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The Movement and Migration of Shrimp, *Penaeus semisulcatus* in Bushehr Coastal Waters, Persian Gulf

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Abstract

The pattern of movement of green tiger prawn, *Penaeus semisulcatus*, was carried out in Bushehr waters, Persian Gulf, in 2003 and 2004. During this experiment 2571 shrimps, *P. semisulcatus* were tagged with green polyethylene steamer tags and released at sea from January 2003 to July 2004. During the open season of shrimps (August and September), 68 shrimps were recaptured but four of the recaptures were excluded due to inconstancies of information. The direction of movement of recaptures was mostly to the north west of the release area and to deeper waters. The majority of recaptures exhibited speed of less than 2 km/day and maximum speed was recorded at 3-4 km/day. The longest distance of 127 km was performed by a female during 95 days liberty. In the Persian Gulf the main of sea current is from the Strait of Hormuz to the Iranian waters, and probably influences the pattern of shrimp movement in the Bushehr area.

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Introduction

Apart from a better understanding of the life cycle of *P. semisulcatus*, knowledge on migration patterns is also an essential component in the identification of stock boundaries. Tagging is a wide spread method of animal identification used for demographic studies and has long been used to monitor dispersal, growth and mortality in the wild populations of prawns (Benzie et al. 1995). In spite of the time and expense involved, tagging experiments are used in fisheries biology because of the usefulness of the data collected.

Some means of differentiating between introduced and wild prawns is needed to monitor the effectiveness of reseeding and fine tuning a release strategy. For this reason, the tag must be small enough to be carried by the prawn, unique to the local population, easy to identify and harmless to the prawn. The extent to which tags increased the mortality through the increase of predation either by making prawns more visible or by impending their ability to escape, has not been effectively determined, but the estimates range from the effects being negligible to highly significant (Hill and Wassenberg 1985).

Analyses of movements occasionally are used to relate animal distribution to an international border (Sheridan et al. 1989), to an artificial border derived from a management strategy (Gitshlag 1986), or to a series of fisheries that may or may not be harvesting the same stock (Moore and McFarlane 1984).

Fish and shrimp are marked and released for various reasons, including species distribution, geographical distribution, growth and mortality, spawning migrations, migration routes and speed of migration. In the present study the movement of green tiger prawn, *Penaeus semisulcatus* was investigated through a series of mark-recapture studies conducted inshore and offshore along the Bushehr waters, Persian Gulf.

Materials and Methods

Tagging Process

Shrimps were marked with green polyethylene steamer tags as described by Marullo et al. (1976). In different methods of shrimp tagging, Marullo et al. (1976) stated that steamer tags were superior to Petersen tags in their laboratory. Steamer tags, first introduced by Marullo et al. (1976), have been increasingly used in prawn fisheries because of their ease of application and generally low tagging mortality (Benzie et al. 1995). The color of an externally visible tag may increase predation on tagged shrimps. In the present study green color tags, similar to surrounding water color, were used in an attempt to decrease predation levels. To estimate mortality caused by the tagging and handling procedures, a lab test was conducted prior to the field tagging experiments. Here, 42 specimens of *P. semisulcatus* were tagged and held in a laboratory tank for 45 days. All tagged specimens survived the entire period.

Shrimps to be marked were caught with bottom trawler LavarII and subjected to towing for 20 - 60 minutes. The green steamer tag used was 3 mm wide and 100 mm long. A stainless steel needle was connected to the end of each steamer tag. To tag a shrimp, the needle was inserted through the abdomen between the second and third segments. The attached steamer then was drawn through the abdominal musculature until the lengths extending from each side of the shrimp were equal, and then the needle was detached (Fig. 1).

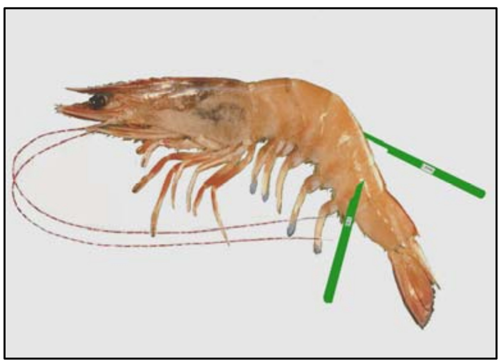

Fig. 1. Tagged prawn, *P. semisulcatus*, in Bushehr waters, Persian Gulf (2003-2004)

After tagging, shrimps were placed into holding tanks on barges for 10-12 hours to observe individuals that may have been damaged after tagging. Dead and moribund shrimps were removed before tagged shrimps were released to the sea. The date, sex, position and serial tag number were recorded. Some of the tagged shrimps were measured at the beginning of the study but measurement was later stopped to reduce handling stress that may contribute to abnormal behaviour or survival of tagged individuals. In each tag was printed with the name of the country (abbreviation) and a serial number. Tags were deployed every month during the period of January 2002 through July 2004. Tagging efforts were more intensive during three periods comprising, two months before the shrimp fishing season, during the open shrimp fishing season and two months after closure of the shrimp fishing season.

