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Fishery resources of Sabah Al-Ahmad Sea City waterways: A potential contributor for Kuwait's fisheries

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Recent reports demonstrate that Arabian Gulf Shellfish and Finfish fisheries are in serious decline, in particular those of Kuwait. This decline is attributed to over fishing, pollution, loss of nursery ground, reduction in riverine input via the Shatt Al-Arab, and climate change. When completed in 2018, Sabah Al-Ahmad Sea City, Kuwait, will contain circa 200 km of waterways providing over 50% of extra coast line for Kuwait. Seine netting and gargoor traps have been deployed annually, since the first phase (A1) of this coastal township was opened to the sea in 2004, to monitor Shell and Fin fish populations within the waterways. Present work describes the diversity and abundance of commercial (edible and potential ornamental value) species now inhabiting the waterways, which comprise over 60% of the species marketed in Kuwait. Analysis of catch data reveals that the waterways act as spawning, nursery and feeding habitats for important species such as Epinephelus coioides *(Orange-Spotted Grouper),* Penaeus semisulcatus *(Banana Shrimp) and* Portunus segnis *(Blue Swimming Crab). As no commercial fishing is allowed, the Sea City waterways act as a significant conservation area for Kuwait's fish stocks.*

Keywords: fish stocks, nursery grounds, ichthyoplankton, artificial waterways

Introduction

Arabian Gulf fisheries for fish and Shrimp are currently harvested well beyond their sustainable levels (Grandcourt et al., 2005), and this is particularly so for Kuwait (Al-Sabbagh and Dashti, 2009; Al-Zaidan et al., 2013). Apart from over fishing, inshore nursery habitat loss of over 20 km of coast in Kuwait alone, pollution, loss of riverine input via the Shatt Al-Arab and climate change have resulted in a 53% decline in Shrimp and 40% decline in Fin fish catches between 1985 and 2013 (Al-Husaini et al., 2015). The situation is so serious that Al-Zaidan et al. (2013) predict that fish consumption in Kuwait (22.32 kg yr^{-1} per capita in 2010) may drop to an availability of only 0.5 kg per capita by 2025.

A loss of productive coastal nursery grounds is a major contributor to decline in fisheries (Bishop,

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2002). Construction of Sabah Al-Ahmad Sea City (hereafter Sea City) in the south of Kuwait creating circa 200 km of shallow (4 m deep) waterways, with an estimated water spread area of 19.6 km^2, might be expected to help compensate for habitat loss elsewhere. Since the start of the project in 2004, water quality and circulation within the waterways has remained excellent, powered by wind and tides alone. All the natural Arabian Gulf marine habitats have been recreated within the waterways, which now have sand beaches, mudflats, mangroves, salt marshes, rock and Seagrass intertidally and sands, mixed rock and sand, coral and Seagrass subtidally. Over 1,500 macrobiota species now occur in the waterways, including 100 species of Fin and Shellfish (Jones and Nithyanandan, unpublished). Since 2005 annual fish surveys have been conducted using gargoor (wire traps) and seine nets; results of these surveys are analysed to determine the Sea City waterways contribution to Kuwait's fisheries.

This study aims to describe the fishery resources found in Sea City waterways and provides quantitative data to demonstrate how these resources may contribute towards Kuwait's open sea fisheries.

Materials and methods

The waterways were excavated from the desert and opened to the sea in phases (Figure 1); phase A1 was opened in February 2004, A2 in February 2006, A3 east December 2009, A3 west April 2011, A4 September 2013 and A5 is anticipated to open in 2018. As resources (human) are limited, each phase was subjected to fishing for a period of 3 years, before moving to the next phase as this was flooded.

Data on diversity, abundance and catch (g) of finfish and shellfish were collected by conducting fishing surveys using gargoor (fish trap) and seine net during summer–autumn months (2005–2014). A minimum of 3 commercial galvanised wire single entrance fish traps (gargoor) were baited (with sardines and chicken) and left to allow entry of fish for 24 h. In 2005 gargoors were set on open sand substrate and close to rock revetments/groynes, whereas in 2010–2011 they were set next to the concrete piles supporting the tidal gate (Figure 1), and adjacent to a rock island in A3. Random collections were carried out through SCUBA diving.

