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The Finfish Bycatch of the Bahrain Shrimp Trawl Fisheries

Abstract: Finfish bycatch data were collected for the Bahrain shrimp fishery on a bi-weekly basis during the period from February 1999 to January 2000. Sampling was conducted by a commercial fishing boat in the shrimping ground between latitudes 26° 15´47´´ and 26° 28´38´´N and longitudes 50° 32´27´´ and 50° 48´23´´E. In all bycatch collections, 92 finfish species belonging to 44 families were identified. Fish to shrimp ratio monthly means ranged from 1.5-31:1 and 0.9-21:1 on a weight and number basis respectively. Lower ratios were found in February and March 1999, and higher ratios were found in April and November 1999. Monthly mean numbers of fin-fish species in the bycatch ranged from 17 to 28 species, while one to three species were found in 50% of bycatch by numbers. The presence of commercial finfish species in the shrimp bycatch indicates the interference of the shrimp fishery with other fisheries found in Bahrain waters. *G. argyreus* was the most abundant bycatch species. Higher numbers of small fishes emphasized the importance of reducing small fish numbers in the future development of the Bahrain Bycatch Reduction Device (BRD). Monthly abundances and size information were presented for the 20 most abundant finfish species in the shrimp bycatch.

Keywords: shrimp bycatch, finfish, Bahrain

الأسماك الزعنفية في الصيد الجانبي لمصايد جر الربيان البحرينية

إ ع عبدالقادر

المستخلص: تم تجميع بيانات صيد الأسماك الزعنفية في الصيد الجانبي لمصايد جر الربيان لكل أسبوعين خلال الفترة من فبراير 1999م إلى يناير 2000م. استخدمت سفينة صيد تجارية في المعاينات في منطقة صيد الربيان بين خطوط عرض ´´47´15°26 و ´´38.´28° 26 شمالا و خطوط طول ´´27´32° 50 و ´´23´48° 50 شرقا. تم تعريف 92 نوعا من الأسماك الزعنفية و التي تنتمي إلى 44 عائلة من جميع عينات الصيد الجانبي. تراوحت المعدلات الشهرية لنسب الأسماك إلى الربيان من 1,5:1 إلى 1:31.0 و من 0.9:1 إلى 21.0:1 على حسب الوزن و العدد على الترتيب. و جدت هذه النسب متدنية في فبراير و مارس 1999م، و كانت مرتفعة في أبريل و نوفمبر 1999م. تراوح متوسط أعداد أنواع الأسماك في الصيد الجانبي من 17 إلى 28 نوعا، بينما وجد أن 50 في المائة من صيد الأسماك الزعنفية الجانبي بالأعداد يتكون من نوع واحد إلى ثلاثة أنواع من الأسماك. يدل إن وجود الأنواع التجارية من الأسماك الزعنفية في صيد الربيان الجانبي تدل على تداخل مصايد الربيان مع المصايد الأخرى الموجودة في مياه البحرين. وجد أن بدح الرياش *G. argyreus* هو النوع الأكثر توفرا في صيد الربيان الجانبي. تأكد الوفرة العالية للأسماك الصغيرة تأكد على أهمية خفض أعداد الأسماك الصغيرة في التطوير المستقبلي لأجهزة خفض الصيد الجانبي في البحرين. و قد تم عرض المعلومات لأعداد و أحجام عشرين نوعا من لأسماك الزعنفية و التي تصدرت كميات صيد الربيان الجانبي.

كلمات مدخلية: الربيان– صيد جانبي– أسماك زعنفية – البحرين.

Introduction

Bahrain's shrimping fleet has expanded considerably since 1981, from 40 boats to about 400 boats in the 1998-1999 shrimp season (Abdulqader, 1999). In addition to the effect of the over-fishing problem on the shrimp stock, these boats have intensified the bycatch quantities generated by this sector. Shrimp bycatch has been identified as one of the most important environmental issues of worldwide concern (Andrew and Pepperell, 1992; Alverson *et al.* 1994, Kennelly, 1995, Saila, 1983). Finfishes make up most of the shrimp bycatch; their direct mortality in shrimp trawls is of primary concern (Liggins and Kennelly, 1996). Decline in finfish fisheries is usually linked to the shrimp fishery (Soldal and Engas, 1997, Harris and Dean, 1998). To reduce this impact, considerable efforts have been made to develop and implement Bycatch Reduction Devices (BRD) for the use of shrimp fisheries (Averill, 1989; Brewer *et al.* 1998; Broadhurst , and Kennelly , 1994 , 1995 ; Broadhurst *et al.*1999; Garcia-Caudillo *et al.* 2000; Matsuoka, and Kan, 1991; Rulifson *et al.* 1992; Thorsteinsson, 1992; Wallace, and Robinson, 1994; Watson *et al.* 1986; Watson, and Taylor, 1996). This work aims to highlight the shrimp finfish bycatch problem in Bahrain waters and

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to provide a description of the finfish component of the shrimp bycatch; this is basic information for future Bahrain BRD development.

The 1998 fishery census revealed that 6,830 fishermen were involved in fishing in Bahrain waters; and they used 2,274 boats (Radhi, *et al.* 1999). About 15% of these boats were shrimp trawlers, mainly comprised of larger boats. In addition to shrimp trawl, several different types of fishing gear are used in Bahrain waters; these include fixed and drift gillnets, barrier tidal traps, wire traps, trolls, and hooks and lines. Total fish landings from Bahrain waters was 11,718 tons in the year 2000, with a first sale value of 24.9 million US Dollars (Fisheries Statistical Section, 2001). Several fish groups were found dominating this year's landings; they included in order of importance, crab (single species *Portunus pelagicus*) 20%, shrimp (dominated by single species *Penaeus semisulcatus*) 18%, Siganidae (dominated by single species *Siganus canaliculatus*) 18%, Lethrinidae 12%, Serranidae (dominated by single species *Epinephelus coioides*) 6%, Sparidae 5%, Carangidae 4%, Gerreidae 3%, and other groups. Total finfish landings from Bahrain waters ranged from 6,084 to 7,147 tons for the years 1990 to 2000 (Fisheries Statistical Section, 2001).

