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Estimation of CPUE and CPUA of three caught fish by bottom trawler in the Motaf fishing grounds, Bushehr Province, Persian Gulf, Iran

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Abstract. *Seyed Hosseini SM, Paighambari SY, Pouladi M, Shabani MJ. 2018. Estimation of CPUE and CPUA of three caught fish by bottom trawler in the Motaf fishing grounds, Bushehr Province, Persian Gulf, Iran. Biodiversitas 19: 1434-1440.* This study was conducted to estimate catch per unit effort (CPUE) and catch per unit area (CPUA) of Giant trevally (*Caranx ignobilis* Forsskål, 1775), Bigeye scad (*Selar crumenophthalmus* (Bloch, 1793), and Sulphur goatfish (*Upeneus sulphureus* (Cuvier, 1829). Sampling operations were done by a stern trawler in the Motaf fishing grounds located in the Persian Gulf during summer 2016. Overall, 36 hauls were done in two depths of 50-60 m and 60-70 m. In this research, the highest length frequencies of *C. ignobilis*, *S. crumenophthalmus,* and *U. sulphureus* were in the length classes of 56.5-61.5, 22-23.5 and 14-15.5 cm, respectively. The results of CPUE for *C. ignobilis*, *S. crumenophthalmus*, and *U. sulphureus* were 3, 0.159 and 0.078 kg h^{-1}, while the results of CPUA were 45.03, 2.44 and 1.91 kg km^{-2}, respectively. Also, CPUE values for mature and immature forms of *C. ignobilis* were 5.05 and 0.65 kg h^{-1}, for *S. crumenophthalmus* were 0.2 and 0.07 kg h^{-1}, and for *U. sulphureus* were 0.13 and 0.04 kg h^{-1}, and CPUA values for *C. ignobilis* were 22.51 and 5.02 kg km^{-1}, for *S. crumenophthalmus* were 22.03 and 10.95 kg km^{-1}, and for *U. sulphureus* were 27.4 and 12.77 kg km^{-1} at the depths of 50-60 m and 60-70 m, respectively. Finally, it was concluded that effective fishing of *C. ignobilis* and *U. sulphureus* is affordable at depths above 60-70 m, and it was not different for *S. crumenophthalmus* at fishing depths.

Keywords: Bigeye scad, bottom trawler, giant trevally, sulphur goatfish, Persian Gulf

INTRODUCTION

Carangidae is a family of fish which is among the most valuable commercial fish on the coast of Bushehr, Iran, in the Persian Gulf. This family has a large variety of different species and has 140 known species in the world (Carpenter et al. 1977; Honebrink 2000; Smith-Vaniz 2003; Nelson 2006). Its species are distributed in all tropical and subtropical waters of the world, and they are one of the most important reserves in the Persian Gulf and Oman Sea which need to be further understood in the environmental field. Most species have been found in estuaries and saline waters, while some are oceanic and live far from the coasts. It's a carnivorous hunter and feeds on crustaceans and fish. Overall, 45 species belong to 21 genera exist in Iranian waters of the Persian Gulf and Oman Sea (Sattari et al. 2004). Goatfish are also carnivorous and mainly feed on worms and crustaceans and It usually forms small groups (Sattari et al. 2004; Randall and Kulbicki 2006; Uiblein and McGrouther 2012). Its residence varies according to different species. Their habitat is throughout the Persian Gulf, the Sea of Oman, in the tropical and temperate seas, the Indian Ocean, Hawaii, and Iceland (Sattari et al. 2004).

The Persian Gulf is surrounded by Iran from the north, by Kuwait and Iraq from the west, and by Saudi Arabia, Bahrain, Qatar and the United Arab Emirates from the south. Its breadth is 240000 km^2, and after the Gulf of Mexico and the Hudson Bay, it is the third largest gulf in the world. Fishing industry plays an important role in the economy of marginal countries in the Persian Gulf, especially in three coastal provinces of Iran - Khuzestan in the northwest, Hormozgan in the northeast, and Bushehr in the central part of the Persian Gulf (Esmaeili 2006). Among the three southern provinces of the Iran which are connected to the Persian Gulf, Bushehr Province has more than six hundred kilometers coastline with the Persian Gulf and it has a special economic and strategic position. In recent years, there has been a decline in fish catch rates due to the high fishing effort by traditional and industrial fishing systems (Niamaimandi et al. 2007).