Releases were made at sunset to reduce the possibility of bird predation. Attempts at recapture were made only during the shrimp season, an approximately two month period (August and September). Fishermen were informed through posters describing the tagging program that were distributed to fisheries cooperatives, as well as articles published in a local fisheries magazine. A tagging program awareness film was broadcast on national television three times prior to the shrimp fishing season. To encourage fishermen to report recaptures, a reward of USD 6 was paid for the return of each marked shrimp accompanied by information regarding the date, capture depth, and the location of recapture. Most of the fishing vessels are equipped with electronic geo-positioning systems (GPS), which provided accurate locations for >80% of recaptures. Official letters, along with posters, were sent to fisheries research institutes and companies of neighbouring Kuwait, Bahrain and Saudi Arabia; the purpose was to explain the objectives, increase awareness of the tagging program, and to seek cooperation for tag recaptures.

Most recaptures were made by fishermen inside the study area. After recovery of tagged prawns, the distance moved was calculated in a straight line from the release site. Also, speed of the movement, days at liberty, distance and depth of the recaptured shrimps were calculated. Data analysis was completed using Excel program.

Results

Release and Recaptures

The study sampled a total of 2571 prawn, *P. semisulcatus* tagged and released from January 2003 to July 2004. Of these, 68 (2.5%) were recaptured during the open season in the Bushehr area. A total of 1969 prawns were tagged from January to December 2003 that included 705 males and 1264 females (Table 1). From January to July 2004, a total of 602 shrimps including 216 males and 386 females were tagged and released in the study area. From a total of 2571 shrimps tagged, 921 (36%) were males and 1650 (64%) were females.

During two open shrimp seasons in the Bushehr area during August-September (2003-2004), 68 tag recoveries included 21 (31%) males and 47 (69%) females (Table 2).

Most of the marked-recaptured prawns were discovered by fishermen when they were sorting their catches at sea, however, sometimes marked shrimps were found by employees of processing plants after the catch had been unloaded from a vessel. A total of 47 tagged prawns were recaptured in the open season of 2003 including 15 males and 32 females. The remaining 21 recoveries were made in August-September of 2004.

Four recaptures were excluded due to inconsistencies in recapture information Three of the specimens were recaptured in the open season of 2003 and one from 2004. The remaining 64 recaptures were included in analyses of distance, time, speed and depth.

Table 1. Number of tagged and recaptured males and females of *Penaeus semisulcatus* in the Bushehr waters, Persian Gulf (2003-2004)

Year	Number tagged			Number released				
	Males	Females	Total	Males	Females	Total	Omitted	Recapture rate (%)
2003	705	1264	1969	15	32	47	3	2.2
2004	216	386	602	6	15	21	1	3.3
Total	921	1650	2571	21	47	68	4	2.5

Table 2. Percentage of released and recaptured male and female, *p. semisulcatus* in different depths of Bushehr waters, Persian Gulf (2003-2004).

		0-5	5-10	10-15	15-20	20-25	25-30
Male	Released	--	27	36	27	10	--
	Recaptured	-	45	27.5	27.5	--	--
Females	Released	3	50	6.5	31.5	9	--
		-					
	Recaptured	6.5	16	35.5	35.5	--	6.5

Components of Movement

Several notable features of *P. semisulcatus* behaviour were illustrated through the tagging data. Depending upon where the tagged shrimps were released, most recaptured females moved to the deeper waters, whereas males tended to occupy shallow waters. Table 2 and figures 2 and 3 show that for males, 45% of total recoveries were made in the 6-10 m depth range, an area where 27% of the males were released. In spite of the fact that 10% of the males were released in 21-25 m depths, no recoveries were made at this depth. The females tended to move to deeper waters. Although 50% of the females were released in 6-10 m depths, only 16% of these were recaptured at this depth. In contrast, 6.5% of the females were released in 11-15 m depths and 35.5% of these were recaptured in this depth. Maximum recapture depths were 11-20 m for females and males (Table 1 and Figs. 2 and 3).

The majority of all *P. semisulcatus* recaptures exhibited movement time of less than 2 km/day (Fig. 4) although the maximum speed recorded for females was 3-4 km/day.

