore waters of northeastern Langkawi. Numerals on top heading refer to sampling stations (see Figure 1 for location on map); lower, middle, upper, indicate lower reaches, middle reaches and upper reaches respectively, ** indicate commercially exploited species, * species of low commercial value but consumed

Family	Species	Common name	Mangrove (estuary)												Coastal Inlets							
			St. Ayer Hangat				St. Kilim				St. Kicap											
			lower	middle	upper	lower	middle	upper	lower	middle	upper	lower	middle	upper	lower	middle	upper	lower	middle	upper		
Ailidae	* <i>Ailus caelatus</i>	Embered Catfish																				
	* <i>Ailus leuognis</i>	Thin-spine Sea Catfish																				
	* <i>Ailus venosus</i>	Vined catfish																				
	* <i>Ailus sp.</i>	Catfish																				
Agonistidae	* <i>Chelodactylus milnaris</i>	Soldier catfish																				
	<i>Apogon trilineatus</i>	Cardinal Fish																				
Balichthidae	<i>Alphacanthus zeylanicus</i>	Giant flatfish																				
	<i>Tylosurus crocodilus</i>	Hound snoutfish																				
Belontiidae	<i>Tetraodon lineatus</i>	Four-headed																				
	<i>Callionymus sagitta</i>	Dragonet																				
Cirrhitidae	* <i>Acheilichthys</i>	Indian threadfish																				
	* <i>Aliphanes diabolus</i>	Shrimp Starfish																				
	* <i>Aluon macle</i>	Yellowtail scad																				
	* <i>Caranx sp.1</i>	Trevally																				
	* <i>Carangoides armatus</i>	Longfin trevally																				
	* <i>Carangoides equus</i>	Whitfin Cavalla																				
	* <i>Caranx melanocephalus</i>	Malabar trevally																				
	* <i>Carangoides praeustus</i>	Brown-backed Trevally																				
	* <i>Carangoides sp.1</i>	Trevally (blackish)																				
	* <i>Caranx (Caranx) gonialis</i>	Giant Trevally																				
	* <i>Scomberomorus commersonianus</i>	Talking Queenfish																				
	* <i>Scomberomorus leyan</i>	Double spotted queenfish																				
* <i>Lates calcarifer</i>	Sulawesi																					
Centroponidae																						
Chirocentridae	<i>Chirocentrus domib</i>	Dorab wool-bearing																				

			Mangrove (estuary)												Coastal Inlets																					
			Sp. Ayer Hitam						Sp. Kilim						Sp. Kilap																					
			lower			middle			upper			lower			middle			middle																		
Family	Species	Common name	1	2	3	4	5	6	7	8	9	10	14	15	16	17	18	32	29	23	24	25	26	27	28	41	30	31	20	21	22	18				
Cypselidae	<i>Acanthaluteres chinensis</i>	Chinese Gizzard Shad																																		
	<i>Heckelichthys punctatus</i>	Spotted Herring																																		
Oryziatichthys	<i>Sardinella firmibata</i>	Fringescale sardine																																		
	<i>Sardinella gibbosa</i>	Goldstripe sardine																																		
	<i>Oryziatichthys liturata</i>	Long-tongue Sole																																		
	<i>Oryziatichthys punctifera</i>	Spotted tongue sole																																		
Dayriidae	<i>Dayrius kawai</i>	Blue-spotted Shogunay																																		
	<i>Dayrius zugi</i>	Pink-edged Shogunay																																		
Draconidae	<i>Heteroclinus walkei</i>	Scaly Shogunay																																		
	<i>Heteroclinus walkei</i> (Misaka sp. 1 & sp. 2)	Scaly Shogunay																																		
Eupomidae	<i>Dryocopus lineatus</i>	Spotted Bullfish																																		
	<i>Elops maculatus</i>	Tempounder																																		
Egragrinidae	<i>Stalophanes commersonii</i>	Commerçon's snappers																																		
	<i>Stalophanes sp. 1</i>	Ambovy																																		
Ephippidae	<i>Thryssa hamiltoni</i>	Hamilton's thryssa																																		
	<i>Thryssa myxalis</i>	Mottled Thryssa																																		
Gobiidae	<i>Thryssa setoensis</i>	Longfin thryssa																																		
	<i>Ephippius ephippius</i>	Spotfish																																		
Gobiidae	<i>Gomphosoma subrepleta</i>	Demibody Silver-biddy																																		
	<i>Gomphosoma filamentosus</i>	Whip Silver-biddy																																		
Gobiidae	<i>Arenigobius heteromaculatus</i>	Green-spotted Goby																																		
	<i>Goby sp. 1</i>	Goby																																		
Gobiidae	<i>Gobid</i>	Gobid																																		
	<i>Paluanus septuagintatus</i>	Goby																																		
Gobiidae	<i>Gobid sp. 1</i>	Goby																																		
	<i>Gobid sp. 2</i>	Goby																																		
Gobiidae	<i>Gobid sp. 3</i>	Goby																																		
	<i>Gobid sp. 3</i>	Goby																																		