A 50 m long × 2.0 m high seine net (mesh size 2 cm) was deployed from a sand beach by towing one end of the net out at 90° to the beach by boat and bringing it round in a semi-circle back to the beach. The area swept by the net is circa 400 m^2. A minimum of three hauls were conducted each year, and fishing was conducted both during the day and night. For both methods of fishing all species captured were identified and individual weight (g) and length (cm) recorded.

In addition ichthyoplankton and crustacean larvae were sampled from 2006 to 2013 to determine which commercial species either enter Sea City waterways as planktonic larvae, or are spawned within the waterways. Initially monthly surveys

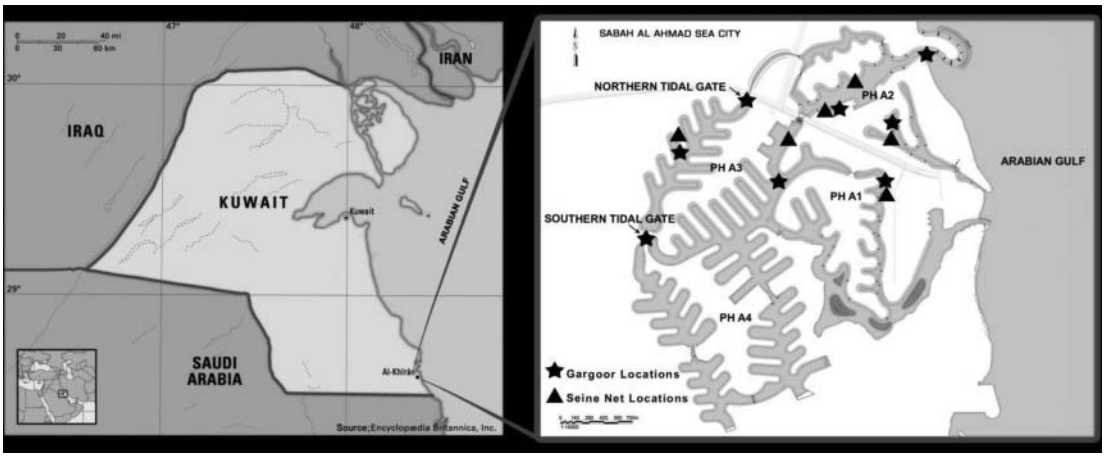

Figure 1. Sabah Al-Ahmad Sea City lagoons of phase A1–A4 with locations of gargoor and seine net surveys.

were conducted using a diving torch at night to attract ichthyoplankton and crustacean larvae and capturing with a hand net for 10 min periods in each phase. In later surveys (2010–2013) a Coleman and Seagrove surf net (Coleman and Seagrove, 1955) was towed along the beaches for 100 m at a depth of 0.5 m at night as an additional method for trapping ichthyoplankton. Identification of planktonic stages of penaeid Shrimp was completed using Al-Yamani et al. (1995), and for fish larvae Richards (2008).

Statiscal anlaysis was carried out using Microsft Excel® 2007. A two-tailed t-test was conducted to understand whether gargoor installed near rock groynes caught more Groupers than those in open water. Size frequency histograms were constructed for commercially important species of fishes, Shrimp and Crab to understand size groups and occurrence of non-spawning and spawning species.

Results

Diversity, abundance and catch

Ten years of survey using both methods of fishing recorded 83 commercially (edible and potential ornamental species) important Fin and Shellfish species, with *Liza klunzingeri* being the most abundant (see Table S1 in the online supplementary files). Common genera include *Epinephelus, Gerres, Pomadasys, Plectorhinchus* and *Liza*.

Commercial species not occurring in Sea City waterways include anadromous *Pampus argenteus*, estuarine *Otolithes ruber, Tenualosa ilisha*, coral reef species *Lutjanus malabaricus* and deeper water species such as *Pomadasys kaakan*. Important Shellfish in Sea City include *Penaeus semisulcatus, Penaeus latisulcatus, Portunus segnis* and *Sepia pharaonis*.

Apart from commercial food fish species, some 27 species of Aquarium Fish also occur in Sea City. These include members of the families: Syngnathidae, Apogonidae, Pomacanthidae, Pomacentridae, Blennidae, and Gobiidae (Table S1). Several of these species are new records for Kuwait (Jawad et al., 2015).

