Macrothink Institute™

Aquatic Science and Technology
ISSN 2168-9148
2013, Vol. 1, No. 1

Retained and Discarded Bycatch from Kuwait's Shrimp Fishery

Weizhong Chen (Corresponding author)

Aquaculture, Fisheries and Marine Environmental Department

Kuwait Institute for Scientific Research, 13109 Safat, Kuwait

Tel: 965-2495-6373 E-mail: wchen@kisr.edu.kw

Sulaiman Almatar

Aquaculture, Fisheries and Marine Environmental Department

Kuwait Institute for Scientific Research, 13109 Safat, Kuwait

Adel Alsaffar

Aquaculture, Fisheries and Marine Environmental Department

Kuwait Institute for Scientific Research, 13109 Safat, Kuwait

Abdul Rehman Yousef

Aquaculture, Fisheries and Marine Environmental Department

Kuwait Institute for Scientific Research, 13109 Safat, Kuwait

Received: September 20, 2012 Accepted: November 20, 2012 Published: January 1, 2013

doi:10.5296/ast.v1i1.2778 URL: http://dx.doi.org/10.5296/ast.v1i1.2778

Abstract

The quantity and species compositions of both retained and discarded bycatch of the Kuwait's shrimp fishery was investigated for the first time directly through onboard observation and sampling of a fishing vessel. The observations were conducted on a 131 tonne double-rigged shrimp trawler twice a month during the shrimp season from September 2010 through January 2011. The shrimp catch rate declined sharply from 19.6 to 1.1 kg/h as the season progressing, while bycatch rate remained in a high and relatively stable between

106 and 81.5 kg/h, and resulted in a large variation (5.4-73.6) of byatch-to-shrimp ratio from the season's start to the season end. The retained bycatch was always low (11.6-15.9% of the total bycatch) throughout the season. The total species recorded in the bycatch was 112, with 55 retained and 93 discarded at sea. Thirty-nine species occurred both in retained and discarded bycatches. *Saurida tumbil*, *Nematalosa nasus*, *Sphyraena flavicauda*, *Acanthopagrus latus* and *Otolithes ruber* were the most dominant fish species in the retained bycatch. Discards dominated both by undersized commercially valuable species including *Ilisha melastoma*, *Pomadasys stridens*, *Nematalosa nasus*, *Saurida tumbil* and *Upeneus doriae*, and by non-commercial species such as catfishes, sharks and rays. Based on monthly bycatch-to-shrimp ratio, the percentage of the retained bycatch and the recorded shrimp landings, the total bycatch of Kuwait's shrimp fishery was estimated to be 15,704 t for the 2010/11 season. Of the total bycatch, only 2192 t (14%) was retained, while the majority 13, 512 t (86%) was discarded at sea. Of the 93 discarded species, 55 are commercially valuable species, representing 61% (8242 t) of the total discarded bycatch.

Keywords: Bycatch, Species composition, Shrimp fishery, Kuwait

1. Introduction

Kuwait is a country with few renewable resources. Fisheries are the most important naturally occurring renewable food resource, and shrimp rank first in value. Over the past decade, annual shrimp landings have averaged around 2000 metric tons (t). The shrimp catch represents 25 to 45% of the total fishery landings and 37 to 50% of the total fishery product value in Kuwait. Shrimp are only fished by bottom trawl from two types of boats: industrial steel boats and artisanal fiberglass (dhow) boats. Kuwait's shrimp fishery targets three species: *Penaeus semisulcatus*, *Metapenaeus affinis, Parapenaeopsis stylifera*, and usually, more than 50% of catch is *P. semisulcatus*. Similar to other tropical and sub-tropical shrimp trawl fisheries (Stobutzki et al., 2001; Tonks, et al., 2008; Davies, et al., 2009), Kuwait's shrimp fishery also captures large quantities of bycatch (as high as 35,000-55,500 t) every year. These bycatches were mostly dumped at the sea with little (<2%) retained (Ye et al., 2000), resulting in a huge quantity of wasted food resources and killing large number juveniles of commercial species.

Although a few studies (Mathews & Samuel, 1984; 1989a; Ye et al., 2000, Bishop et al., 2001; Al-Ayoub et al., 2005) have addressed the bycatch issue in Kuwait, most of the previous studies collected bycatch data from a research vessel with very limited information about bycatch composition. For example, in the studies of Mathews and Samuel (1984; 1989a; 1989b), the bycatch was separated into four categories: (1) fine fish with high marked price to be retained; (2) Catfish; (3) Elasmobranchs; (4) mixed fish. No detailed species composition was reported for the discarded mixed fish. Moreover, the previous studies collected data from areas in which fishing was not permitted, including Kuwait Bay and within the three nautical miles along the coast, as well as from the commercial fishing grounds during and outside fishing season. Bycatch rates and the bycatch to shrimp ratios are usually high in Kuwait Bay and during the closed shrimping season. The results of previous studies probably do not accurately represent the bycatch of the fishery. Meanwhile, with the increasing market demand accompanied with the growing population and economy, less valuable species and small size individuals of valuable species previously discarded are now probably retained since they are found in the fish market.

In order to obtain the latest and detailed information about the total quantities and species composition of the bycatch, including both retained and discarded, and to investigate the quantity of lost juveniles of commercial species and the potential impacts on stock size, and thereafter the yields of the commercially important fish species, we conducted this study, so that better management measures of the shrimp fishery can be adopted to protect both the shrimp resources and fin-fish stocks.