		Mangrove (estuary)																																		
		Sp. Ayer Hanyat										Sp. Kilim										Sp. Kisap		Coastal lakes												
Family	Species	Common name	lower					middle					upper					lower					middle					20		21		22		38		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			
Mugilidae	<i>Chelon macleodensis</i>	Largessal mullet	E 99* 50.222	E 99* 50.099	E 99* 50.394	E 99* 50.8.6	E 99* 49.97.2	E 99* 50.412	E 99* 50.081	E 99* 50.566	E 99* 49.32.2	E 99* 49.58.6	E 99* 49.53.6	E 99* 50.217	E 99* 50.75.3	E 99* 52.140	E 99* 52.125	E 99* 51.793	E 99* 51.952	E 99* 52.37.8	E 99* 51.41.8	Bubu	E 99* 54.224	E 99* 54.143	E 99* 54.224	E 99* 54.15.8	E 99* 53.179	E 99* 53.38.4	E 99* 53.41.5	E 99* 53.174	E 99* 52.52.4	E 99* 52.15.6	E 99* 53.658			
	<i>Liza subviridis</i>	Greenback mullet	N 6* 27.21.3	N 6* 27.21.3	N 6* 27.30.0	N 6* 27.12.9	N 6* 27.01.2	N 6* 27.330	N 6* 27.377	N 6* 27.537	N 6* 26.17.7	N 6* 26.59.7	N 6* 26.00.6	N 6* 25.855	N 6* 25.98.6	N 6* 25.470	N 6* 25.37.6	N 6* 25.063	N 6* 25.120	N 6* 25.05.6	N 6* 25.22.8	No GPS	E 99* 54.224	E 99* 54.143	E 99* 54.224	E 99* 54.15.8	E 99* 53.179	E 99* 53.38.4	E 99* 53.41.5	E 99* 53.174	E 99* 52.52.4	E 99* 52.15.6	E 99* 53.658			
	<i>Liza liza</i>	Table mullet																																		
	<i>Liza wagneri</i>	Diamond scaled Grey Mullet																																		
	<i>Vilivilua buchanani</i>	Blue-jacket Mullet																																		
	<i>Vilivilua curvirostris</i>	Loganin mullet																																		
	<i>Upeneus bassalis</i>	Red Mullet Goulish																																		
	<i>Upeneus subpinus</i>	Sulphur goulish																																		
	<i>Automyliodon maculatus</i>	White spotted eagle ray																																		
	<i>Nampterus lineatus</i>	Coral broadfin beam																																		
<i>Scoloplos vernalis</i>	White cheek Morone Bream																																			
<i>Cetomacron rhomboides</i>	Horn-nosed bonfish																																			
<i>Pseudocaranx elongatus</i>	Deep Flounder																																			
<i>Platycephalus</i>	Eel catfish																																			
<i>Platycephalus</i>	Plough tailhead																																			
<i>Platycephalus</i>	Bar-tailed Flathead																																			
<i>Platycephalus</i>	Large-spined Flathead																																			
<i>Siganus microdon</i>	Cotton-tail fish																																			
<i>Liza filicina</i>	Indian filefish																																			
<i>Liza melanozona</i>	Black filefish																																			
<i>Liza</i> sp.	Filefish																																			
<i>Opsanus beta</i>	Yardoni																																			
<i>Opsanus beta</i>	Spotted Sail																																			
<i>Scorpaenopsis</i>	Goose croaker																																			
<i>Diodontidae</i>	Baligang Croaker																																			
<i>Demipinna</i>	Kent Croaker																																			
<i>Johnius</i> sp.1	Croaker																																			
<i>Johnius</i> sp.2	Croaker																																			