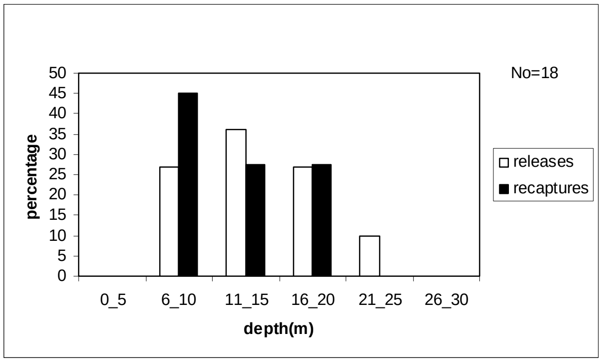

Fig. 2. Comparison of released and recaptured depths of males, *P. semisulcatus* in Bushehr waters, Persian Gulf (2003-2004)

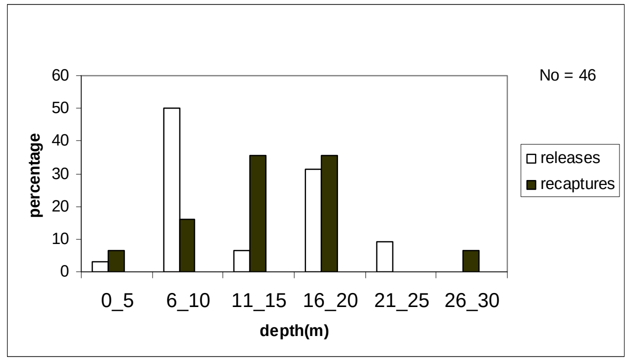

Fig. 3. Comparison of released and recaptured depths of females, *P. semisulcatus* in Bushehr waters, Persian Gulf (2003-2004)

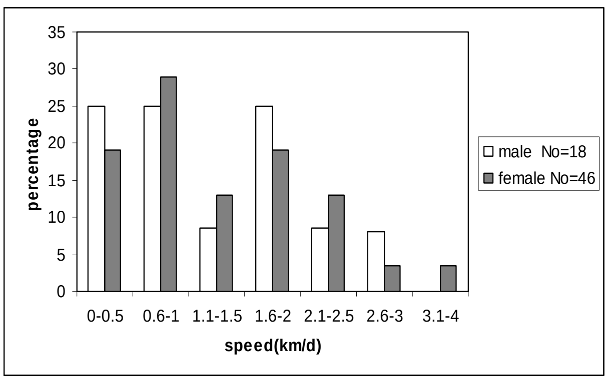

Fig. 4. Comparison of movement speed of males and females of recaptured prawn, *P. semisulcatus* in Bushehr waters, Persian Gulf (2003-2004)

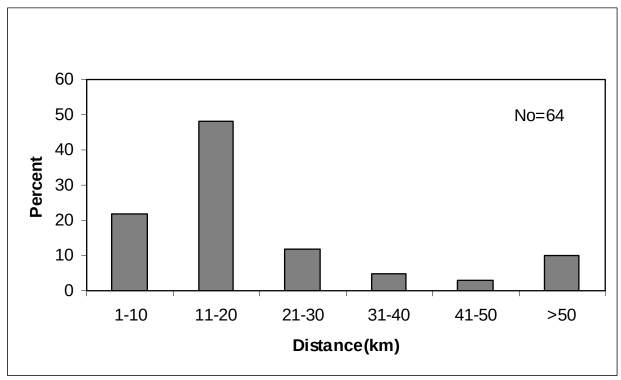

Fig. 5. Percentage of movement of tagged prawn, *P. semisulcatus* in Bushehr waters, Persian Gulf (2003-2004)

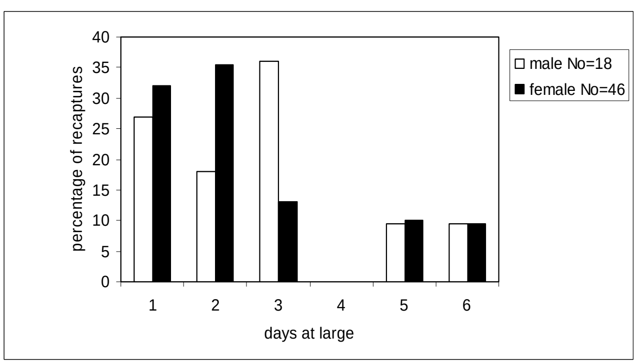

Fig. 6. Comparison of days at large for recaptured male and female *P. semisulcatus* in Bushehr waters, Persian Gulf (2003-2004)

More than 70% of the shrimps recorded from this experiment were recaptured <20 km from the release locations. Of the remainder, 20% moved >20 km from the release locations and 10% moved >50 km (Fig. 5).