The Bahrain shrimp fishing fleet is comprised of fiberglass and wooden boats, their total length ranging from 5 to 23m. All boats are powered either by outboard or inboard engines; 86% of these boats use winches in net hauling. These boats are stern trawlers using one net at a time. Shrimp fishing is mainly conducted at night. Most nets used are made according to the Gulf of Mexico flat net design; their foot-rope length ranges from 9 to 43m. About 400 boats were licensed for the 1998/1999 shrimp season (Abdulqader 2000a). A fishing ban period is introduced annually during one time period usually extended for an average of four months. The 1999-2000 ban period extended from 1 April to 31 July 1999.

A single shrimp species *Penaeus semisulcatus* makes up about 95% of the Bahrain shrimp landings (Abdulqader 1999). During the period from 1980 to 2000, the highest shrimp landing was 3,565 tons in 1996 and the lowest was 754 tons in 1992 (Fisheries Statistical Section, 2001). The decline in 1992 was a consequence of the Gulf War. Catches are usually sorted for shrimp, crab, and marketable fishes. The remaining portion of the catch is discarded at sea.

2.Materials and methods

2.1. Sampling procedures

Eighty hauls were conducted on a biweekly basis from February 1999 to January 2000. These hauls were conducted to compare the catches of conventional and BRD shrimp trawl nets. Since all trawlers are using a single net in their fishing operations, two similar size boats were used in these comparisons; each boat hauled one net type. Both boats were made of fiberglass with a 270hp inboard diesel engine; their total lengths were 21 and 19m. Nets used were flat type Gulf of Mexico otter trawls; their foot-rope length was 29m. This work is restricted to the catch data of the conventional net; BRD data are not presented here.

Fishing was conducted mostly in a fixed area between latitudes lat. 26° 15′47″ and 26° 28′ 38″N and longitudes 50° 32′ 27″ and 50° 48′23″E. Prior to each sampling, the two boats approached each other and took the starting point of the sampling path. Two boats remained as close as possible to each other during the sampling; the average distance between the two boats was about ten meters. Most hauls were conducted in a straight line for a two hour period. Two fishing trips were conducted a month during the first and the third week of the month, except for March 1999 and January 2000 when only one trip per month was conducted. An average of four two-hour hauls were usually conducted per fishing trip at a fixed speed of about 6.5 km per hr. All samplings were conducted at night.

Data were collected on a haul basis; these include GPS co-ordinates and time at the start and end of the haul. Bottom water temperatures were recorded before each haul. Temperatures were not recorded for October 1999, December 1999 and January 2000.

Finfish bycatch species were sorted, based on their total length, as small (< 30 cm) and big fish (> 30 cm). Total weights were recorded in the case of small fish, while total weights, numbers by species, and individual lengths were recorded for big fish. Total weight and number were also recorded for the shrimp portion of the catches. In addition, samples were collected from small fish catches for species and size composition details. The whole small fish catches were taken as samples in the cases where the small fish catches were less than 35 kg, otherwise about 35kg was collected randomly from the small fish catch.

In the laboratory, small fish samples were sorted according to their species; total weight and number, and individual lengths were recorded per species. Lengths were recorded from sub-samples in cases where it was not possible to work the whole sample; this was common for species which appeared in relatively high numbers in the sample. Sub-sample weights were determined on the basis of number of fish per kilo. In cases where the number of fish equalled or exceeded 100 fish per kilo, two-kilo sub-samples were collected. Weights of the sub-samples increased with the decrease in the number of fish per kilo. Three, four, five, six, seven, and eight kilos were collected for the cases where numbers per kilo were less than 100, 80, 70, 60, 50, and 40 respectively. Fish species were identified according to Al-Baharna (1986).

2.2. Data handling and analysis

Data was collected on a haul basis; this included total shrimp and finfish weights and numbers, number of finfish species in shrimp bycatch, abundance and size data per finfish species, and water temperature data. In addition, a list of finfish species found in the shrimp bycatch throughout the study is documented. The analysis aims to highlight the shrimp fishery interference with other fisheries found in Bahrain waters; also to describe the finfish component of Bahrain shrimp catches. This is basic information for future BRD development in Bahrain. Data are analyzed to present the monthly changes in the bycatch characteristics. Shrimp fishery interference will be considered here for the cases when a commercial valued species is found abundantly or frequently in the shrimp bycatch. All data analyses and presentations were carried out by using the SPSS version ten.

Monthly means and confidence intervals of fish to shrimp ratio were calculated by direct averaging of the fish to shrimp ratios of individual hauls for the respective months. Fish to shrimp ratios based on number and weight were calculated by dividing fish numbers and weights by their respective shrimp values. Similarly, monthly means for temperature, total abundance, species number, and length values were calculated. The overall species abundances were determined by direct averaging of the abundance values of the individual haul of all months. Species abundance is expressed here in weight of fish by kilos and number of fish in a two-hour haul. By assuming that the effective width of the trawl is 70% of its foot-rope linear length, a swept area of 0.52 km^2 will result from 6.5 km per two hours. To demonstrate the dependence of the shrimp bycatch bulk on a few species, the number of species in 50% of the catch in number was adopted.

The Cluster Analysis method was applied with monthly average species composition data to develop similarities between species and months. Cluster Analysis is a classification technique for placing similar entities or objects into groups or clusters (Ludwig and Reynolds, 1988). The K-means Clustering method was used for similarities between species; this method handles a large number of cases (SPSS, 1999). The Hierarchical Clustering Method was used for similarities between months. For the latter method, in spite of the widespread popularity of the Euclidean group distance measure, Ludwig, and Reynolds (1988) do not recommend its use with ecological data because of the misleading results which can be obtained. They suggest the use of the Bray-Curtis and relative Euclidean method for ecological data, and particularly the use of the Chord Distance method (Pielou, 1984). The Chord Distance method is one of the methods used by the SPSS statistical software; this method is known by the SPSS as Cosine distance method (SPSS Inc., per. com.). This method was applied for similarities between months.