2. Materials and Methods

All data were collected by scientific observers onboard a fishing vessel during the shrimp season from September 2010 to January 2011 (Table 1). The fishing vessel "Muytahead 6" is a USA-made steel boat, 25.3 M long and with 131 t gross weight. "Muytahead 6" used double rigged trawl with net specifications as follows: body mesh size 51 mm, codend mesh size 45 mm, head rope 21.3 m, foot rope 23.2 m, approximate opening 16 m (wide)×2.5 m

(height). “Muytahead 6” operated regularly as all the other fishing vessels at the local shrimp fishing ground throughout the entire shrimp season. Data were collected twice a month. During the sampling day, bycatch was recorded and collected from subsample of each of two trawl tows. The duration for each tow was approximately 3 h (recorded) with average speed of 3 knots. The catch rates (kg/tow) were standardized into kg/h based on recorded fishing durations for each tow to remove any differences caused by variation in fishing duration.

Table 1. The dates and numbers of sampled tows for each survey

Date	Sampled tows
20 Sep. 2010	3
3 Oct. 2010	2
6 Oct. 2010	2
7 Nov. 2010	2
21 Nov. 201	2
22 Dec. 2010	2
28 Dec. 2010	2
12 Jan. 2011	2
Total	17

All the catch from both nets was first sorted into shrimp, fine fish and discards by the fishermen as usual. The fine fish were then identified to species by the scientific observers. For each species, the length of each individual fish was measured to nearest *cm*, total number of fish was counted, and total weight of all individual for that specific species was weighted to nearest *g* using a portable electronic balance. For discards, large-size individuals of sharks, rays and catfish were difficult to include in a sub-sample unless the sub-sample was large enough. To reduce sub-sample size and the subsequent work, we treated these large individuals separately. We first collected the large size (approximately >1 kg) sharks, rays and catfishes, and then counted and weighted each after identified to species. A sub-sample of around 5 *kg* was collected from the remaining small-size discards for subsequent analysis. All the remaining discards were put into baskets and weighted with a steelyard. Both the large size and remaining small size discards were then returned to the sea. In the laboratory, the small-size discards were analyzed in a same way as the fine fish except that small size shrimps were measured to nearest mm.

Bycatches of fine fish and discards were analyzed separately. Species composition for fine fish was obtained directly from the collected data, while species composition for discards was obtained the following way: the individual number and total weight of each species from a sub-sample were first raised by the weight proportion of the sub-sample in the total catch of that tow, and then combined with the data of large-size individuals collected before sub-sampling. The percentage of retained bycatch was then calculated based on the total weight of fine fish and that of discarded fish. Monthly catch rates of some important commercial species were plotted to investigate reasons behind the seasonal variations of the catch rates.

To further analyze the discarded fish data, all the discarded species were separated into commercial species (individuals would have been retained had they been allowed to grow) and non-commercial species. The species number, total weight and total individual number for both commercial and non-commercial species from the discarded bycatch were calculated. Catch rates (kg/h) of both commercial and non-commercial species were then estimated.

We estimated monthly and annual retained and discarded bycatch for the entire shrimp trawl fishery by the following procedures: the monthly total bycatch was estimated using the monthly bycatch-to-shrimp ratios multiplied by the recorded monthly total shrimp catches; the monthly retained and discarded bycatches were estimated using percentages of retained bycatch from our investigation and the monthly estimated total bycatch; and the annual retained and discarded bycatch are the sums of the monthly retained and discarded bycatch. The annually discarded commercial species for the entire fishery were calculated based on the estimated total discarded bycatch and the species composition of the discards.

3. Results

3.1 Total Catches of Shrimp and Bycatch

Total shrimp catch from 17 tows was 314.1 kg, averaging 7.0 [±3.1 (standard error)] kg/h. Total bycatch was 4411.9 kg, with a mean 95.9 (±3.9) kg/h. About 14% (617.2 kg) of the bycatch was landed. The remaining 86% of the bycatch was discarded at the sea. The bycatch to shrimp ratio for the season was 13.78.

3.2 Monthly Catch Rates and Bycatch to Shrimp Ratios

The catch rate for shrimp was highest (19.6 kg/h) in September and dramatically declined as the season progressing. It was only 1.1 kg/h in the following January. While bycatch rate declined fairly slowly from 106 kg/h to 81.5 kg/h. The byatch to shrimp ratio was lowest (5.42) in September and increased to around 20 in October, November and December, and reached very high (73.64) in January (Table 2). The monthly retained and landed bycatch was 11.6-15.9% of the total bycatch.

Table 2. The sampled monthly catch rates (kg/h with standard errors) for shrimp and bycatch and bycatch/shrimp ratios

	September	October	November	December	January	Season
Tows	3	4	4	4	2	17
Total Shrimps (kg/h)	19.6 (±16.2)	5.7 (±1.4)	3.8 (±0.8)	4.7 (±0.7)	1.1 (±0.6)	7.0 (±3.1)
P. semisulcatus (kg/h)	2.8 (±0.8)	4.3 (±1.6)	3.6 (±0.8)	2.6 (±0.6)	1.1 (±0.6)	3.3 (±0.2)
M. affinis (kg/h)	16.7 (±16.6)	1.4 (±1.0)	0.2 (±0.1)	0.07 (±0.03)	0.0	3.7 (±3.3)
Fine fish (kg/h)	13.2 (8.9)	12.1 (±3.2)	15.3 (±1.7)	13.0 (±3.2)	12.5 (±2.7)	13.2 (±1.3)
Discards (kg/h)	92.9 (21.1)	92.4 (±21.2)	80.9 (±11.7)	78.2 (±16.5)	69.0 (±4.1)	82.7 (±3.2)
Total bycatch (kg/h)	106.0 (18.1)	104.5 (±22.6)	96.2 (±12.4)	91.2 (±19.0)	81.5 (±1.5)	95.9 (±3.7)
Bycatch/shrimp ratio	5.42	18.47	25.31	19.53	73.64	13.78
% of landed bycatch	12.42	11.61	15.89	14.23	15.34	13.78