			Mangrove (estuary)												Coastal Inlets																					
			Sg. Ayer Hangat						Sg. Kilim						Sg. Kelang																					
			lower		middle		upper		lower		middle		middle		Lower		middle		middle		middle															
Family	Species	Common name	1	2	3	4	5	6	7	8	9	10	14	15	36	16	17	18	32	29	23	24	25	26	27	28	41	40	31	20	21	22	38			
	<i>Paragastropoda harauensis</i>	Speck prawn	E 99° 50.222	N 6° 27.410															No GPS																	
	<i>Pangonidius longicauda</i>	Dog prawn																	No GPS																	
	<i>Penaeus affinis</i>	Western King Prawn																																		
	<i>Penaeus merguensis</i>	Bangka Prawn																																		
	<i>Penaeus monodon</i>	Tiger prawn																																		
Sergestidae	<i>Acetes</i> sp.	Stagesid shrimp																																		
Squilla	<i>Chiosquilla litorea</i>	Marine shrimp																																		
	<i>Chiosquilla penanga</i>	Marine shrimp																																		
Harpacticoidae	<i>Harpacticoida harau</i>	Marine shrimp																																		
Caprellidae	<i>Caprella bhreata</i>	Box crab																																		
Epilabidae	<i>Melippe romphi</i>	Stone/mud crab																																		
	<i>Myomenippe harauensis</i>	Stone/mud crab																																		
Mejilidae	Sp. 1	Mud crab																																		
	Sp. 2	Mud crab																																		
(Bacchylus)	<i>Hyas</i> sp.	crab																																		
	Crab sp. G	crab																																		
	Crab sp. D	crab																																		
	Crab sp. E	crab																																		
	Crab sp. F	crab																																		
	<i>Macromphasma turkellii</i>	Crab																																		
Copepodidae	<i>Copepodina</i> crab	Copepod crab																																		
	<i>Parthysia</i> sp.	Crab																																		
	<i>Ampelisca heterotarsus</i>	Xanthid crab																																		
	<i>Gammarus bispinosus</i>	crab																																		
	<i>Charybdis acuta</i>	Swimming crab																																		
	<i>Charybdis arisae</i>	Penaeid crab																																		
	<i>Charybdis lineata</i>	Coville crab																																		

		Muinggoe (estuary)																																																		
Family	Species	Common name	Sg. Ayer Hangan								Sg. Kilim								Sg. Kisap								Coastal Inlets																									
			lower				middle				upper				lower				middle				middle				lower				middle																					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32																		
	<i>Charybdis naxos</i>	Swimming crab																																																		
	<i>Charybdis sp. 1</i>	Swimming crab																																																		
	<i>Procaprellus agilis</i>	Swimming crab																																																		
	<i>Portunidae sp. 1</i>	Swimming crab																																																		
	<i>Portunidae sp. 2</i>	Swimming crab																																																		
	<i>Portunidae haeri</i>	Swimming crab																																																		
	<i>Portunus pelagicus</i>	Flower crab																																																		
	<i>Squilla sp.</i>	Mangrove mud crab																																																		
	<i>Thalassidroma crassipes</i>	Coastal swimming crab																																																		
	<i>Thalassidroma sp.</i>	Swimming crab																																																		
(Mesosomata)	<i>Tachypleus gigas</i>	Horseshoe crab																																																		
	<i>Carcinus rotundicauda</i>	Horseshoe crab																																																		
	<i>Stomatopoda</i>	Crustacean																																																		
	<i>Squilla aculeata</i>	Cuttlefish																																																		
	<i>Squilla oculata</i>	Cuttlefish																																																		
	<i>Gammarus olivaceus</i>	Venus clam																																																		
	<i>Cyprinus ruber</i>	Volu molen																																																		
	<i>Murex sp.</i>	Murex shell																																																		
	<i>Anadara granosa</i>	Blood cockle																																																		
	<i>Goniostomus sp.?</i>	Starfish																																																		
Total			0	6	1	1	12	2	4	0	0	0	0	1	1	2	1	1	1	2	1	1	4	1	2	1	2	1	1	4	3	2	2	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0