Trap (Gargoor) catches

The mean catch of Fin and Shellfish per trap in each phase by weight (g) shows the highest catch in 2005 (Phase A1) which entirely consists of *E. coioides* (Figure 2).The high catch in 2005 (Phase A1) consists entirely of *E. coioides*. Only the gargoors close to revetments caught *E. coiodes* ($p = \leq 0.0001$). This phase was opened to the sea in February 2004 and not fished until autumn 2005. The decline in trap catches in later years may be due to disturbance caused by boat traffic. Phase A2 was sampled within six months of flooding and catches increased over time. Phase A3 east was fished in 2010 only nine months after flooding. Over the years

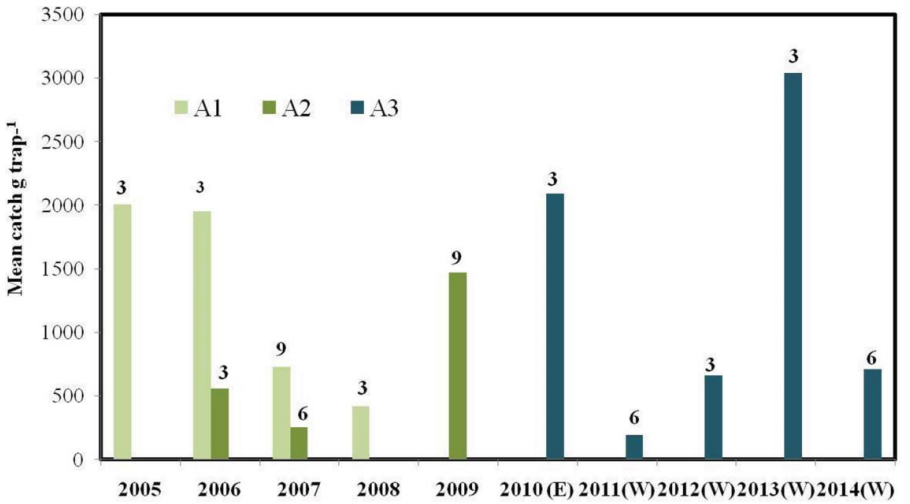

Figure 2. Mean catch (g trap^{-1}) of fish, crabs and Cuttlefish caught in Gargoor in each phase of Sea City waterways, 2005–2014. Number over each bar indicate number of traps; E = east, W = west.

2011–2014 phase A3 west was sampled, showing a catch increase over time.

Epinephelus coioides dominated trap catches with 52 fish weighing a total of 42.79 kg caught over 10 years (Table S1).

A total of 57 traps were set over 10 years which gives a mean weight of 0.751 kg of *E. coioides* per trap. However, in 2010 traps were set in A3 east near an island and caught open water species such as *Scomberomorus commersonianus, Pomadasys kaakan* and *Crenidens crenidens* but no Grouper. Similarly in 2013 traps set close to the tidal gate in A3 west and rock island caught mostly portunid crabs. As it has been demonstrated that Grouper are only caught in traps placed next to rock revetments, the total number of traps may be reduced to 51 giving a mean catch of 0.839 kg trap^{-1} of *E.coioides*.

Apart from *S. commersonianus,* other taxa found in traps were Haemulidae, Sparidae, Siganidae, Chaetodontidae and Tetraodontidae, together with the Portunid Crab, *Portunus segnis*.

Seine net catches

Catch per seine haul and number of hauls each year in each phase of Sea City (Figure 3) shows that the highest catch was obtained during 2012 in phase A3. Day and night seine net fishing and shows a mean catch of 729 g night haul^{-1} and 1217 g day haul^{-1} (Table 1). *Penaeus semisulcatus* was common in night seine net hauls taken in September/October in phase A3 west from 2012 with highest catch g haul^{-1} (Figure 3). There is a general trend observed towards increase in catch over time from the flooding of each phase.

Over 60 species were taken in seine nets with common families including Mugilidae, Hemiramphidae, Belonidae, Platycephalidae, Sillaginidae, Gerreidae, Haemulidae, Sparidae and Siganidae, the last dominating catches. Night seine nets contained high numbers of *Penaeus semisulcatus, Portunus segnis* and *Sepia pharaonis*, particularly in phase A3 west.