The bottom trawl method is limited to shrimp fishing in Bushehr Province, Iran which the quota is defined is by Fisheries Department each year. The by-catch rate has become a progressively important issue to fishermen and fisheries managers for evaluation of trawl nets in Iranian marine environments. Trawl fishing system is a common method in the Persian Gulf. The Iranian trawl fishery in the Persian Gulf can be divided into two categories, the cutlassfish trawlers designated for ribbon fishes and the demersal shrimp trawlers (Valinassab et al. 2006; Raeisi et al. 2011). Due to the importance of maintaining aquatic resources in the south of Iran, the most important and appropriate way to preserve these species is to prevent its over-fishing and catching of immature fish. They are usually caught using bottom trawlers and gill nets (Raeisi et al. 2011). Investigation on distribution patterns of several

fishes in Oman Sea and the Persian Gulf have been performed by different scholars (Valinassab et al. 2006; Noroozi and Valinassab 2007; Paighambari and Daliri 2012; Parsa et al. 2014; Ghotbeddin et al. 2014; Zeinali et al. 2017), but no detailed documents are available on the distribution patterns of demersal fish in this fishing area. The main purposes of this research were an estimation of CPUA and CPUE for mature and immature fish belonging to Giant trevally, Bigeye scad, and Sulphur goat in deeper layers of 50 m by a bottom trawler in Bushehr waters.

MATERIALS AND METHODS

Study area

Sampling operations were carried out by a stern trawler in summer 2016. In this study, the operation area was located in Motaf fishing grounds in the geographical location of 27° 00 to 28° 03' N and 51° 41' to 52° 11' E in the south of Bushehr Province, Iran (Figure 1).

During field sampling, 36 hauls were done in two depths of 50-60 m and 60-70 m. According to the daily operations record, net hauling operations were carried out three times a day and each time was 4 hours at an average speed of 3.5 knots, and depths were varied in proportion to the depth of the fishing area. In order to conduct fishing and sampling operations, the commercial trawler (stern trawler) with a length of 26 m, a width of 7.4 m, a power of 600 horsepower, equipped with an echo sounder, GPS and radar was used. Also, the type of fiber used in bottom trawler was made of polyamide (Table 1). All fish were counted, weighed, and identified to the species level according to standard fish keys (Fisher and Binachi 1984; Carpenter et al. 1997).

For calculating the CPUE values of three species, the catch weight of any species in total catch weight was divided over the total time of net throwing and the average of CPUE was determined at each time of net throwing. The Gulland equation was used to evaluate CPUE index for each hauling operation (Gulland 1983):

$$CPUE = Cw / t$$

Where Cw is the total weight of the species in the station (kg), and t is net hauling time (h).

For assessing the status of three species, the main indicator was the level of catch per unit area (CPUA), which was calculated for each net throwing period and then the average values were obtained. By calculating these averages, the amount of biomass was obtained separately at different depths. CPUA rate was obtained from the following formula (Sparre and Venema 1998):

$$a = D \times hr \times X_2$$
$$CPUA = Cw \div a$$

Where a is a net hauling area (km^2), D is traveled distance (km), hr is the length of the head rope (km), X_2 is the fraction of the head rope length, Cw is catch rate by weight (kg), CPUA is catch per unit area at each station.

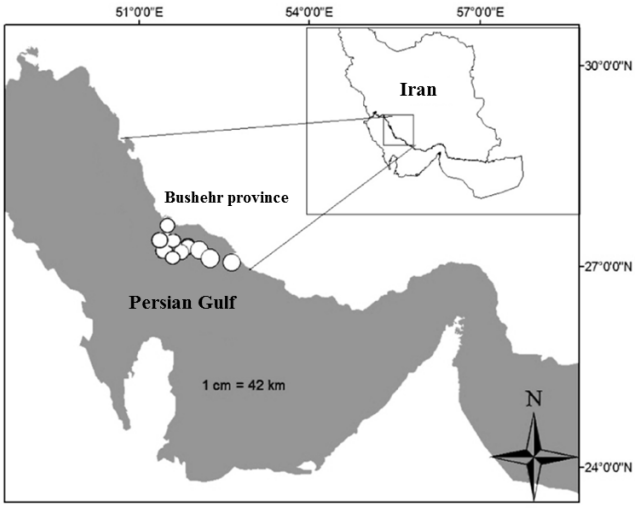

Figure 1. The geographical location of the sampling sites in the Motaf fishing grounds, Bushehr Province, Iran (Circles represent sample areas)