			Open Waters									
			Selat Peluru					Gua Cherita				
Family	Species	Common name	19	37	39	40	42	11	12	13	43	44
			N 6° 25' 11.5" E 99° 53' 17.0"	N 6° 24.540" E 99° 53.972"	No GPS	N 6° 24.435" E 99° 53.935"	NO GPS	N 6° 27.774" E 99° 51.956"	No GPS T.Jong	N 6° 26.162" E 99° 51.559"	N 6° 27.075" E 99° 51.620"	N 6° 28.610" E 99° 50.676"
Ariidae	* <i>Arius caelatus</i>	Engraved Catfish						•	•			
	* <i>Arius tenuispinis</i>	Thin-spine Sea Catfish										
	* <i>Arius venosus</i>	Veined catfish	•									
	* <i>Arius sp.</i>	Catfish							•			
	* <i>Osteogeneiosus militaris</i>	Soldier catfish							•			
Apogonidae	<i>Apogon hyalasma</i>	Cardinal Fish										
Batrachoididae	<i>Allenbatrachus grunniens</i>	Grunting toadfish										
Belontiidae	<i>Tylosurus crocodilus crocodilus</i>	Hound needlefish								•		
Callionymidae	<i>Callionymus sagitta</i>	Arrow-headed Dragonet										
Carangidae	* <i>Alectis indicus</i>	Indian threadfish	•									
	* <i>Alepes djeddaba</i>	Shrimp Scad		•	•							
	* <i>Atule mate</i>	Yellowtail scad						•				
	* <i>Carangid sp.1</i>	Trevally										
	* <i>Carangoides armatus</i>	Longfin trevally						•				
	* <i>Carangoides equula</i>	Whitefin Cavalla										
	* <i>Carangoides malabaricus</i>	Malabar trevally						•				
	* <i>Carangoides praestus</i>	Brown-backed Trevally							•			
	* <i>Carangoides sp.1</i>	Trevally (blackish)						•				
	* <i>Caranx ignobilis</i>	Giant Trevally										
	* <i>Scomberoides commersonianus</i>	Talang Queenfish								•		
	* <i>Scomberoides lysan</i>	Doublespotted queenfish								•		
	* <i>Lates calcarifer</i>	Seabass										
	Centropristidae	* <i>Chirocentrus dorab</i>	Dorab wolf-herring						•			
Clupeidae	* <i>Anadontostoma chacurda</i>	Chacunda Gizzard Shad		•	•	•		•		•		
	* <i>Herklotsichthys punctatus</i>	Spotted Herring										
	* <i>Sardinella frimbriata</i>	Fringescale sardinella						•				
	* <i>Sardinella gibbosa</i>	Goldstripe sardinella								•		
Cynoglossidae	* <i>Cynoglossus lingua</i>	Long-tongue Sole				•						•
	* <i>Cynoglossus puncticeps</i>	Speckled tonguesole										
Dasyatidae	* <i>Dasyatis kuhlii</i>	Blue-spotted Stingray					•					
	* <i>Dasyatis zugei</i>	Pale-edged Stingray							•			
	* <i>Himantura walga</i>	Scaly Stingray										
	* <i>Urolophus sp.? (short 2-spined tail)</i>	Stingaree										
Drepanidae	* <i>Drepane punctata</i>	Spotted Batfish										
Elopididae	* <i>Elops machnata</i>	Tenpounder										
Engraulidae	* <i>Stolephorus commersonii</i>	Commerson's anchovy						•				
	* <i>Stolephorus sp.1</i>	Anchovy										
	* <i>Thryssa hamiltonii</i>	Hamilton's thryssa						•		•		
	* <i>Thryssa mystax</i>	Moustached Thryssa								•	•	
	* <i>Thryssa setirostris</i>	Longjaw thryssa						•				
Ephippidae	* <i>Ephippus orbis</i>	Spadefish	•									
Gerreidae	* <i>Gerres abbreviatus</i>	Deepbody Silver-biddy		•	•					•		
	* <i>Gerres filamentosus</i>	Whipfin Silver-biddy		•								
Gobiidae	<i>Acentrogobius viridipunctatus</i>	Green-spotted Goby										
	<i>Goby sp. 1</i>	Goby										
	Gobiid	Goby										
	<i>Palutrus scapulopunctatus</i>	Goby										