Size frequency analysis

Size frequency analysis of fish species which were abundant in catches (Figure 4) shows that *E. coioides* (Figure 4a), ranges from 29 to 55 cm in total length. *Diplodus sargus kotschyi, Gerres oyena, G. longirostris* and *Acanthopagrus latus* (Figures 4b–e) all fall within the size frequencies of pre-spawning stocks. However, the mullet (*Liza klunzingeri*) size frequencies (Figure 4f) range from juvenile to fully mature adults (15.6 cm) with a peak at 13 cm of pre-spawning fish. Size frequency data for *P. semisulcatus* taken in these catches show largest peaks are between 12 and 16 cm total length (Figure 5b). Mean Shrimp

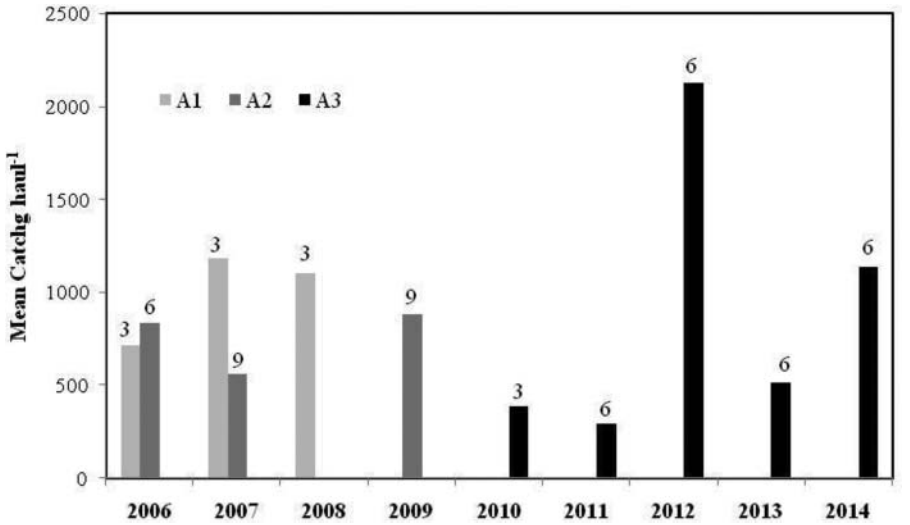

Figure 3. Mean catch (g haul^{-1}) of fish and shrimps caught in sine net in each phase of Sea City waterways, 2006–2014. Number over each bar indicates number of hauls.

Table 1. Mean catch g haul $^{-1}$ in each phase during day or night in Sea City waterways. Numbers in parenthesis indicates number of hauls.

Phase	Day/ Night	2006	2007	2008	2009	2010	2011	2012	2013	2014
A1	Night	718(3)	1181.6(3)	1104.8(3)						
A2	Day	1563(3)	260.8(6)		1006.4(3)					
A2	Night	111.6(3)	1154.2(3)		419(3)					
A2	Night				1217.6(3)					
A3	Day						137.3(3)	4006.2(3)	631(3)	917.3(3)
A3	Night					389(3)	449.3(3)	249.8(3)	399.1(3)	1358.5(3)

catch per haul in A3 west was 249 g per haul^{-1} for 2011–2014 with catches rising from 201 g in 2011 to 505 g haul^{-1} in 2014 (n = 12). The area swept by the seine net is 400 m^2, equating to a mean catch of 0.623 g m^{-2}. Finally the size frequency plot for *Portunus segnis* (Figure 5b) suggests that the Blue Crab completes the whole life cycle within Sea City waterways.

Ichthyoplankton

Icthyplankton collected in Sea City waterways over the period 2006 to 2013 (Table 2) shows that the dominant fish family was the Clupeidae with at least 4 species of which *Sardinella* sp. and *Herklotsichthys lossei* were concentrated during summer months, while other Clupeidae were found throughout the year. The larvae of Serranidae were found most abundantly in June, which is consistent with the breeding pattern for *E. coioides* (Grandcourt et al., 2005). Fish ova were found from March until December (Table S1) confirming that at least some fish species breed in Sea City waterways.

Crustacean larvae

Early post larval stages of *Metapenaeus affinis* and *M. stebbingi* occurred mainly in the autumn months. *Penaeus semisulcatus* post larvae were common in March to May and again, to a lesser extent, in August to October. This fits well with the major spawning season in early spring and second minor spawning in autumn (Price and Jones, 1975). No early stage zoea or mysis stages were found, confirming that Shrimp migrate to the open sea to spawn. *P. semisulcatus* early post larvae require Seagrass or *Sargassum* cover for survival as they cannot burrow in sand (Jones and Al-Attar, 1982; Al-Attar, 1984). Thus the expansion of these vegetative resources within Sea City waterways in recent years enhances the nursery aspect of the Sea City waterways.