Despite the importance of the monthly data on size and abundance , it is not practical to present these data for all finfish species found in this study. These data are presented only for the first 20 species found in the rank of abundance (Table 1).

Table 1. The scientific, local, common, and family name are presented for all finfish species found in the shrimp bycatch throughout the study period. Also the overall abundance (number in 2hr haul, or in swept area of 0.26 km^2), order from high to low in the rank of abundance (between brackets), and K-mean clustering are presented per species. The first 20 species in the rank of abundance are shown in bold.

Fishes names			Family name	Abundance (order in rank)	K-means clusters
Sceintific	Local	Common			
Apogon cyanosoma	Sehaihet el-raai	Goldstriped Cardinalfish	Apogonidae	0.2 (52)	4
Apogon quadrifasciatus	Sehaihat el-raai	Four-banded Cardinalfish		<0.1 (54)	4
Apogon sp.	Sehaihet el-raai	Cardinalfish3		5.1 (34)	4
Arius thalassinus	**Chim**	**Giant sea catfish**	**Ariidae**	**25.2 (17)**	**4**
Batrachus grunniens	Naghagah	Toadfish	Batrachoidae	0.3 (51)	4
Ablennes hians	Musaffaha	Barred Needlefish	Belonidae	<0.1 (54)	4
Petroscirtes ancylodon	Abu-mlaise	Sabre-toothed Blenny	Blennidae	<0.1 (54)	4
Pseudorhombus arsius	Khofaa'h	Large-tooth Flounder	Bothidae	8.3 (28)	4
Callionymus persicus	Wahar Amlas	Gulf Dragonet	Callionymidae	7.4 (31)	4
Alectis indicus	Khait	Indian Threadfish Trevally	Carangidae	<0.1 (54)	4
Alepes melanoptera	Jannees	Blackfin Scad		18.9 (22)	4
Atule mate	Jinnees	Yellowtail Scad		0.3 (51)	4
Carangoides malabaricus	Jash	Malabar Trevally		1.4 (43)	4
Gnathanodon speciosus	Rabeeb	Golden Trevally		0.3 (51)	4
Megalaspis cordyla	Teety	Hardtail Scad		1.2 (45)	4
Scomberoides commersonianus	Lehlah	Largemouth Queenfish		3.5 (37)	4
Selar crumenophthalmus	**Balegge**	**Bigeye Scad**		**342.9 (5)**	**2**
Seriolina nigrofasciata	Hamam arabee	Blackbanded Trevally		0.7 (47)	4

Trachinotus blocchii	Bu-sulbukh	Snubnose Pompano		0.1 (53)	4
Trachurus indicus	Khedhrah	Arabian Scad		1.6 (42)	4
Rhizoprionodon acutus	Naood	Milk Shark	Carcharhinidae	3.2 (38)	4
Chirocentrus nudus	Heff	Whitefin Wolf Herring	Chirocentridae	<0.1 (54)	4
Nematalosa nasus	**Jwaff**	**Block's Gizzard Shad**	**Clupeidae**	**20.9 (20)**	**4**
Sardinella albella	Oom	White Sardinella		0.3 (51)	4
Sardinella gibbosa	Oom	Goldstripe Sardinella		7.7 (29)	4
Dactyloptena orintalis	Firyaleh	Oriental Flying Gurnard	Dactylopteridae	0.1 (53)	4
Echeneis naucrates	Lazzaq	Sharksucker	Echeneididae	0.3 (51)	4
Stolephorus indicus	Oom	Indian Anchovy	Engraulididae	0.1 (53)	4
Platax tiera	Imad	Batfish	Ephippididae	<0.1 (54)	4
Gerres filamentosus	**Rayasheh**	**Long-finned Mojarra**	**Gerreidae**	**47.3 (11)**	**4**
Gerres argyreus	**Badh El-rayash**	**Blackfin Mojarra**		**2081.6 (1)**	**1**
Cryptocentrus lutheri	Nabbat	Luther's Goby	Gobiidae	<0.1 (54)	4
Gobiidae	Nabbat	Goby		<0.1 (54)	4
Istigobius ornatus	Nabbat	Ornate Goby		0.4 (50)	4
Plectorhinchus sordidus	Janam	Grey Grunt	Haemulidae	0.2 (52)	4
Pomadasys stridens	**Jimjam**	**Striped Grunt**		**64.6 (10)**	**4**
Chiloscyllium arabicum	Hayyasseh	Abrabian Carpet Shark	Hemiscylliidae	3.9 (36)	4
Leiognathus bindus	**Tarachee**	**Orangefin Ponyfish**	**Leiognathidae**	**46.7 (12)**	**4**
Leiognathus equulus	**Rayasheh Areedhah**	**Common Ponyfish**		**27.2 (16)**	**4**
Lethrinus elongatus	Sooley	Longnose Emperor	Lethrinidae	0.2 (52)	4
Lethrinus lentjan	Baksheeneh	Redspot Emperor		6.8 (32)	4
Lethrinus mahsenoides	Jimeh	Redfin Emperor		0.1 (53)	4
Lethrinus nebulosus	Sharee	Spangled Emperor		13.5 (24)	4
Lutijanus fulviflammus	**Naisarah**	**Dory Snapper**	**Lutjanidae**	**31.6 (14)**	**4**
Lutjanus lutjanus	Naisarah	Bigeye Snapper		<0.1 (54)	4
Lutjanus malabaricus	Hamrah	Malabar Blood Snapper		<0.1 (54)	4
Alutera monoceros	Bughoomee	Unicorn Filefish	Monacanthidae	<0.1 (54)	4
Paramonacanthus choirocephalus	Bughoomee	Pig-face Filefish		0.5 (49)	4
Paramonacanthus oblongus	Bughoomee	Hair-finned Filefish		0.3 (51)	4
Stephanolepis diasros	**Chlaib El-dhow**	**Reticulated Filefish**		**45.1 (13)**	**4**
Parupeneus heptacanthus	Hawamer	Cinnabar Goatfish	Mullidae	10.7 (25)	4
Upeneus sulphureus	**Hummer Farsee**	**Yellow Goatfish**		**378.0 (4)**	**3**
Upeneus tragula	Ra'ai	Darkband Goatfish		19.0 (21)	4
Aetomyleus nichofi	Thour Amer	Striped Eagle Ray	Myliobatidae	<0.1 (54)	4
Nemipterus bleekeri	**Bassij**	**Bleeker's Threadfin Bream**	**Nemipteridae**	**77.3 (9)**	**4**
Scolopisi taeniatus	**Ebzaymee**	**Banded Spinecheek**		**88.8 (8)**	**3**
Scolopsis ghanam	Zarra'a	Dotted Spinecheek		1.1 (46)	4
Parastromateus niger	Halwayo	Black Pomfret	Parastromateidae	0.2 (52)	4
Pegasus natans	Longtail Seamoth	Pegasidae		<0.1 (54)	4
Platycephalus indicus	Waharah	Bartail Flathead	Platycephalidae	16.3 (23)	4
Sorsogona tuberculata	Waharah	Tuberculated Flathead		<0.1 (54)	4
Plotosus lineatus	Ai	Striped Eel Catfish	Plotosidae	0.1 (53)	4
Pomacanthus maculosus	Anfouz	Yellowbar Angelfish	Pomacanthidae	1.3 (44)	4
Rachycentron canadus	Sikin	Cobia	Rachycentridae	<0.1 (54)	4
Rhynchobatus djiddensis	Hrairee	Shovel-nose	Rhinobatidae	<0.1 (54)	4
Rastrelliger kanagurta	Khedhrah	Indian Mackerel	Scombridae	9.7 (26)	4
Scomberomorus commerson	Chanaad	Narrow-barred Spanish Mackerel		1.1 (46)	4
Epinephelus coioides	Hamoor	Grouper	Serranidae	0.1 (53)	4