			Open Waters									
			Selat Peluru					Gua Cherita				
Family	Species	Common name	19	37	39	40	42	11	12	13	43	44
			E 99° 53' 17.0" N 6° 25' 11.5"	E 99° 53.972' N 6° 24.540'	No GPS	E 99° 53.935' N 6° 24.435'	NO GPS	E 99° 51.956' N 6° 27.774'	T. Jong	No GPS	E 99° 51.559' N 6° 26.162'	E 99° 51.620' N 6° 27.073'
Gymnuriidae	Gobiid sp 1	Goby										
	Gobiid sp 2	Goby										
	Gobiid sp 3	Goby										
Haemulidae	* <i>Gymnura poecilura</i>	Longtail Butterfly Ray					•					
	* <i>Plectorhinchus flavomaculatus</i>	Lemon Sweetlips										
Haemulidae	* <i>Plectorhinchus gibbosus</i>	Harry hotlips	•									
	* <i>Pomadasys argenteus</i>	Silver Grunter										
	* <i>Pomadasys argyreus</i>	Bluecheek Silver Grunt		•		•						
	* <i>Pomadasys hasta</i>	Silver Grunter								•		
	* <i>Pomadasys kaakan</i>	Javelin grunter										
	Hemiscylliidae	<i>Chiloscyllium griseum</i>	Grey Bambooshark	•								
<i>Chiloscyllium indicum</i>		Slender Bamboo Shark		•								
Labridae	<i>Halichoeres scapularis</i>	Zigzag Wrasse										
Leiognathidae	* <i>Leiognathus brevirostris</i>	Shortnose Ponyfish		•		•			•	•		
	* <i>Leiognathus equalis</i>	Common Ponyfish				•						
	* <i>Leiognathus leuciscus</i>	Whipfin ponyfish						•				
	* <i>Leiognathus sp.</i>	Ponyfish						•				
	* <i>Leiognathus splendens</i>	Splendid ponyfish						•				
Lobotidae	* <i>Secutor ruconius</i>	Deep pugnose ponyfish		•				•	•			
	* <i>Lobotes surinamensis</i>	Atlantic tripletail										
Lutjanidae	* <i>Lutjanus argentimaculatus</i>	Mangrove Red Snapper										
	* <i>Lutjanus johnii</i>	Golden Snapper										
	* <i>Lutjanus lutjanus</i>	Bigeye snapper						•				
	* <i>Lutjanus russelli</i>	Russell's Snapper										
	* <i>Lutjanus stellatus</i>	Star Snapper										
Megalopidae	* <i>Megalops cyprinoides</i>	Indo-Pacific Tarpon										
Monacanthidae	<i>Acreichthys tomentosus</i>	Bristle-tail file-fish										
	<i>Acreichthys tomentosus</i>	Leatherjacket										
	<i>Monacanthus chinensis</i>	Fan-bellied leatherjacket	•				•					
Mugilidae	<i>Monacanthus choircephalus</i>	Pig-faced Leatherjacket										
	* <i>Chelon macrolepis</i>	Largescale mullet										
	* <i>Liza subviridis</i>	Greenback mullet										
	* <i>Liza tade</i>	Tade mullet										
	* <i>Liza vaiensis</i>	Diamond-scaled Grey Mullet					•					
	* <i>Valamugil buchanani</i>	Blue-tailed Mullet										
Mullidae	* <i>Valamugil cunnesius</i>	Longarm mullet										
	* <i>Upeneus bensasi</i>	Red Mullet Goatfish										
Mullidae	* <i>Upeneus sulphureus</i>	Sulphur goatfish						•				
	* <i>Aetomylaeus maculatus</i>	White spotted eagle ray	•									
Nemipteridae	* <i>Nemipterus hexodon</i>	Ornate threadfin bream							•			
Nemipteridae	* <i>Scolopsis vosmeri</i>	White-cheek Monocle Bream										
	<i>Ostracion rhinorhynchus</i>	Horn-nosed boxfish										
Ostraciidae	<i>Ostracion rhinorhynchus</i>	Horn-nosed boxfish										
Paralichthyidae	* <i>Pseudorhombus elevatus</i>	Deep Flounder					•					
Plotosidae	* <i>Plotosus canius</i>	Bel catfish										
Platycephalidae	* <i>Grammolitex scaber</i>	Rough flathead							•			
	* <i>Platycephalus indicus</i>	Bar-tailed Flathead										
	* <i>Suggrundus macracanthus</i>	Large-spined Flathead										
Pristigasteridae	* <i>Ilisha filigera</i>	Coromandel ilisha								•		