Table 1. Characteristics of the used trawl during the study period in the Motaf fishing grounds, Bushehr Province, Iran (summer 2016)

Characteristics	Size
Net mesh size (STR)	400 mm in the net body & 75 mm in the cod-end
Towline (Galvanized)	250 m
The total length of the net	50 m
Bridles length (Galvanized)	50 m
Headrope length (PA)	41 m
Footrope length (PVD)	26 m
Lazy line (Cotton)	50 m
Net bag length and width	9 m & 3 m

Also, Sturges formula was used to determine the length classes of the three species between different depths (Sturges 1926):

$$R = (Max\text{-}Min) + 1$$
$$K = 1 + 3.3 \log n$$
$$C = R / k$$

Where R is the number of samples, K is a number of categories, n is sample number, and C is the distance between classes.

For comparing the obtained length frequency for three species between different depths, the two-sample non-parametric Kolmogorov-Smirnov test was used. Shapiro-Wilkes test was performed to check the normality of the data. The data were transmitted to log10 (x + 1) to remove heterogeneity of variances and normalize them. One-way analysis of variance (ANOVA) was applied to compare CPUA and CPUE values at different depths. Charts were depicted in Excel software version 2010 and data analysis was performed using R software.

RESULTS AND DISCUSSION

The frequency percentages of three species were studied in comparison with the depths of 50-60 m and 60-70 m, and the results are shewed in Table 2. According to Table 2, there is a significant difference among the abundance of 3 species with depths of 50-60 m and 60-70 m in Motaf fishing grounds ($P < 0.05$).

In this study, the highest length frequencies of *C. ignobilis*, *S. crumenophthalmus,* and *U. sulphureus* lengths were in length classes of 56.5-61.5, 22-23.5 and 14-15.5 cm, respectively. The length frequency percentages of *C. ignobilis* are shown in Figure 2. Based on these results, fish with the total length of 71-74 cm in the depths of 50-60 m, and fish with a total length of 57-62 cm in the depths of 60-70 m were most dominant. Hence, there was an inverse relationship between the size of species and the depth, and as a result, larger fish were found at lower depths. Based on the length frequency of Bigeye scad (Figure 3), it was concluded that the relationship between the total length of *S. crumenophthalmus* and depth of fishing area was inverse (same as *C. ignobilis*). As the depth increased, the average length of *S. crumenophthalmus* was reduced. Accordingly, fish with a total length of 25-27 cm in the depths of 50-60 m, and fish with a total length of 22.3-23.8 cm in the depths of 60-70 m had the highest frequency. Based on Figure 4, it was observed that the relationship between depth and total length for *U. sulphureus* is positive in comparison with other species. So that, fish with a total length of 13-14.5 cm in the depths of 50-60 m, and fish with a total length of 15-16.5 cm in the depths of 60-70 m were dominant groups.