Siganus canaliculatus	Saffy	Pearlspotted Rabbitfish	Siganidae	7.6 (30)	4
Sillago sihama	**Hassoom**	**Silver Sillago**	**Sillaginidae**	**28.4 (15)**	**4**
Aesopia cornuta	Lessan	Horned Zebra Sole	Soleidae	2.7 (39)	4
Euryglossa orientalis	Tabag Lazag	Oriental Sole		<0.1 (54)	4
Solea bleekeri	Lessan	Bleeker's Sole		0.1 (53)	4
Acanthopagrus berda	Sheem	Black Bream	Sparidae	0.1 (53)	4
Acanthopagrus bifasciatus	Faskar	Doublebar Bream		<0.1 (54)	4
Argyrops spinifer	Kofar	Long-spined Bream		2.4 (40)	4
Cheimerius nufar	Andag	Barred Silvery Bream		9.1 (27)	4
Crenidens crenidens	Batan	Karanteen Bream		0.1 (53)	4
Diplodus sargus kotschyi	Emchawah	Onespot Bream		2.0 (52)	4
Rhabdosargus haffara	**Gorgofan**	**Haffara Bream**		**139.6 (6)**	**4**
Sphyraena obtusata	**Dwailmee**	**Yellowfinned Barracuda**	**Sphyraenidae**	**22.3 (18)**	**4**
Himantura uarnak	Lukhmah Rakta	Spotted Stingray	Stegostomatidae	0.6 (48)	4
Saurida tumbil	**Kasoor**	**Greater Lizardfish**	**Synodontidae**	**22.2 (19)**	**4**
Synodus varieatus	Kasoor	Variegated Lizardfish		<0.1 (54)	4
Chelonodon patoca	Fugul	Milky-Spotted Puffer	Teraodontidae	<0.1 (54)	4
Gastrophysus lunaris	Fugul	Green Rough-backed Puffer		6.6 (33)	4
Pelates quadrilineatus	**Zamroor**	**Fourlined Terapon**	**Teraponidae**	**515.7 (2)**	**3**
Terapon jarbua	Theeb	Jarbua Terapon		4.8 (35)	4
Terapon puta	**Zamroor**	**Smallscalled Terapon**		**89.7 (7)**	**4**
Triacanthus biaculeatus	**Chlaib El-dhow**	**Short-nosed Tripodfish**	**Triacanthidae**	**422.5 (3)**	**4**

Results

Seawater bottom temperature showed a seasonal pattern, where it increased from February 1999 and maximized in August 1999 (Figure 1). Monthly abundance means and confidence intervals for all finfish in shrimp bycatch are presented in Figure 2 based on weight and number. An increase in abundance values were found during the period from April to July 1999, which coincided with the period of rising water temperature; it also coincided with the shrimp fishing ban period. Lower abundance values were found during February, March, December 1999, and January 2000. The seasonal differences in fish abundance are found to be statistically significant at $p<0.001$ in weight ($F=11.427$) and number ($F=5.537$) cases.

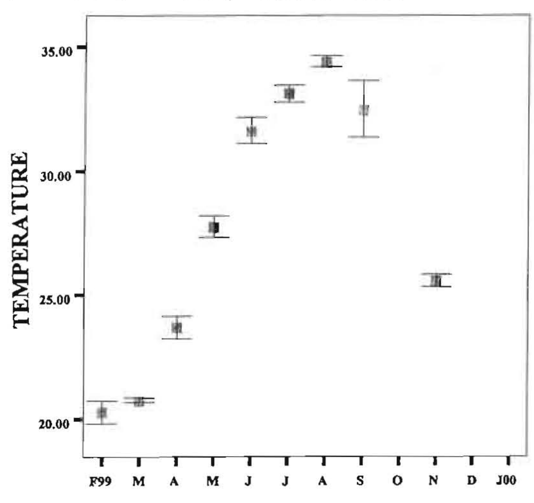

Figure 1. Monthly means (± SE) of the sea-bottom water temperature (CO); no records for October, December 1999, and January 2000.