			Open Waters									
			Selat Peluru					Gua Cherita				
Family	Species	Common name	19	37	39	40	42	11	12	13	43	44
			N 6° 25' 11.5"	N 6° 24.540'	No GPS	N 6° 24.435'	NO GPS	N 6° 27.774'	No GPS	N 6° 26.162'	N 6° 27.075'	N 6° 28.610'
			E 99° 53' 17.0"	E 99° 53.972'		E 99° 53.935'		E 99° 51.956'	T. Long	E 99° 51.559'	E 99° 51.620'	E 99° 50.676'
Scathophagidae	* <i>Ilisha melastoma</i>	Indian ilisha						•				
	* <i>Ilisha sp.</i>	Ilisha										
	* <i>Opisthopterus tardoore</i>	Tardoore						•				
	* <i>Scatophagus argus</i>	Spotted Scat										
Sciaenidae	* <i>Dendrophysa russelii</i>	Goatee croaker			•	•				•		
	* <i>Johnius belangerii</i>	Belanger's Croaker	•						•			
	* <i>Johnius carutta</i>	Karut Croaker										
	* <i>Johnius sp.1</i>	Croaker										
	* <i>Johnius sp.2</i>	Croaker										
	* <i>Johnius sp.3</i>	Croaker								•		
	* <i>Pennahia anea</i>	Bigeye Croaker										
	* <i>Pennahia macrocephalus</i>	Big-head pennah croaker	•						•			
	* <i>Rastrelliger kanaurta</i>	Indian Mackerel						•	•	•		
Scorpenidae	<i>Trachicephalus uranoscopus</i>	Stargazing stonefish						•				
Serranidae	* <i>Epinephelus tawina</i>	Estuary Grouper										
	* <i>Epinephelus sexfasciatus</i>	Six-bar Grouper		•								
Siganidae	* <i>Siganus canaliculatus</i>	White-spotted Spinefoot			•							
	* <i>Siganus javus</i>	Java Rabbitfish										
Sillaginidae	* <i>Sillago sihama</i>	White Sillago			•				•	•		
Sparidae	* <i>Acanthopagrus berda</i>	Picnic Seabream										
	* <i>Dentex angolensis</i>	Angola Dentex										
Sphyrnidae	* <i>Sphyrna barracuda</i>	Great Barracuda										
	* <i>Sphyrna jello</i>	Pickhandle barracuda								•		
Synodontidae	* <i>Saurida tumbil</i>	Greater Lizard fish		•								
Tetraodontidae	<i>Chelonodon patoca</i>	Estuarine Blowfish			•	•						
	<i>Tetraodon fluviatilis</i>	Green pufferfish										
Triacanthidae	* <i>Triacanthus biculeatus</i>	Hollow-snouted Tripod		•	•	•		•				
Toxotidae	* <i>Toxotes jaculatrix</i>	Banded archerfish										
Total		123	9	11	9	9	5	21	13	17	1	1
Invertebrate												
Alpheidae	* <i>Alpheus sp</i>	Snapping Prawn										
Penaecidae	* <i>Metapenaeopsis stridulans</i>	Sand prawn										
	* <i>Metapenaeus affinis</i>	Pink prawn							•			
	* <i>Metapenaeus sp</i>	prawn										
	* <i>Parapenaeopsis hardwickii</i>	Spear prawn							•			
	* <i>Parapenaeopsis hungerfordi</i>	Dog prawn							•			
	* <i>Penaeus latisulcatus</i>	Western King Prawn										
	* <i>Penaeus merguensis</i>	Banana Prawn							•	•	•	
	* <i>Penaeus monodon</i>	Tiger prawn										
Sergestidae	* <i>Acetes sp</i>	Sergestid shrimp										
Squillidae	* <i>Oratosquilla interrupta</i>	Mantis shrimp							•			
	* <i>Oratosquilla perpensa</i>	Mantis shrimp							•			
Harpisquillidae	* <i>Harpisquilla harpax</i>	Mantis shrimp						•				
Calappidae	<i>Calappa bilineata</i>	Box crab										
Eriphiidae	* <i>Menippe rumphii</i>	Stone/mud crab										
	* <i>Myomenippe hardwickii</i>	Stone/mud crab							•			