3.3 Bycatch Composition

The bycatch consisted of 92 species of finfish, at least ten species of crustaeceans, six species of sharks and rays, three species of cephalopods and one species of sea snake (Table 3). The total retained species was 55 and that of discarded was 93. In total 39 species occurred both in retained and discarded bycatches. The monthly retained and discarded catch rates for some important commercial species showed seasonal changes (Fig 1). *Acanthopagrus latus* mainly occurred in November and January with most of the catch retained. *Otolithes ruber* occurred throughout the season, but large numbers of juveniles were caught and discarded in September. *Saurida tumbil* was highly abundant from September through November with almost all the catch discarded at the sea and was also abundant in December and the following January with about half of the catch retained. Two *Nemipterus* species (*N. bipunctatus* and *N. japonicas*) mostly occurred in October and November with most of their catches retained.

3.4 Species Composition of the Retained Bycatch

Although 55 species occurred in the retained bycatch, common species (>1%) numbered only 19. Total catch of these 19 species, however, represented more than 90% of the retained bycatch. Of the 19 species, *Saurida tumbil* ranked first (13.8%), followed by the crab (*Portunus pelagicus*, 11.5%), *Nematalosa nasus* (10.1%), *Sphyraena flavicauda* (9.9%). The very important commercial species *Acanthopagrus latus* and *Otolithes ruber* ranked 5th (8.8%) and 6th (8.3%) respectively. Except *Nematalosa nasus*, all the first ranked six species occurred frequently. For example, *Otolithes ruber* occurred in all the samples, while *Saurida tumbil* and *Acanthopagrus latus* occurred in 88.2% of the samples. These six species represented more than 60% of the total retained bycatch (Table 4).

3.5 Species Composition of the Discarded Bycatch

The discarded 3542.6 kg (86%) bycatch consisted of 75 fish species, at least nine species of crustaeceans, six species of sharks and rays, three species cephalopods and one species of sea snake. Of 93 discarded species, 55 had commercial value, while 38 species had no commercial value. On average, each fished hour resulted in 52.9 kg discarded bycatch, in which 32.3 kg were juveniles of commercial species, representing 61 % of the total discarded bycatch per hour (Table 5).

The most commonly captured species (>1%) numbered 20. These 20 species represent 88% of the total discarded bycatch. *Ilisha melastoma* ranked first (12.2%), followed by *Pomadasys stridens* (9.4%), *Nematalosa nasus* (9.1%), *Parapenaeopsis stylifera* (8.0%), *Saurida tumbil* (6.91%) and *Upeneus doriae* (6.8%). All these species except *Nematalosa nasus* occurred in most of the samples. These six top ranked species represented more than 50% of the total discarded bycatch (Table 4).

Table 3. Taxonomic composition of retained and discarded bycatch of the Kuwait's shrimp fishery. Relative abundance index (total weight from 17 sampled tows): +>0, ++>1, +++>10, ++++>100 kg

Family	Scientific name	Common name	Retained	Discarded
Finfish				
Apogonidae	*Apogon taeniatus*	twobelt cardinal		++
Ariidae	*Netuma bilineatus*	Bronze catfish	++	+++
	Netuma thalassina	Giant sea catfish		+++++
	Plicofollis tenuispinis	Thinspine sea catfish		+++++
Blenniidae	*Xiphasia setifer*	Hairtail blenny		++
Carangidae	*Alectis indica*	Indian threadfish	++	
	Alepes djedaba	Shrimp scad	++	++
	Alepes kleinii	Razorbelly scad		+++
	Atropus atropos	Cleftbelly trevally	++	++
	Atule mate	Yellowtail scad	+	+++
	Carangoides bajad	Orangespotted travelly		+
	Carangoides chrysophrys	Longnose trevally	++	
	Carangoides malabaricus	Malabar trevally	+	++
	Decapterus russelli	Indian scad		+++
	Megalaspis cordyla	Torpedo scad	++	++
	Parastromateus niger	Black pomfret	++	++
	Scomberoides commersonnianus	talang queenfish	++	+++
	Selaroides leptolepis	Yellowstripe scad		++
	Trachurus indicus	Arabian scad	+	
	Ulua mentalis	Longrakered trevally	+	
Chirocenitrdae	*Chirocentrus dorab*	Dorab wolf herring	++	+++
	Chirocentrus nudus	Whitefin wolf-herring	++	+++
Clupeidae	*Dussumieria acuta*	Rainbow sardine		+++
	Nematalosa nasus	Bloch's gizzard shad	+++	+++++
	Sardinella albella	White sardinella		+
	Sardinella gibbosa	Goldstripe sardinella		++
Cynoglossidae	*Cynoglossus arel*	Largescale tonguesole	+++	+++
Dasyatidae	*Himantura bleekeri*	Bleeker's whipray		++
	Himantura gerrardi	Sharpnose stingray		++
	Himantura imbricata	Scaly whipray		++
	Himantura uarnak	Honeycomb stingray		++
	Pastinachus sephen	Cowtail stingray		+++
Engraulidae	*Thryssa dussumieri*	Dussumier's thryssa		++
	Thryssa vitrirostris	orangemouth anchovy		++
	Thryssa whiteheadi	Whitehead's thryssa		+++
Ephippidae	*Drepane punctata*	Spotted sicklefish		++
	Ephippus orbis	Orbfish	+	++
Gerridae	*Gerres acinaces*	longtail silver-biddy	+	++
	Gerres filamentosus	Whipfin silverbiddy		++
Gobiidae	*Parachaeturichthys polynema*	Taileyed goby		+
Haemulidae	*Pomadasys kaakan*	Javelin Grunter	+	+
	Pomadasys stridens	Striped piggy		+++++
Hemiscylliidae	*Chiloscyllium arabicum*	Arabian carpetshark		+++++
Leiognathidae	*Leiognathus bindus*	Orangefin ponyfish		+++
	Leiognathus oblongus	Oblong ponyfish		++
Letherinidae	*Lethrinus lentjan*	Pink ear emperor	+	
	Lethrinus microdon	Long nosed emperor	+	
	Lethrinus nebulosus)	Spangled emperor	+	
Menidae	*Mene maculata*	Moonfish		+
Mugilidae	*Liza klunzingeri*	Klunziger's Mullet	+	+
Mullidae	*Upeneus doriae*	Gilded goatfish	+	+++++
	Upeneus sundaicus	Ochrebanded goatfish	+	
	Upeneus tragula	Freckled goatfish	+	+
Muraenesocidae	*Muraenesox cinereus*	Daggertooth pike conger		++