There is a significant correlation between depth and fish size for many demersal species (Macpherson and Duarte 1991; Sinclair 1992; Swain and Wade 1993; Petrakis et al. 2001). During the study period, there were significant differences in the distribution of length frequency of caught species among different depths. In the research by Stefanescu et al. (1992) on the relationship between size and depth in demersal fish communities in the west of the Mediterranean Sea, there was a significant correlation between water depth and fish size. So that, with the increase in depth, smaller sizes of fish replaced with medium and large sizes of fish. Totally, Giant trevally reaches to 1.7 m in length and a weight of 60 kg. Also, S. crumenophthalmus grows to about 70 cm (Kuiter and Tonozuka 2001). The maximum recorded total length for U. sulphureus (TL) is 30 cm (Kumaran and Randall 1984). The first maturity occurs at length of 60 cm in *C. ignobilis* (Hutchins and Swainston 1986), at length of 17 cm in *S. crumenophthalmus* (CMFRI 2016), and at length of 13.1 cm in U. sulphureus (Reuben and Vijayakumaran 1994). The catching of immature fish is one of the available challenges in fishing management because they have to catch fish which were spawned at least once. In the exploitation of fish stocks, three factors of spawning, growth, and survival of large broodstocks are important. The researchers believe that the fishing nets should be designed to remove aquatic fish smaller than LM_{50} and catch bigger size of fish to maintain aquatic resources. Fishing with a length less than LM_{50} has been reported by many researchers and all of them point to the vulnerability of non-target stocks (Kaymaram et al. 2011; Raeisi et al. 2011; Paighambari and Daliri 2011; Kazemi et al. 2014). *C. ignobilis* resides in the widespread regions of marine environments, and it can endure the saline fluctuations in the rivers and estuaries. It has been known as a semi-pelagic fish which spends time throughout the water column; however is typically a demersal fish in the aquatic environment (Smith and Parrish 2002; Wetherbee et al. 2004). This fish is commonplace in shallow coastal waters of some environments, including rocky reefs, corals, lagoons, channels and tidal flats. Mature individuals have a tendency to move to deeper depths greater than 80 m. Nevertheless, large individuals frequently return to the shallower waters for hunting or reproduction (Leis et al. 2006; Meyer et al. 2007). *S. crumenophthalmus* occurs in schools, and large ones usually exist in inshore or shallow waters to depths of 170 m (Roux and Conand 2000; Kuiter and Tonozuka 2001). It is naturally an open ocean pelagic species. *U. sulphureus* occurs from depths of 20 to 60 m. The maximum recorded total length (TL) is 30 cm (Kumaran and Randall 1984). *U. sulphureus* inhabits coastal waters of continents and large islands, and generally over mud substrate (Randall and Kulbicki 2006).

During the study, it was found that fish with greater lengths formed a dominant volume of fishing operations which indicated the dynamics of fish stocks in the sampling season. The difference in the length distribution of a species in different seasons can be due to seasonal regeneration among the species (Martins and Haimovici 1996; Tonks et al. 2008; Welch et al. 2013). Most of the trapped bony fish in the bottom trawlers are demersal fish. Benthic species are one of the most important commercial fish populations in the Persian Gulf, but in recent years there has been a 21% reduction in their catch, and their catch rates have dropped (reduction of catch is the same as catch rate dropped, repetition) One of the most important reasons is increased overfishing and by-catch pressure on benthic fish in recent years (Valinasab et al. 2006).

Table 2. Comparison of the number and frequency percentage of three species at depths of 50-60 m and 60-70 m in the Motaf fishing grounds, Bushehr Province, Iran (summer 2016)

Species	*Caranx ignobilis*		*Selar crumenophthalmus*		*Upeneus sulphureus*	
Depth	**Number**	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
50-60 m	40 [b]	30.08 %	33 [b]	28.95 %	47 [b]	30.13 %
60-70 m	92 [a]	69.92 %	81 [a]	71.05 %	108 [a]	69.87 %