			Open Waters									
			Selat Peluru					Gua Cheria				
Family	Species	Common name	19	37	39	40	42	11	12	13	43	44
			E 99° 53' 17.0" N 6° 25' 11.5"	E 99° 53.972' N 6° 24.540'	No GPS	E 99° 53.935' N 6° 24.435'	NO GPS	E 99° 51.956' N 6° 27.774'	No GPS	E 99° 51.559' N 6° 26.162'	E 99° 51.620' N 6° 27.075'	E 99° 50.676' N 6° 28.610'
Majidae	Sp. 1	Majid crab										
	Sp.2	Majid crab										
(Brachyura)	<i>Hyastenus</i> sp.	crab										
	Crab sp. G	crab	•									
	Crab sp. D	crab										
	Crab sp. E	crab										
	Crab sp. F	crab										
Ocypodidae	<i>Macrophthalmus latreillei</i>	Crab										
	Ocypodidae crab	Ocypode crab										
Parthenopidae	<i>Parthenope</i> sp.	Crab										
Xanthidae	<i>Atergatis intergerrimus</i>	Xanthid crab										
Pilumnidae	<i>Galene hispidosa</i>	crab										
Portunidae	<i>Charybdis acuta</i>	Swimming crab										
	* <i>Charybdis anisodon</i>	Portunid crab				•		•				
	* <i>Charybdis feriata</i>	Crucifix crab							•			
	* <i>Charybdis natator</i>	Swimming crab							•			
	<i>Charybdis</i> sp.1	Swimming crab									•	
	* <i>Pedopthalmus vigil</i>	Sentinel crab										
	Portunidae sp. 1	Swimming crab					•					
	Portunidae sp. 2	Swimming crab			•							
	<i>Portunus haani</i>	Swimming crab										
	* <i>Portunus pelagicus</i>	Flower crab	•		•			•	•			
	* <i>Scylla</i> sp	Mangrove mud crab										
	* <i>Thalamita crenata</i>	Crenate swimming crab										
	<i>Thalamita</i> sp.	Swimming crab										
(Merostomata)	<i>Tachypleus gigas</i>	Horseshoe crab										
	<i>Carcinoscopius rotundicauda</i>	Horseshoe crab										
Sepiidae	* <i>Sepia aculeata</i>	Cuttlefish										
	* <i>Sepia esculenta</i>	Cuttlefish										
Veneridae	* <i>Gafrarium dispar</i>	Venus Clam										
Volutidae	* <i>Cymbium melo</i>	Volute melon										
Muricidae	<i>Murex</i> sp.	Murex shell										
Arcidae	* <i>Anadara granosa</i>	Blood cockle										
Goniasteridae	<i>Goniodiscaster</i> sp.?	Starfish										
Total:	50		2	0	2	1	1	1	11	2	1	1

Table 2. Matrix of distance measures computed for 5 main sampling sites, northeast Langkawi

Sites	Percent disagreement				
	Hangat	Kilim	Kisap	Coastal inlets	Open waters
Air Hangat	.00	.49	.44	.42	.65
Kilim	.49	.00	.45	.36	.55
Kisap	.44	.45	.00	.33	.50
Coastal inlets	.42	.36	.33	.00	.50
Open water	.65	.55	.50	.50	.00

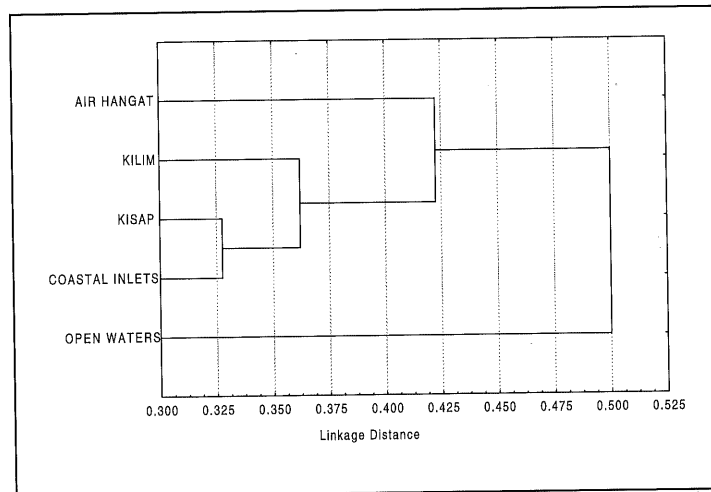


Figure 2. Dendrogram from cluster analysis of fish species (presence-absence data) recorded from Sg. Air Hangat, Sg. Kilim, Sg. Kisap, Coastal inlets and Open Nearshore Waters, northeastern Langkawi.