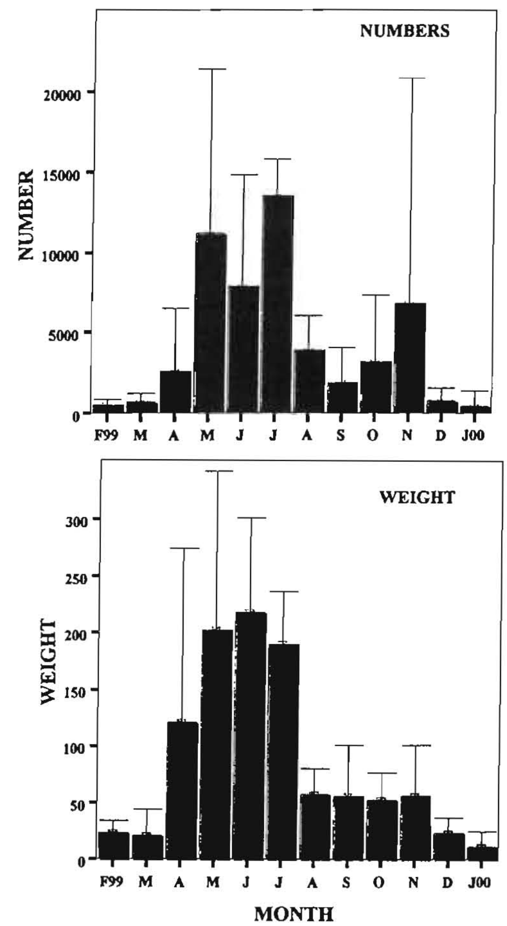

Figure 2. Shows the monthly means (± CI) of finfish abundance in shrimp bycatch based on weight in kilograms and number of fish in two hour hauls at a speed of 6.5 km per hr and by using 29m net based on foot-rope length; the generated swept area estimated as $0.52 km^2$.

The highest fish to shrimp ratios were found in April and November 1999, while the lowest ratios were found in February and March 1999, on both a weight and number basis (Figure 3). The ANOVA test indicated no significant differences between ratios based on numbers (F=1.545 at p=0.143), but there is a significant difference (F=2.581, p=0.009) between ratios based on weight. Fish-to-shrimp monthly mean ratios ranged from 1.5:1 to 31:1, and from 0.9:1 to 20:7 on a weight and number basis respectively.

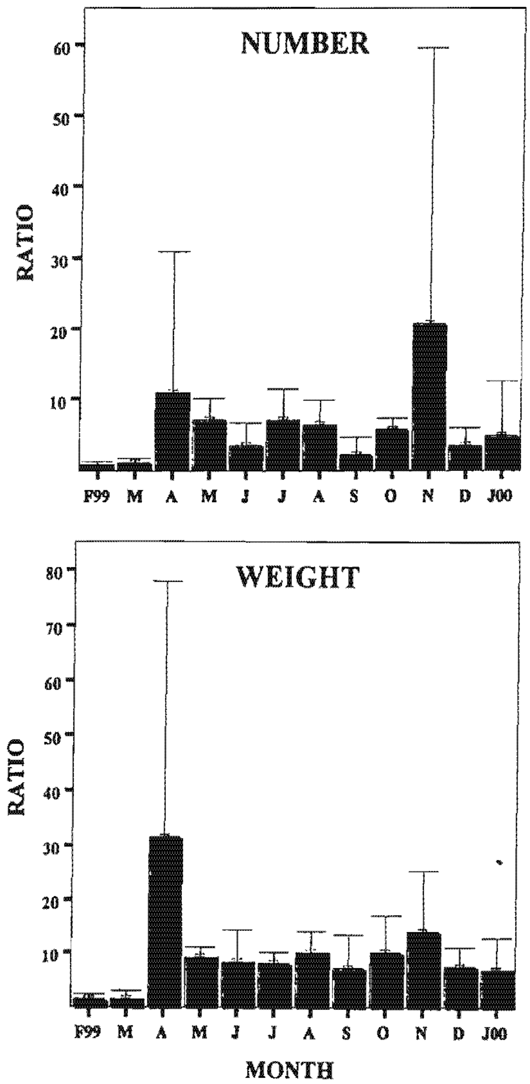

Figure 3. Shows the monthly means of fish-to-shrimp ratios (± CI) on number and weight basis. Ratio calculated by dividing number and weight of fin-fish to the respective shrimp values.

There were no significant differences (F=1.524, p=0.149) between the means of a number of species for different months (Figure 4). Similarly there were no significant differences (F=1.919, p=0.056) between monthly means of number of the species found in 50% of the finfish bycatch (Figure 5). Monthly means of the number of species found in 50% of the bycatch ranged from 1 to 3 species.

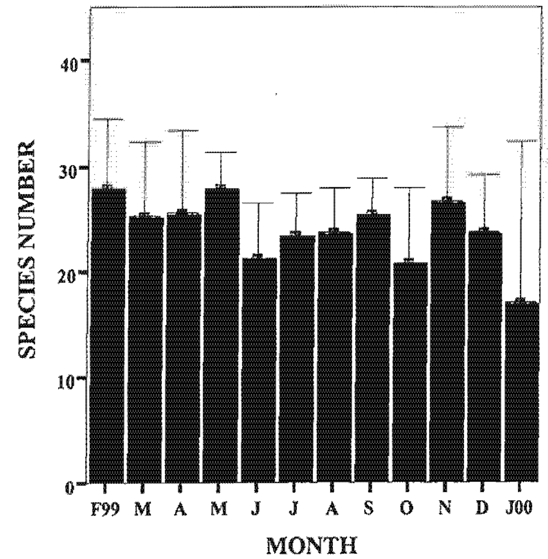

Figure 4. Shows monthly means (± CI) of number of finfish species in shrimp bycatch.