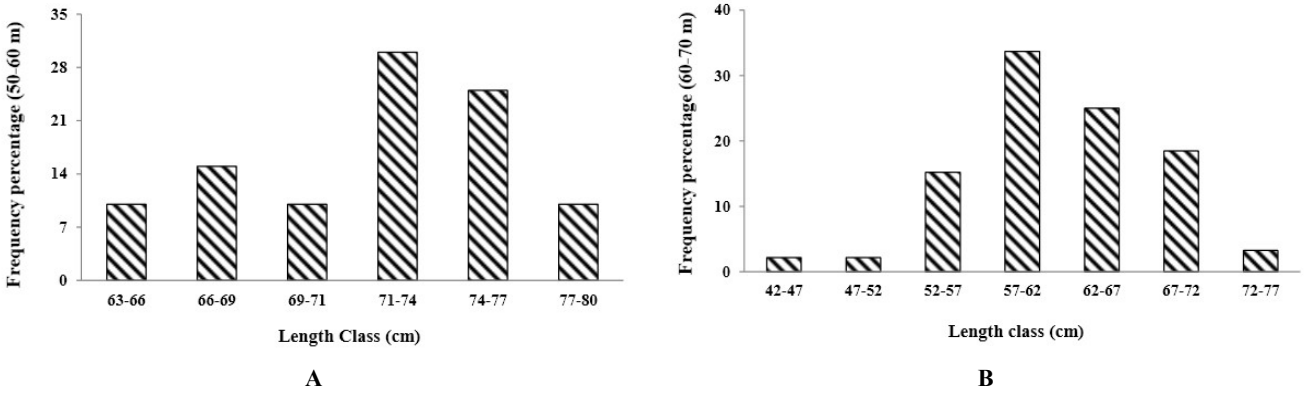

Figure 2. The length frequency percentage of *C. ignobilis* in the Motaf fishing grounds, Bushehr Province, Iran (summer 2016). A. Depth of 50-60 m, B. Depth of 60-70 m

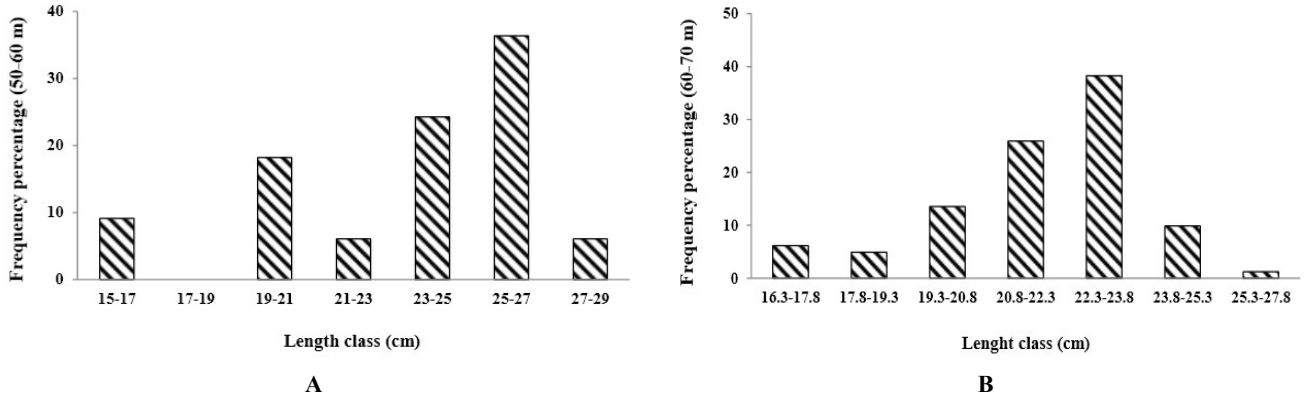

Figure 3. The length frequency percentage of *S. crumenophthalmus* in the Motaf fishing grounds, Bushehr Province, Iran (summer 2016). A. Depth of 50-60 m, B. Depth of 60-70 m