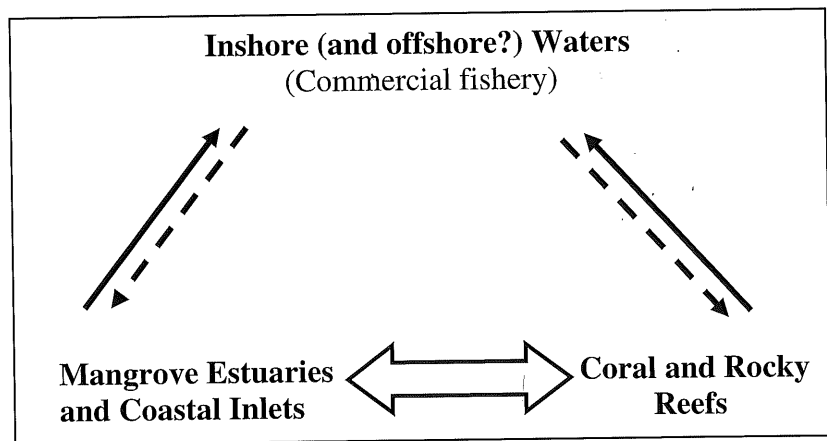


Figure 3. Proposed linkages between mangrove estuaries/ coastal inlets, coral reefs and open near shore waters of northeastern Langkawi, with respect to fish ecology. Broad arrow indicates movements of fishes between mangrove and coral reef habitats for feeding; solid arrows indicate movements of fishes to inshore and probably offshore marine waters for maturation and spawning (commercial fishery occurs here); broken narrow arrows indicate movement of larval or post larval fishes to coastal habitats that serve as nursery areas.

CONCLUSION

A total of 116 species of fishes, including those from estuaries and open nearshore waters has been recorded for northeastern Langkawi, since the first survey conducted in April 2003. The mangrove-fringed estuaries and coastal inlets are home to 91 fish species; this is an increase of 24 species from the 67 species recorded in the first Langkawi survey in April 2003. It is believed that more species, particularly the demersal species, are present in the estuaries with further samplings. The 50 odd species recorded from the open nearshore waters from Pulau Peluru Strait to Gua Cherita is also an under-estimate of its true diversity since samplings were limited. However, it is noted that half of the fish species present also occur inside the mangrove-fringed estuaries and waterways. Hence, the coastal fishery is to some extent dependent on the mangrove ecosystem of northeastern Langkawi. This scenario probably represents part of a bigger picture – that ecological linkages between the inshore waters, mangroves and coral reefs exist, involving fish movements for maturation/spawning, feeding and utilization of these coastal habitats as nursery areas. Further research is necessary to establish such habitat interactions for sustainable development of Langkawi's coasts.

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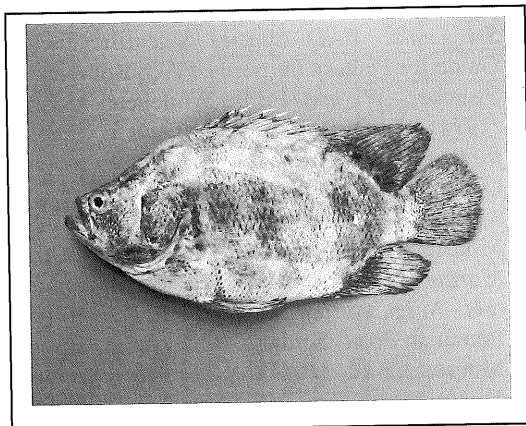
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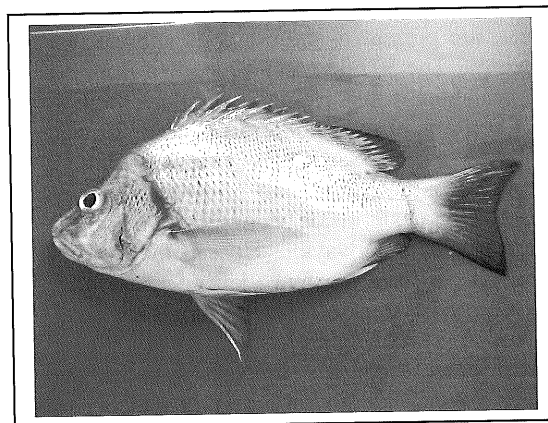
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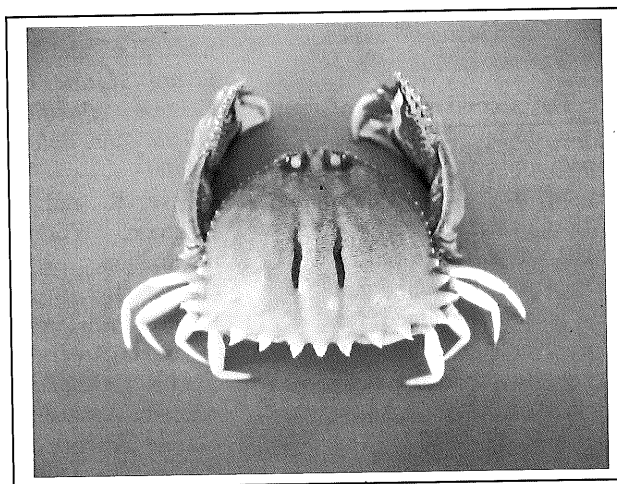
Appendix



Lobotes surinamensis



Lutjanus stellatus



Calappa bilineatus