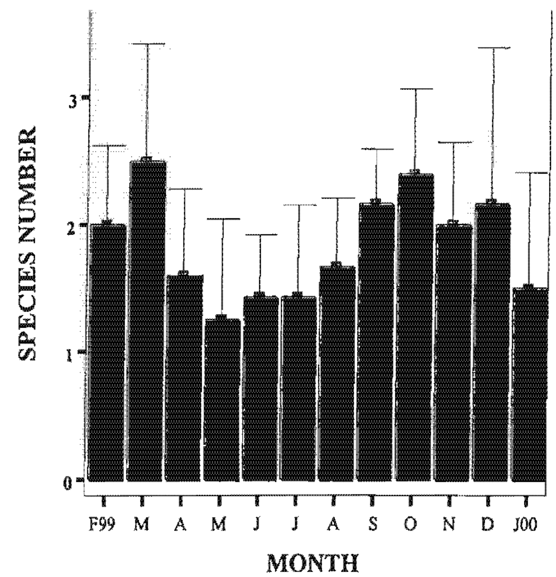

Figure 5. Shows the monthly means of number of fin-fish species (± CI) in the 50% of the bycatch based on number.

The K-means Clustering method suggested that finfish species can be categorized in 4 clusters or groups (Table 1). *G. argyreus* and *S. crumenophthalmus* are found in Cluster 1 and 2 respectively. Cluster 3 contains three species; *U. sulphureus*, *S. taeniatus*, and *P. quadrilineatus*. The remaining 87 species are suggested to be grouped in Cluster 4. The Hierarchical Clustering method suggests a two monthly groups at the same similarity level; May 99 to November 99 and April 99 for the first group, December 99 and January 99 for the second group (Figure 6).

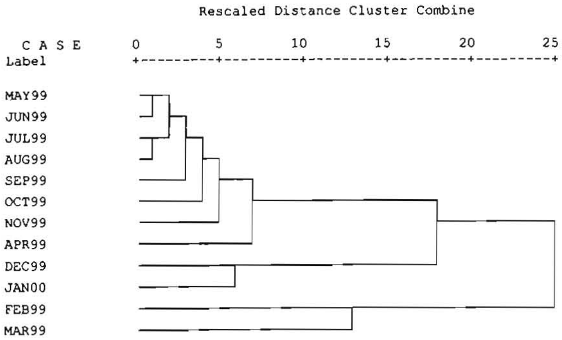

Figure 6. Shows results of the Hierarchical Clustering method on similarities between months based on monthly species composition data. Distance measure is based on Cosine method, and within group linkage is used in amalgamating clusters.

Representatives of 92 finfish species belonging to 44 families were caught in the shrimp bycatch throughout the study period (Table 1). The overall abundance value per species is presented, as is their ranking order of abundance. Monthly abundance and total length means for the first 20 most abundant species (Table 1) are shown in figures 7 & 8. *G. argyreus* is the most abundant species, it was found throughout most of the year with two peak periods from May to July 1999 and November 1999 (Figure 7a). Mean length values for this species were equal to or less than 10cm throughout the year (Figure 8a).