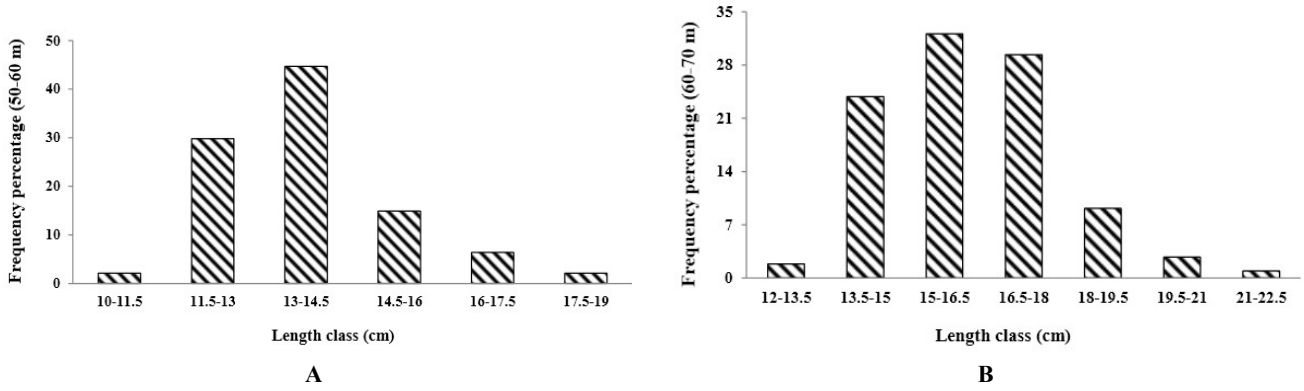

Figure 4. The length frequency percentage of *U. sulphureus* at the depth of 50-60 m in the Motaf fishing grounds, Bushehr Province, Iran (summer 2016). A. Depth of 50-60 m, B. Depth of 60-70 m

A large proportion of the species in the by-catch composition of fish are commercial and valuable fish. These species may be exploited before maturity stage due to the type of net design. Also, other discarded species disappear in the same way (Kazemi et al. 2014). Based on the nature of the fishing method, mid-water and bottom

trawl methods have a high diversity of species in their bag, because these gears catch all fish on their path in a non-selective way. Fishing activities at depths of less than 50 m cause a lot of pressure on commercial and non-commercial species. Increased pressure on commercial fishing will reduce the catches of these species in the future. Subsequently, the pressure on non-commercial species leads to a collapse of the ecosystem balance (Alverson 1994).

In this research, CPUE and CPUA values were evaluated both in terms of weight and number of caught species (Table 3). In this study, CPUE values were calculated by collecting data from the catch operations in the sampling seasons. The results for *C. ignobilis*, *S. crumenophthalmus,* and *U. sulphureus* were 3, 0.159 and 0.078 kg h^{-1}, respectively. Investigation of the catch index in CPUE of three species in different depths showed that the depth variable has a significant impact on the CPUE of the *C. ignobilis* ($P < 0.05$). So that, CPUE value was decreased with increasing depth, but CPUE for both *S. crumenophthalmus* and *U. sulphureus* were not significantly different from the depth change ($P > 0.05$) because CPUE levels did not differ much in different depths. Based on the results, the average rate of CPUA for *C. ignobilis*, *S. crumenophthalmus,* and *U. sulphureus* were 45.03, 2.44 and 1.91 kg km^{-2}, respectively. Also, the highest and lowest CPUA values were at the depth of 60-70 m (21 kg km^{-2}) and 50-60 m (9 kg km^{-2}), respectively.

According to table 4, CPUA and CPUE of mature forms of *C. ignobilis* and *S. crumenophthalmus* at depths of 50-60 m were more than 60-70 m, but the highest CPUE and CPUA for *U. sulphureus* were belonged to immature and mature fish at depths of 60-70 m, respectively. Accordingly, maturity percentages of 3 above mentioned species were 27%, 73% and 10% for matures and 90%, 16% and 84% for immatures, respectively.

Catch per Unit of effort (CPUE) and catch per unit area (CPUA) are the basic quantity to compute stock density in assessments, and these estimations are utilized to acquire other evaluations such as biomass approximations and abundance indices for essential commercial fish stocks (Hinton and Maunder 2003; Nguyen 2005; Haggarty and King 2006; Zeinali et al. 2017). Biomass and CPUA estimates are as stock indices for management of demersal resources (Sparre and Venema 1992; Haggarty and King 2006). Determination of fish distribution and community structure are two important primary and fundamental steps to improve our understanding and knowledge of marine ecosystem (Anderson et al. 1998; Stauffer 2004; Kotwicki et al. 2011). These changes were probably due to the concentration of fish mass in shallow waters nutritional and reproductive behavior or seasonal migration during the sampling period (Meyer et al. 2001). Munro and Somerton (2002) stated that catch patterns for a trawl survey are dependent on the density of available fish, sampled volume by trawl, and trawl efficiency for a particular species. Catch rates, or catch per unit effort (CPUE), for survey trawls have been shown to be correlated with environmental variables such as salinity, temperature, near bottom light, and wave height and winds (Smith et al. 1991; Ryer and Barnett 2006; Kotwicki et al. 2009; Wieland et al. 2011). According to the study of Paighambari and Daliri (2012), during two fishing years; 608.9 and 844.8 kg of *U. sulphureus* were collected as by-catch species which was comprised of 3.68 and 6.41% of the total catch. Also, CPUE values were 5.42 and 5.86 kg h^{-1}, respectively. In a study by Kazemi et al (2014), *U. sulphureus* comprised of 5.58 kg of the total weight (0.1% of the total catch) of by-catch in the shrimp trawl and CPUE of *U. sulphureus* was 0.08 kg h^{-1}. Desired depth layer of different species might be associated with environmental conditions, prey, predator, and type of sea bottom (Swain and Wade 1993). According to compared data, it can be seen that CPUA for the immature form of *U. sulphureus* is higher than other species, which indicated the overfishing of this species in the fishing season.