Family	Scientific name	Common name	Retained	Discarded
Nemipteridae	*Nemipterus bipunctatus*	Delagoa threadfin bream	+++	++
	Nemipterus japonicus	Japanese threadfin bream	+++	++
	Nemipterus peronii	Notched Threadfin bream		++
	Nemipterus randalli	Randall's threadfin bream	+	+
	Scolopsis taeniatus	Black-streaked monocle bream		+
Paralichthyidae	*Pseudorhombus arsius*	Largetooth flounder	++	
Platycephalidae	*Platycephalus indicus*	Bartail Flathead	+++	++
	Rogadius pristiger	Thorny flathead		+++
Polynemidae	*Polydactylus sextarius*	Blackspot threadfin	++	+++
Pristigasteridae	*Ilisha compressa*		++	+++
	Ilisha melastoma	Indian ilisha	++	+++++
Sciaenidae	*Johnius belangerii*	Belenger's croaker		++
	Johnius borneensis	Sharpnose hammer croaker	++	++
	Johnius carutta	Karut croaker	+	++
	Johnius dussumieri	Sin croaker		++
	Otolithes ruber	Tigertooth Croaker	+++	+++
	Pennahia anea	Greyfin croaker	+	+++
	Protonibea diacantha	Blackspotted croaker	++	
Scombridae	*Rastrelliger kanagurta*	Golden-striped mackerel	+++	+
	Scomberomorus commerson	Narrow-barred Spanish mackerel		++
	Scomberomorus guttatus	Indo-Pacific king mackerel	++	++
Serrannidae	*Epinephelus bleekeri*	Duskytail grouper	+	
Sillaginidae	*Sillago sihama*	Silver sillago	+	
Soleidae	*Brachirus orientalis*	Oriental sole	++	
	Solea stanalandi	Stanaland's sole		++
Sparidae	*Argyrops spinifer*	King soldierbream	+	++
	Acanthopagrus latus	Orange-spotted grouper	++++	++
	Crenidens crenidens	Karenteen seabream	+++	++
	Diplodus sargus kotschyi	One spot seabream	++	++
	Rhabdosargus haffara	Haffara seabream	+	
Sphyraenidae	*Sphyraena flavicauda*	Yellowtail barracuda	+++	+++
	Sphyraena putnamiae	Sawtooth barracuda	++	
	Sphyraena qenie	Blackfin barracuda	+	
Stromateidae	*Pampus argenteus*	Silver pomfret	++	
Synanceiidae	*Synanceia nana*	Red Sea Stonefish		+
	Synanceia verrucosa	Stonefish		+
Synodontidae	*Saurida tumbil*	Greater lizardfish	+++	+++++
	Saurida undosquamis	Brushtooth lizardfish	+	++
Terapontidae	*Terapon theraps*	Largescaled therapon		+++
Tetraodontidae	*Lagocephalus lunaris*	Green rough-backed puffer		+
Triacanthidae	*Pseudotriacanthus strigilifer*	Long-spined tripodfish		+
	Triacanthus biaculeatus	Short-nosed tripodfish		++
Trichiuridae	*Eupleurogrammus glossodon*	Longtooth hairtail		++
	Eupleurogrammus muticus ?	Smallhead hairtail		++
Crustaceans				
Penaeidae	*Megokris granulosus*	coarse shrimp		++
	Metapenaeopsis stridulans	Fiddler shrimp		+
	Metapenaeopsis affinis	Jinga shrimp		++
	Metapenaeus stebbingi	Peregrine Shrimp		++
	Parapenaeopsis stylifera	Kiddi shrimp		+++++
	Penaeus semisulcatus	Green tiger prawn		+
Portunidae	*Portunus pelagicus*	flower crab	+++	++
Scyllaridae	*Thenus orientalis*	Flathead lobster	++	
Squillidae	*Oratosquillina interrupta*	mantis shrimp		+++
	Unidemtified Small crabs			+++
Molluscs				
Loliginidae	*Loligo duvauceli*	Indian squid		+
Octopodidae	*Octopus cyaneus*	Big blue octopus		++
Sepiidae	*Sepia pharaonis*	Pharaoh cuttlefish	+++	
Reptile				
Hydrophidae	*Hydrophis sp.*	Seasnake		++