All larval stages of *P. segnis* from zoea 1 to megalopa were found in the night-time plankton samples with peak catches in May and June confirming that this species completes the life cycle within Sea City waters. Similarly the egg masses of *S. pharaonis* are common on intertidal and subtidal rocks, and adults are often taken in seine nets indicating a resident population.

Discussion

Sea City catches contain approximately 60% of the main commercial species landed in Kuwait (Al-Husaini et al., 2015). Fish and invertebrate species of potential ornamental trade interest found in Sea City waterways include 27 fish and 3 nudibranch species (Table S1), several of which are new records for Kuwait (Nithyanandan, 2012; Jawad et al., 2015). These species require a range of diverse rock, coral, seaweed and Seagrass habitats, which have been created within Sea City waterways. However marine ornamental species in Kuwait and elsewhere in the Arabian Gulf need further investigation to explore sustainable harvest and hatchery technology for trade.

Although it is relatively easy to compare numbers of Fin and Shellfish species within Sea City to those in the open sea, it is more difficult to compare abundances. However, the gargoors used in Sea City were commercial units used in commercial fisheries. Al-Husaini et al. (2015) review gargoor

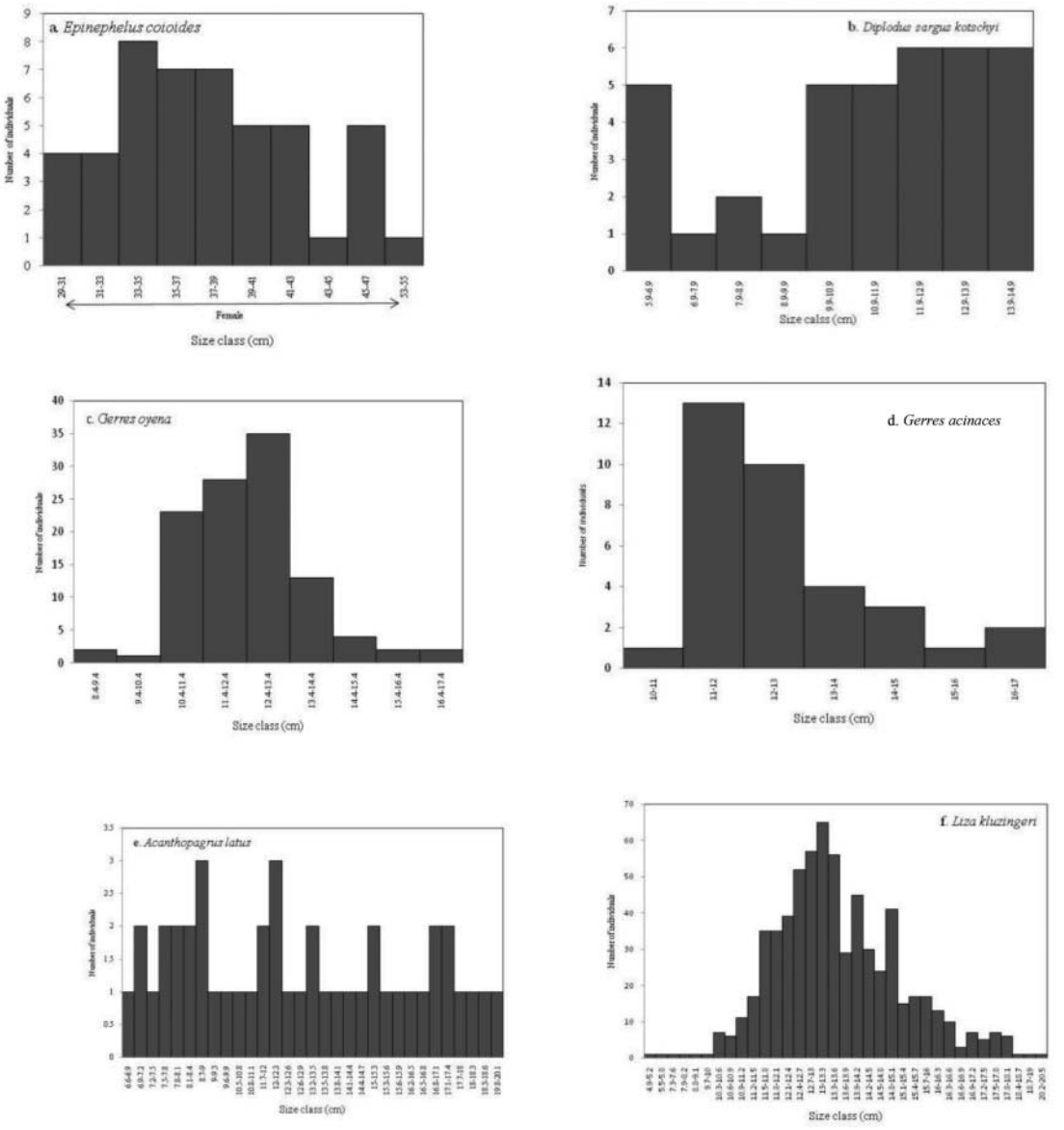

Figure 4. Size class (cm) of edible fish species caught in Sea City during 2005–2014.

catches for Grouper and show a decline from 4.8 kg in 1982–1987, to 0.962 kg in 1992, 0.373 kg in 1992 and 0.494 kg in 2003–2005. Moreover in these years other than Shrimp trawling there is lack of fishing effort estimates for several gears (Al-Husaini et al., 2015). Hence Sea City mean catch per gargoor (0.751–0.839 kg trap^{-1}) demonstrates almost double the abundance caught recently in the open sea.