Table 3. Comparison of CPUE and CPUA according to weight and number of *C. ignobilis*, *S. crumenophthalmus* and *U. sulphureus* at depths of 50-60 m and 60-70 m in the Motaf fishing grounds, Bushehr Province (summer 2016)

Species	Parameter	Depth	
		50-60 m	60-70 m
Caranx ignobilis	CPUE.w	3.5±1.08 [a]	2.5±0.84 [b]
	CPUE.n	1.04±0.3 [a]	0.93±0.31 [a]
	CPUA.w	52.42±16.33 [a]	37.64±12.7 [b]
	CPUA.n	15.76±4.54 [a]	14±4.68 [a]
Selar crumenophthalmus	CPUE.w	0.178±0.06 [a]	0.14±0.032 [a]
	CPUE.n	0.86±0.23 [a]	0.83±0.17 [a]
	CPUA.w	2.68±0.89 [a]	2.21±0.49 [a]
	CPUA.n	13±3.45 [a]	12.5±2.54 [a]
Upeneus sulphureus	CPUE.w	0.067±0.022 [b]	0.09±0.03 [a]
	CPUE.n	1.23±0.36 [a]	1.11±0.37 [a]
	CPUA.w	1±0.34 [b]	1.38±0.48 [a]
	CPUA.n	18.5±5.43 [a]	16.77±5.63 [a]

Note: Same letters indicate statistical non- significant difference between different species ($P > 0.05$)

Table 4. Comparison of CPUE and CPUA for mature and immature forms of *C. ignobilis*, *S. crumenophthalmus* and *U. sulphureus* at depths of 50-60 m and 60-70 m in the Motaf fishing grounds, Bushehr Province (summer 2016)

Species	Parameter	Depth	
		50-60 m	60-70 m
Caranx ignobilis	CPUE.M	3.61±1.34 [a]	1.95±0.7 [b]
	CPUE.Im	0	0.61±0.3 [a]
	CPUA.M	16.16±5.05 [a]	10.4±3.52 [b]
	CPUA.Im	0	4.6±2.13 [a]
Selar crumenophthalmus	CPUE.M	0.17±0.05 [a]	0.13±0.035 [b]
	CPUE.Im	0.03±0.01 [b]	2.7±3.6 [a]
	CPUA.M	11.7±2.55 [a]	11.22±2.75 [a]
	CPUA.Im	4.64±1.61 [a]	3.48±3.11 [b]
Upeneus sulphureus	CPUE.M	0.04±0.23 [b]	0.09±0.37 [a]
	CPUE.Im	0.33±0.11 [b]	1.36±0.19 [a]
	CPUA.M	10.01±4.65 [b]	17.2±6.73 [a]
	CPUA.Im	10.83±3.67 [a]	0.16±0.42 [b]

Note: Same letters indicate statistical non- significant difference between different species ($P > 0.05$)

According to the results of this research, it can be concluded that effective and economic fishing operation of *C. ignobilis* and *U. sulphureus* should be done at depths of 50-60 m. However, the implementation of fishing operations for *S. crumenophthalmus* was not different at study depths. Finally, results of this study provide basic information on the distribution of three commercial demersal fish in the north of the Persian Gulf. In order to access a sustainable management of fish resources, fishery managers should protect these fishing areas in the future.

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