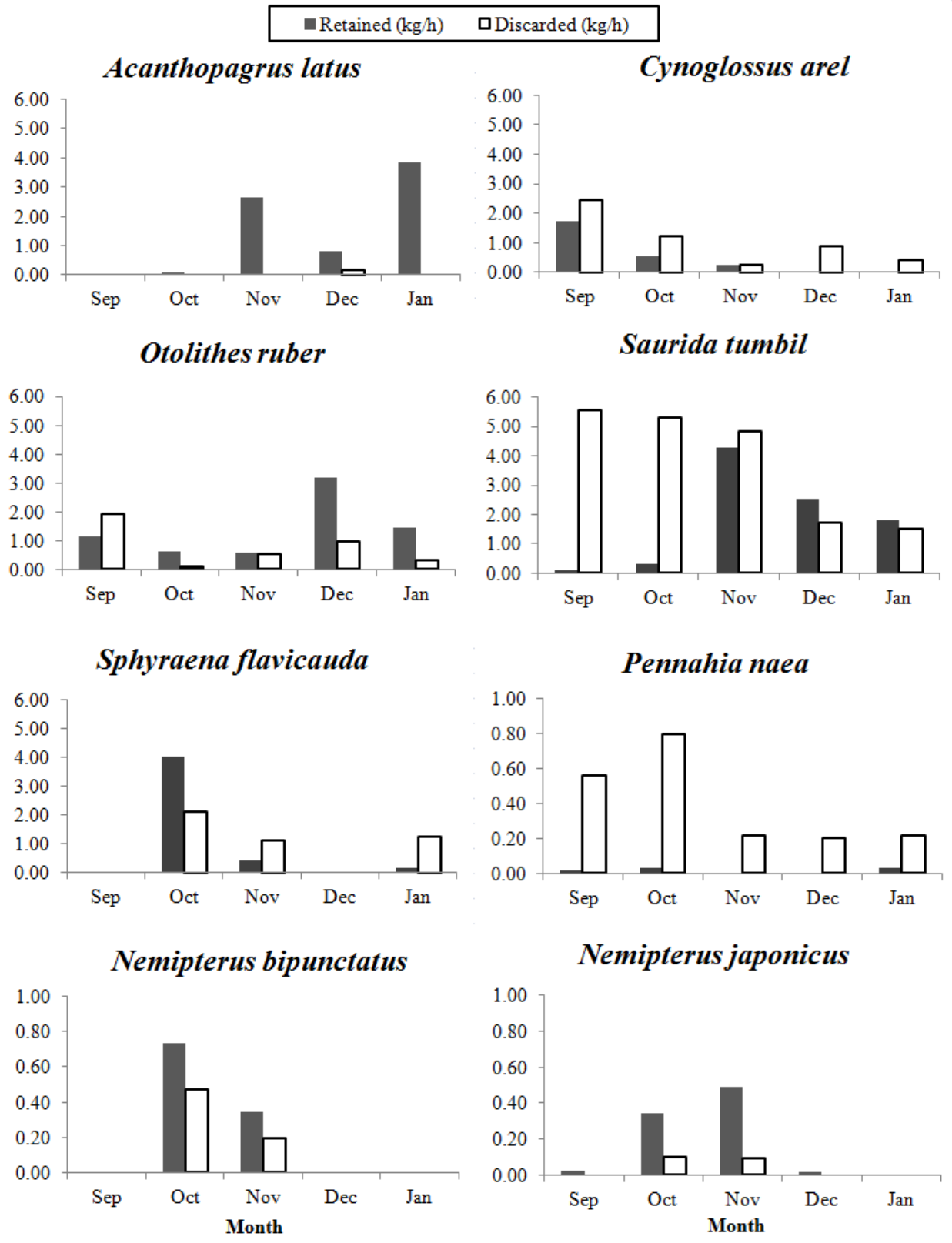

Figure 1. Monthly retained and discarded bycatch rates (kg/h) for some important commercial species

Table 4. The most common species (>1%) in retained and discarded bycatch (species in bold occurred both in retained and discarded bycatches