Al-Husaini et al. (2015) also give *P. semisulcatus* catch rates of 0.8–1.9 kg haul^{-1} at 3.3 knots for trawls taken in 2013–2014 in Kuwait waters. The trawl width used was 16 m (Al-Foudari et al., 2015) so that the area swept in an hour is 97,600 m^2. If the catch rate achieved in Sea City (0.623 g m^{-2}) is applied, the equivalent catch in Sea City is 60.8 kg haul^{-1} in A3 west. Even with a commercial trawl drop in catch efficiency to 60% (J. Bishop personal communication), Sea City contains significant *P. semisulcatus* stocks. Catches were taken from March to December in Kuwait open

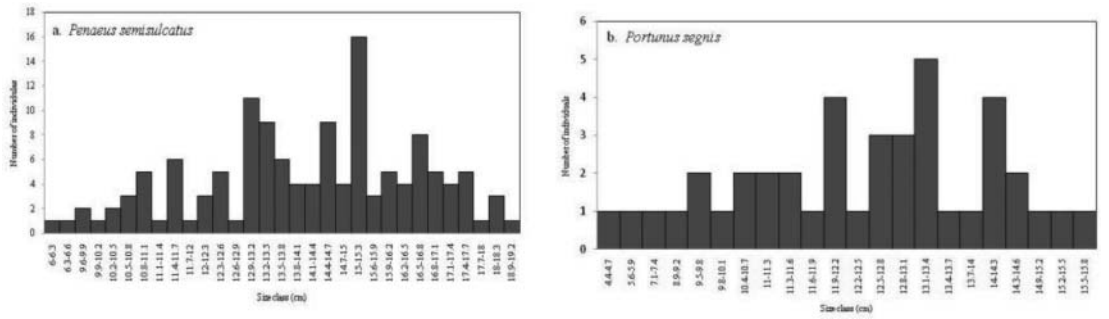

Figure 5. Size class (cm) of edible prawn and crab species caught in Sea City during 2005–2014.

sea (Al-Foudari et al., 2015), and in September and October in Sea City.

Overall the mean catch of Fin and Shellfish in seine nets was 909 g haul^{-1}. In Saudi Arabia, Rabaoui et al. (2015) conducted similar seine net surveys from the shore of Arabian Gulf close to oil and gas facilities where access to fishing was restricted. Seine net catches (106 hauls) produced 72 species of fish with a catch rate of 886 g haul^{-1} which is remarkably similar to values obtained in Sea City waterways. There is a reasonable amount of difference in catches from Sea City as the number of gargoors deployed and seine net hauls per phase during each year were quite variable based on the availability of human resources, which would have presumably influenced the catch. Low mean weight of *E. coioides* caught per trap in this study is probably due to lack of suitable rock habitats in the Sea City with huge holes preferred by this species, rather than rock groynes/revetments with smaller holes.