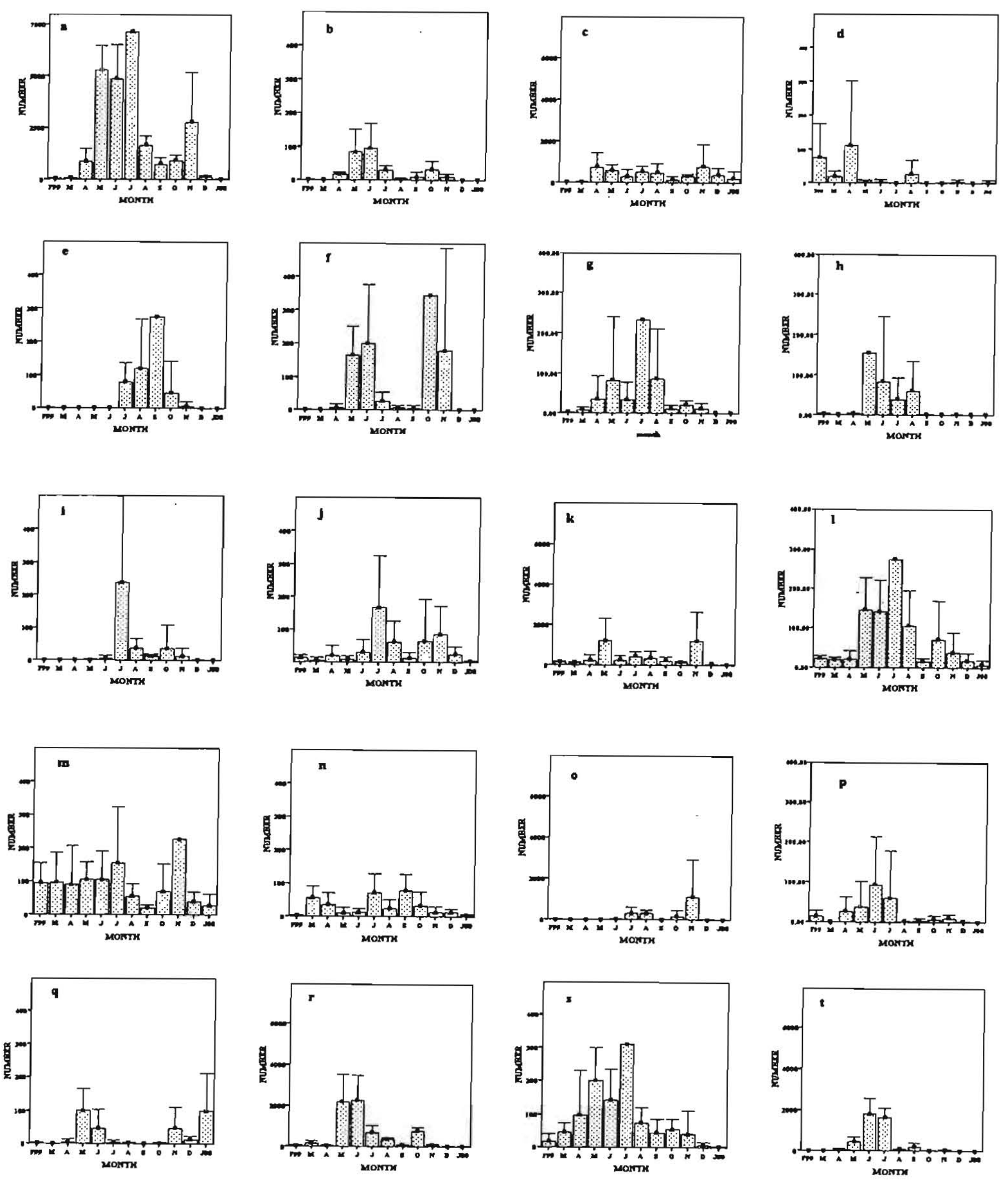

Figure 7. Shows the monthly means (±SE) of finfish species abundance (number of fish in 2hr haul; or in 0.52 km^2 swept area) for the first 20 abundant species; a) *G. argyreus*, b) *A. thalassinus*, c) *S. crumenophthalmus*, d) *N. nasus*, e) *G. filamentosus*, f) *P. stridens*, g) *L. bindus*, h) *L. equulus*, i) *L. fulviflammus*, j) *S.diasros*, k) *U.sulphureus*, l) *N. bleekeri*, m) *S. taeniatus*, n) *S. sihama*, o) *R. haffara*, p) *S. obtusata*, q) *S.tumbil*, r) *P. quadrilineatus*, s) *T. puta*, and t) *T. biaculeatus*.

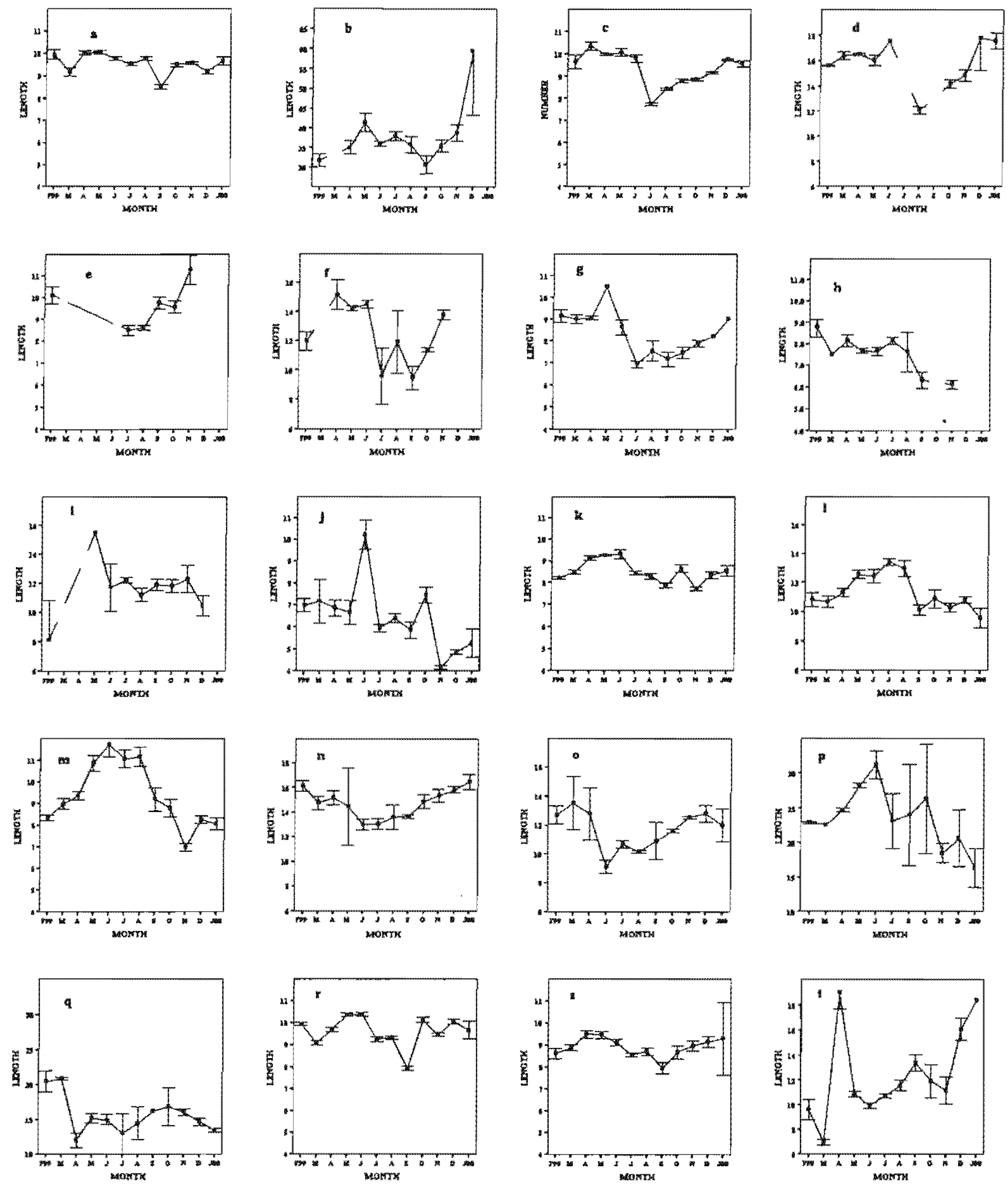

Figure 8. Shows the monthly total length means (±SE) for the first 20 abundant species; a) *G. argyreus*, b) *A. thalassinus*, c) *S. crumenophthalmus*, d) *N. nasus*, e) *G. filamentosus*, f) *P. stridens*, g) *L. bindus, h) L. equulus*, i) *L. fulviflammus*, j) *S.diasros*, k) *U.sulphureus*, l) *N. bleekeri*, m) *S. taeniatus*, n) *S. sihama*, o) *R. haffara*, p) *S. obtusata*, q) *S.tumbil*, r) *P. quadrilineatus*, s) *T. puta*, and t) *T. biaculeatus*.