Order	*Scientific name*	Common name	Catch weight (kg)	Weight %	Cumulative weight %	% of occurrence (n=17)
Retained						
1	***Saurida tumbil***	**Greater lizardfish**	**85.4**	**13.8**	**13.8**	**88.2**
2	*Portunus pelagicus*	flower crab	71.1	11.5	25.3	76.5
3	***Nematalosa nasus***	**Bloch's gizzard shad**	**62.3**	**10.1**	**35.4**	**17.6**
4	***Sphyraena flavicauda***	**Yellowtail barracuda**	**61.3**	**9.9**	**45.3**	**70.6**
5	*Acanthopagrus latus*	Orange-spotted grouper	54.5	8.8	54.1	88.2
6	***Otolithes ruber***	**Tigertooth Croaker**	**51.3**	**8.3**	**62.4**	**100.0**
7	*Platycephalus indicus*	Bartail Flathead	26.1	4.2	66.7	47.1
8	***Cynoglossus arel***	**Largescale tonguesole**	**25.8**	**4.2**	**70.8**	**64.7**
9	*Rastrelliger kanagurta*	Golden-striped mackerel	17.6	2.8	73.7	41.2
10	*Crenidens crenidens*	Karenteen seabream	17.2	2.8	76.5	41.2
11	*Nemipterus bipunctatus*	Delagoa threadfin bream	14.6	2.4	78.8	35.3
12	*Sepia pharaonis*	Pharaoh cuttlefish	12.3	2.0	80.8	17.6
13	*Nemipterus japonicus*	Japanese threadfin bream	11.5	1.9	82.7	41.2
14	*Diplodus sargus kotschyi*	One spot seabream	9.1	1.5	84.1	35.3
15	*Brachirus orientalis*	Oriental sole	8.6	1.4	85.5	52.9
16	*Pseudorhombus arsius*	Largetooth flounder	8.6	1.4	86.9	58.8
17	*Parastromateus niger*	Black pomfret	7.4	1.2	88.1	35.3
18	*Megalaspis cordyla*	Torpedo scad	7.3	1.2	89.3	11.8
19	*Chirocentrus nudus*	Whitefin wolf-herring	7.1	1.1	90.4	29.4
Discarded						
1	*Ilisha melastoma*	Indian ilisha	355.3	12.3	12.3	94.1
2	*Pomadasys stridens*	Striped piggy	272.1	9.4	21.7	82.4
3	***Nematalosa nasus***	**Bloch's gizzard shad**	**263.5**	**9.1**	**30.8**	**35.3**
4	*Parapenaeopsis stylifera*	Kiddi shrimp	232.9	8.0	38.8	88.2
5	***Saurida tumbil***	**Greater lizardfish**	**199.9**	**6.9**	**45.8**	**82.4**
6	*Upeneus doriae*	Gilded goatfish	197.1	6.8	52.6	94.1
7	*Netuma thalassina*	Giant sea catfish	192.2	6.6	59.2	47.1
8	*Plicofollis tenuispinis*	Thinspine sea catfish	171.7	5.9	65.1	52.9
9	*Chiloscyllium arabicum*	Arabian carpetshark	131.0	4.5	69.7	52.9
10	*Netuma bilineatus*	Bronze catfish	74.0	2.6	72.2	52.9
11	*Thryssa whiteheadi*	Whitehead's thryssa	67.1	2.3	74.5	70.6
12	*Atule mate*	Yellowtail scad	60.1	2.1	76.6	11.8
13	*Rogadius pristiger*	Thorny flathead	59.2	2.0	78.7	58.8
14	***Sphyraena flavicauda***	**Yellowtail barracuda**	**48.0**	**1.7**	**80.3**	**35.3**
15	***Cynoglossus arel***	**Largescale tonguesole**	**47.4**	**1.6**	**82.0**	**76.5**
16	*Oratosquillina interrupta*	mantis shrimp	46.7	1.6	83.6	88.2
17	*Pastinachus sephen*	Cowtail stingray	34.2	1.2	84.8	29.4
18	*Decapterus russelli*	Indian scad	33.6	1.2	85.9	11.8
19	***Otolithes ruber***	**Tigertooth Croaker**	**31.7**	**1.1**	**87.0**	**47.1**
20	*Leiognathus bindus*	Orangefin ponyfish	29.5	1.0	88.0	58.8

Table 5. Species number, total weight and total number for the commercial species and non-commercial species in the discarded bycatch from the 17 sampling tows

	Commercial species	%	Non-commercial species	%	Total discarded bycatch
Species	55	59.1	38	40.9	93
Total weight (kg)	1764.9	61.0	1126.8	39.0	2891.7
kg/h	32.3	61.0	20.6	39.0	52.9

3.6 Estimates of Annual Retained and Discarded Bycatches for the Entire Shrimp Fishery

By applying the estimated monthly bycatch/shrimp ratios and percentages of retained bycatch to the entire shrimp trawl fishery to the known monthly total shrimp catch, the monthly total bycatch, retained and discarded bycatch for the entire fishery could be estimated (Table 6). The total annual bycatch for the shrimp fishery was 15,770 t for the 2010/11 shrimp season, in which, only 2258 t bycatch were landed, while 13,512 t were discarded at sea. Of the 13,512 t discarded bycatch, 8242 t represented juveniles of commercial species.

Table 6. Estimated total retained bycatch, discards and total bycatch based on monthly total shrimp catch, bycatch-shrimp ratio and % of retained bycatch in 2010-2011 shrimp season

Item	Aug.*	Sep.	Oct.	Nov.	Dec.	Jan.	Total
Bycatch/shrimp ratio	5.85	5.85	17.37	25.44	19.65	73.43	13.08
% of landed bycatch	12.80	12.80	11.84	16.04	14.26	15.35	13.96
Total shrimp catch (t)	200.9	506.4	217.7	188.8	62.9	23.7	1200.5
Total bycatch (t)	1175.2	2962.5	3782.0	4804.5	1236.5	1743.3	15704.1
Retained bycatch (t)	150.5	379.3	447.9	770.4	176.3	267.6	2192.0
Discards (t)	1024.8	2583.3	3334.1	4034.0	1060.2	1475.6	13512.1
Discards of commercial species (t)	625.1	1575.8	2033.8	2460.8	646.7	900.2	8242.4

Note: *Kuwait shrimp season started from 1st September 2010 through January 2011, however, fishermen started to catch shrimp in August from outside waters (international waters). Since the bycatch data was not available from this month, we used shrimp catch from August and the bycatch data from September to estimate total bycatch from August.

Of the 8242 t discarded juveniles of commercial species, *Ilisha melastoma* (1707 t) ranked first, followed by *Parapenaeopsis stylifera* (1421 t), *Pomadasys stridens* (1387 t), *Saurida tumbil* (933 t) and *Upeneus doriae* (855 t) (Table 7) . Eight species each contributed more than 100 t discards with a total 6829 t. The listed 18 species (Table 7) contributed 87% of the total discarded juveniles of commercial species. These numbers indicated that Kuwait's shrimp fishery kills thousands of tonnes of juveniles of commercial species while capturing less than two thousand tonnes of shrimps in recent years.