Epinephelus coioides is a protogynous hermaphrodite undergoing female to male sex change; sexes can be recognised at circa 24.2 cm (male) and 3 cm (female) total length (Grandcourt et al., 2009). Hence all the *E. coioides* caught in Sea City are probably adult, and range from 1 to

Table 2. Abundance (nos.) of ichthyoplankton and crustacean larvae collected in Sea City 2006–2013.

Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Phylum: Crustacea												
Class: Malacostraca												
Metapenaeus affinis				1	1			8		15	2	
M. stebbingi	3	3	2		1		10	11	17			
Penaeus semisulcatus			10	6	25			1	2	5		
P. latisulcatus				1								
Portunus segnis	1		1	1	18	10	2	4	2	1		
Phylum: Vertebrata												
Class: Pisces												
Family: Clupeidae	6	2	8	3	4	11	12	24	17	6	1	5
Sardinella sp				2	4	16	24	78	8	1	1	
Herklotischthys lossei	1				10	8	17		1	2		3
Family: Atherinidae												
Atherinomorus sp	1	2	4	6	6	6	3	1		2	3	5
Family: Serranidae	8	1				60	3	4		1	2	
Family: Lutjanidae				2	18						1	
Family: Gerreidae	2				1	2						
Family: Mugilidae	4							3		2		3
Fish ova			10	15	3	5	30	4				3

4.5 years in age. Mathews and Samuel (1987) and Grandcourt et al. (2005) found good correlation for growth performance between southern Arabian Gulf stocks and those in Kuwait. Grandcourt et al., (2009) found first sexual maturity for females occurred at the length of 32.0 cm, so that it is possible for the Sea City population to contain spawning stock. Hence most commercial fish species are using the Sea City waterways as nursery, feeding and some possibly as breeding grounds.

For *P. semisulcatus* in the Arabian Gulf minimum total length for spawning is 8.4 cm, 50% spawn at 14.4 cm and 90% spawn at 19.4 cm (Niamaiamandi et al., 2008). Although some spawning occurs throughout the year, most is restricted to December–April, with a peak in March/April (Al-Attar and Ikenoue, 1974; Ye et al., 1999). Hence Sea City appears to be an important reservoir for Shrimp pre spawning stocks. This species moves out into open sea deeper water for spawning (Basson et al., 1977) and developing larval stages drift back to shallow water where they complete development. Lai et al., (2010) describe male *P. segnis* from 3.7 cm carapace width and females from 4.5 cm as being mature, indicating that the whole population measured are mature (Figure 5b). Indeed several specimens trapped in the present study were ovigerous.

Action to reverse the decline in Gulf fisheries (Al-Zaidan et al., 2013; Al-Abdulrazzak et al., 2015; Al-Husaini et al., 2015) and even the long-term survival of the Arabian Gulf ecosystem (Burt 2014; Sheppard 2015) is now urgently required. Some pressures, such as the reduction in flow rates of the Euphrates which impacts anadromous *Tenualosa illisha, Pampus argenteus* and *Otolithes ruber*, are difficult to resolve in the short term, as is the impact of climate change on coral reefs (Sheppard and Loughland, 2002). However, the most important impacts, which are habitat loss and over fishing, can be addressed immediately given political cooperation and fishery management changes (Sheppard, 2015). Present work demonstrates that the construction of mega projects such as Sea City can help reverse the loss of nursery, feeding and breeding habitats. By controlling fishing and pollution within protected artificially created waterways, Fin and Shellfish stocks are enhanced and make a significant contribution to open Arabian Gulf fisheries and the Gulf marine ecosystem in general.

Conclusions

When completed, Sea City will contain circa 200 km of waterways created from saline desert. Monitoring of Fin and Shellfish stocks over 10 years within the expanding waterways revealed that over 100 species of fish and shellfish have colonised the waterways. Of these 83 are commercial species and a further 27 are potential marine ornamental species. Analysis of catches shows *E. coioides* to be twice as abundant as in the open sea, and *P. semisulcatus* over 50 times more abundant. Both species consist of breeding and pre-spawning stock. Most commercial species use the wide range of habitats present as nursery and feeding grounds. Sea City provides a model for future mega projects to help reverse nursery habitat loss and conserve fish stocks in the Arabian Gulf.

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Supplemental material

Supplemental data for this article can be accessed on the publisher's website.

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