Most of the dominant species showed at least two abundant periods in summer and autumn; this included *A. thalassinus, S. crumenophthalmus, P. stridens, L. bindus, S. diasros, U. sulphureus, N. bleekeri, S. taeniatus, S. sihama, S. obtusata, S. tumbil, P. quadrilineatus, T. puta,* and *T. biaculeatus* (Figure 7b, c, f, g, j-n, p-t). The remaining species were found abundant during one time period but with different timings.

Figure 8 suggestes that the monthly total length mean values can classify the first 20 dominant species into three size groups: the first group contains species where mean lengths were equal to or less than 10cm; this includes *G. argyreus, S. crumenophthalmus, G. filamentosus, L. bindus, L. equulus, S. diasros, U. sulphureus, S. taeniatus, P. quadrilineatus,* and *T. puta* (Figure 8c, e, g, h, j, k, m, r, s). The second group contains medium sized species: their mean lengths are equal to or less than 20cm during most of the year; this includes *N. nasus, P. stridens, L. fulviflammus, N. bleekeri, S. sihama, R. haffara, S. tumbil,* and *T. puta* (Figure 8d, f, i, l, n, o, q, t). The third group contains larger fishes and includes *A. thalassinus and S. obtusata* (Figure 8b, p).

Discussion

This work revealed the presence of 92 finfish species belonging to 44 families in the shrimp bycatch. This indicates that the Bahrain shrimp fishery is likely to have interfered with the other fisheries dependant on these species. Several species supporting gillnet fisheries are found in the bycatch; this includes *S. commerson,* which supports the Bahrain Spanish mackerel fisheries (Abdulqader, 2001). This work found that *S. commerson* juveniles were found in the Bahrain shrimp bycatch. Juveniles of both King *S. cavalla* and Spanish mackerel *S. maculates* were reported in bycatches of the South Carolina shrimp fishery (Harris and Dean, 1998). Species belonging to *Clupeidea, Gerreidae, Sparidae*, and *Sphyraenidae* which also support gillnet fishery in Bahrain waters are found in the shrimp bycatch. Juveniles of several fish groups supporting the wire trap fishery are found in the shrimp bycatch, e.g., *Carangidae, Lethrinidae, Lutjanidae, Siganidae,* and *Sparidae* groups. *S. canaliculatus* is the most important species of the *Siganidae* group; this species contributed 18% of the total Bahrain landings in 2000 (Fisheries Statistical Section, 2001). Some of the mentioned fish groups also support the Bahrain troll and hook and line fisheries. This indicates that shrimp fishery interfered with all finfish fisheries of Bahrain waters. In addition to the impact of this interference, there were concerns over the more complex ecological impacts on the trophic structures of marine communities (Broadhurst, 2000). There were also concerns about the turtle population usually foraging in shrimp grounds (Epperly *et al.*, 1995). A total of 1,229 turtle incidence in shrimp trawls were estimated for Bahrain waters in the 1997-1998 season (Abdulqader, 2000b). The future management of the Bahrain shrimp fishery should be directed toward reducing the impact on finfish species and other encountered fauna by adopting the appropriate regulations and practice including implementation of BRD.

This work showed that on each occasion 50% of the finfish bycatch is made up of one to three species (Figure 6); it also determined the first 20 most abundant species in the finfish bycatch (Table 1). It is likely that one member or more of these species are contributing to 50% of the bycatch at any time of the year. Liggins and Kennelly (1996) found only six and five species out of 23 species occurred at mean abundance of greater than 100 per fisher-day in the river and lake respectively of the Clarence river in Australian waters. Most of the abundant species found in this work are small-sized commercial fishes (Figure 8); this includes the most dominant species *G. argyreus*; this species is grouped by the K-means Clustering method in a single group. This indicates that in order to achieve significant finfish bycatch reduction the emphasis should be directed toward the small-sized fishes of the bycatch. This will also determine the future work on the Bahrain BRD development. Broadhurst (2000) broadly classified the BRDs into two categories: those that separate species by differences in behavior; and those mechanically excluded based on size differences. Size similarities between most finfish and shrimp species found in Bahrain waters demands the adoption of a BRD based on differences in behavior. The developed BRD should be able to exclude large animals at an earlier stage. Robins and McGilvray (1999) found a reduction of between 15 and 49% depending upon fishery conditions, and the capture of large animals. Body-form was suggested to explain the species reduction performance (Robins and McGilvray, 1999; Matsushita and Ali, 1997). *T. biaculeatus* was found to cause complete BRD blockage because of the presence of three long strong spines at dorsal and pelvic fin areas (Abdulqader, 2000a). This species appears in schools during summer in Bahrain waters (Figure 7); this period coincided with the annual shrimp fishing ban period. The abundance and size information provided by this work is baseline information for the future BRD work in Bahrain.

This work showed significant differences between monthly fish-to-shrimp mean ratios based on weight, and also showed two peaks in April and November (Figure 3). In Kuwait waters higher ratios were found in the summer periods; these periods included the month of April (Ye *et al.* 2000). For Kuwait waters, fish-to-shrimp ratio based on weight ranged from 5.6:1 to 35.9:1; while lower ratios were found by the present study for Bahrain waters. In Australia, bycatch is typically 6-15 times the weight of the prawn catch (Dredge, 1988; Harris and Poiner, 1990).

This study found higher finfish bycatch abundance in April through July 1999 samplings (Figures 2 & 7). This increase in abundance is likely to be a consequence of the shrimp fishing ban enforced during this period. This is supported by the sharp decline in fish abundance in August 1999 (Figure 2) when shrimp fishing operations were resumed. Ye *et al.* (2000) related the summer higher fish abundance in Kuwait waters to the late spring to early summer spawning by these species. Relatively high abundance mean value was found for April based on weight but not on number; this was caused by the rays' presence in bycatch during this month. The Hierarchical Clustering analysis suggested a similarity between the months of April and November (Figure 6). The relatively higher finfish abundances (Figure 2) found for these months suggested a similar conclusion.

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