Table 7. The estimated total weight (t) and average weight (g) of the juveniles for the major commercial species discarded at sea by the entire Kuwait's shrimp fishery in 2010/11 season

Scientific name	Common name	Estimated total weight (t)	Average weight (g)
Ilisha melastoma	Indian ilisha	1707	12
Parapenaeopsis stylifera	Kiddi shrimp	1421	2
Pomadasys stridens	Striped piggy	1387	56
Saurida tumbil	Greater lizardfish	933	30
Upeneus doriae	Gilded goatfish	855	15
Sphyraena flavicauda	Yellowtail barracuda	234	51
Otolithes ruber	Tigertooth croaker	181	90
Scomberomorus commerson	Narrow-barred Spanish macherel	111	67
Chirocentrus dorab	Dorab wolf herring	81	82
Polydactylus sextarius	Blackspot threadfin	50	30
Scomberoides commersonnianus	Talang queenfish	43	30
Diplodus sargus kotschyi	One spot seabream	41	80
Chirocentrus nudus	Whitefin wolf herring	36	50
Argyrops spinifer	King soldierbream	35	50
Crenidens crenidens	Karenteen seabream	20	55
Scomberomorus guttatus	Indo-Pacific king mackerel	18	57
Acanthopagrus latus	Orange-spotted grouper	8	79
Liza klunzingeri	Klunziger's mullet	7	44

4. Discussion

Mathews and Samuel (1989a) used the catch rate (kg/h) of discarded mixed fish from a research vessel and the total trawl effort (total hours) of the shrimp fishery, to estimate the total mixed fish in annual bycatch was between 11556 and 21213 t from 1978/79 to 1983/84 season . Their "mixed fish" refers the discarded fish excluding sharks, rays, catfish and landed high-value fishes. Their total bycatch should be higher than the above range. Our estimated total bycatch for the 2010/11 season (15704 t) should be close to the low limit of the range estimated by Mathews and Samuel [11556 t +(sharks+ rays+ catfishes +retained bycatch)]. However, our estimated total bycatch is much lower than that (34,737-55,498 t of the late 1980s) of Ye et al. (2000). The reduced total bycatch may imply that the fish abundance has declined since 1980s. Kuwait's total landed fisheries volume has declined by 50% since mid-1990s. Our estimated retained bycatch (14%) is much higher than all the estimations (<2%) made by previous studies, which supports the casual observation that more bycatch is retained now than before because of declining fish landings and increased market demand.

The estimated bycatch-to-shrimp ratio is around 14:1, which is within the range (6.78-15.32:1) estimated by Ye et al. (2000), but much lower than that (71:1) of Bishop (2001). Both the two previous studies used year-round data from a research vessel, however, Ye et al. (2000) excluded Kuwait Bay, a no-fishing area with very high bycatch-to-shrimp ratio, and the high ratio summer season, gave a more realistic ratio for the shrimp fishery. Our

estimated bycatch-to-shrimp ratio is also close to that (13:1) of the prawn fishery in northwestern Australia (Tonks et al., 2008).

This study is the first to directly analyze the bycatch of the Kuwait's shrimp fishery. Although the resulting total bycatch species (112) is comparatively lower than that reported in a tropical Australian penaeid fishery (350 species of teleosts and elasmobranchs) (Stobutzki et al., 2001) and that (195 taxa from 85 families) of prawn trawl bycatch in northwestern Australia (Tonks et al., 2008), it is similar or higher than the total species reported in this area from both bycatch of the shrimp trawling (95 species) (Al-Ayoub et al., 2005) and catches from other surveys. For example, the total reported species was 92 for hadrah (intertidal stake) (unpublished data), 70 for gargoor (cage type fish trap) (Chen et al., 2012). This indicates that total species numbers are area and year dependent. The results from this study should reasonably reflect a true picture of the bycatch composition for the Kuwait's shrimp fishery.

Previously, most (>98%) of the bycatch from Kuwait's shrimp trawl fishery were discarded at sea because of the preference of the local people for high quality fish and the high labour cost to land the bycatch. However, our results showed an increased percentage of retained bycatch probably due to the increased demand (price) resulting from declining fisheries landings and growing population in the last two decades. Total fisheries landings declined from more than 8000 t in the mid-1990s to around 4000 t in the late 2000s. At present, Kuwait imports more than 50% of the annually consumed fresh fish. More bycatch, including small size individuals of presently retained species and individuals of presently discarded species such as catchfish, sharks, rays and bony fish (e.g. clupeidae sp.), may be retained in the future with the continuing increase in market demand. Increased landings of byctch will reduce the waste (discards) and help supply market demand. Doing so, however will have negative impacts on the shrimp fishery. With increasing retention of bycatch, fishermen may shift their target from shrimp to fish species, i.e. they may fish in areas (or during periods) with relatively low shrimp catch. Thus, high retained bycatch may encourage fishermen to expand fishing areas and extend fishing season, i.e. increase the total fishing effort, which would result in further decline of the already overfished shrimp stocks.

Our results showed that the majority (55 out 93) of the discarded species were juveniles of commercial species with an estimated total weight 8242 t for 2010/11season. Almost all of the discards from shrimp trawling were returned dead or dying to the sea, where they are a potential food sources for scavengers (Hill & Wassenberg, 2000; Stobutzki et al., 2001). The low likelihood of survival means that the capture of these species as bycatch results in direct fishing mortality of the commercially important species. This might be one of the factors causing the declining of the total fisheries landings since mid-1990s. Reducing capture of bycatch, especially those commercial juveniles, will certainly benefit other commercial fisheries. The Bycatch Reduction Device (BRD) widely and successfully applied in other countries such as Australia (Broadhurst, 1999; Broadhurst et al., 2002, 2012) and USA (Rogers et al, 1997) should be considered to Kuwait's shrimp fishery to help the recovery of the major commercial fish species.

Meanwhile, the removal of large amount of fish from the shrimp ground are likely to reduce fish predation upon shrimp, especially juveniles. This could affect the natural mortality of the shrimp population (Mathews & Samuel, 1989a). Gulland (1989) suggested that the optimum opening date for the shrimp season should be delayed when shrimp natural mortality was low. It is important to understand how bycatch, especially discards, affects both commercial finfish and shrimp stocks and as food available to scanvengers so that we can fully determine the impact of trawling on the ecosystem as a whole.

Acknowledgments

We thank Captain Sayed Geshlan and his crew from "Muytahead 6" of the United Fishery of Kuwait for their great support in our onboard observations and sampling, and our colleague Dr. James Bishop for reviewing our manuscript.

References

Al-Ayoub, S., Al-Husaini, M., Al-Baz, A., Chen, W., Alsaffar, A. H., Bishop, J. M., . . . Murad, H. (2005). *Application of by-catch reduction devices to Kuwait's shrimp fishery. Final report,* KISR 7762, Kuwait Institute for Scientific Research, Kuwait.

Bishop, J. M., Ye, Y., Alsaffar, A. H., Fetta, N., Abdulqader, E., Lui, Q., . . . Al-Ibrahim, E. H. (2001). *Shrimp Stock Assessment in the Western Arabian Gulf by Countries of the Gulf Cooperation Council, Final Report* (MB021C). Kuwait Institute for Scientific Research Report No. 6291, Kuwait.

Broadhurst, M. K. (1999). Use and success of composite square-mesh codends in reducing bycatch and in improving size-selectivity of prawns in Gulf St. Vincent, South Australia. *Fishery Bulletin, 97*, 434-448.

Broadhurst, M. K., Brand, C. P., & Kennelly, S. J. (2012). Evolving and devolving bycatch reduction devices in an Australian penaeid-trawl fishery. *Fisheries Research, 113*, 68-75. http://dx.doi.org/10.1016/j.fishres.2011.09.006

Broadhurst, M. K., Kangas, M. I., Damiano, C., Bickford, S. A., & Kennelly, S. J. (2002). Using composite square-mesh panels and the Nordmøre-grid to reduce bycatch in the Shark Bay prawn-trawl fishery, Western Australia. *Fisheries Research, 58*, 349-365. http://dx.doi.org/10.1016/S0165-7836(01)00390-3

Chen, W., Al-Baz, A., Bishop, J. M., & Al-Husaini, M. (2012). Field experiments to improve the efficacy of gargoor (fish trap) fishery in Kuwait's waters. *Chinese Journal of Oceanology and Limnology, 30*(3), 535-546. http://dx.doi.org/10.1007/s00343-012-1212-x

Davies, R. W. D., Cripps, S. J., Nickson, A., & Porter, G. (2009). Defining and estimating global marine fisheries bycatch. *Marine Policy, 33*, 661-672. http://dx.doi.org/10.1016/j.marpol.2009.01.003

Gulland, J. A. (1989). The optimum opening date in shrimp fishing; A sensitivity analysis. *Kuwait Bulletin of Marine Science, 10*, 71-79.

Hill, B. J., & Wassenberg, T. J. (2000). The probable fate of the discards from prawn trawlers fishing near coral reefs A study in the northern Great Barrier Reef, Australia. *Fisheries Research, 48*, 277-286. http://dx.doi.org/10.1016/S0165-7836(00)00185-5

Mathews, C. P., & Samuel, M. (1984). The stock of "mixed fish" in Kuwait, the "by-catch" and their potential for exploitation. Proceedings, *Third Shrimp and Fin Fisheries Management Workshop* (ed. C.P. Mathews), pp. 376-412, Kuwait: Kuwait Institute for Scientific Research.

Mathews, C. P., & Samuel, M. (1989a). The relation between by-catch, shrimp catches and shrimp landings in Kuwait. *Kuwait Bulletin of Marine Science, 10*, 135-146.

Mathews, C. P., & Samuel, M. (1989b). Multi-species dynamic pool assessment of shrimp by-catch in Kuwait. *Kuwait Bulletin of Marine Science, 10*, 147-168.

Rogers, D. R., Rogers, B. D., Silva, J. A., Wright, V. L., & Watson, J. W. (1997). Evaluation of shrimp trawls equipped with bycatch reduction devices in inshore waters of Louisiana. *Fisheries Research*, *33*(1-3), 55-72. http://dx.doi.org/10.1016/S0165-7836(97)00060-X

Stobutzki, I. C., Miller, M. J., Jones, P., & Salini, J. P. (2001). Bycatch diversity and variation in a tropical Australian penaeid fishery: the implications for monitoring. *Fisheries Research, 53*, 283-301. http://dx.doi.org/10.1016/S0165-7836(00)00273-3

Tonks, M. L., Griffiths, S. P., Heales, D. S., Brewer, D. T., & Dell, Q. (2008). Species composition and temporal variation of prawn trawl bycatch in the Joseph Bonaparte Gulf, northwestern Australia. *Fisheries Research, 89*, 276-293. http://dx.doi.org/10.1016/j.fishres.2007.09.007

Ye, Y., Alsaffar, A. H., & Mohammed, H. M. A. (2000). Bycatch and discards of the Kuwait shrimp fishery. *Fisheries Research, 45*, 9-19. http://dx.doi.org/10.1016/S0165-7836(99)00105-8

Copyright Disclaimer