Movements of tagged *P. semisulcatus* were generally northwesterly to the Bushehr area waters. The longest recorded distance moved by a tagged *P. semisulcatus* in this study was performed by a female released in Helaileh (28° 50’ N, 50° 48’ E) at 10 m depth in June (2004) and recaptured 95 days and 127 km later off Imam Hassan (29° 50’ N, 50° 08’ E). Generally, the results indicated that *P. semisulcatus* did not move great distances, however distance moved increased with time at liberty. A notable exception was of a female at liberty for 381 days (the maximum time in this study) which had travelled only 20 km. This shrimp could have moved a large distance and then returned to the released location as part of its annual cycle of movement.

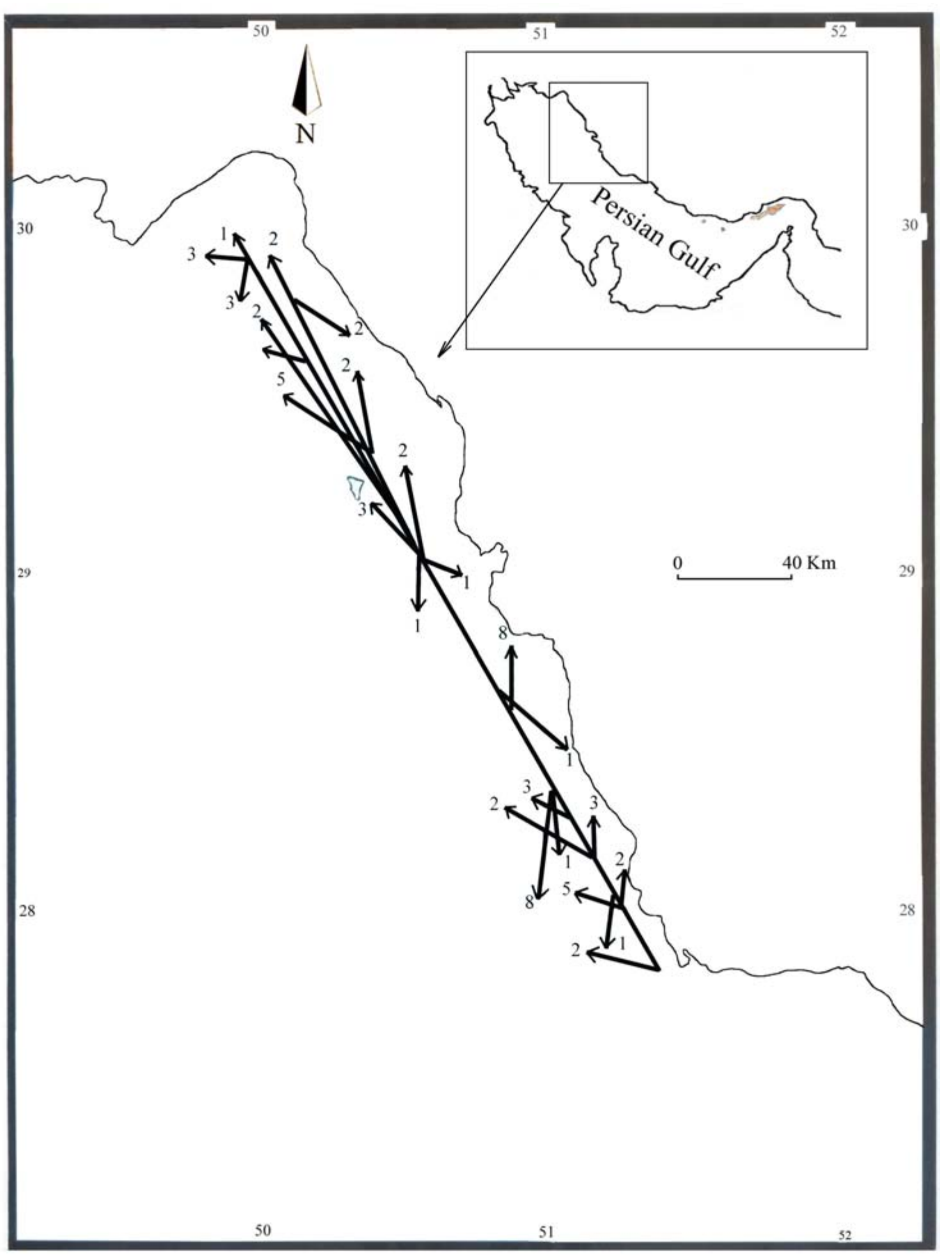

Fig. 7. Movement of tagged prawn, *P. semisulcatus* recovered along the Bushehr coastal waters, Persian Gulf (2003-2004).

More than 80% of the females and 75% of the males were recaptured 20-29 days after release (Fig. 6). The females were mostly recaptured within 10-19 days and males after 20-29 days. The predominant movement direction of tagged *P. semisulcatus* in the present study was from the southern area to the northern area; and from the middle area to the southern area (Fig. 7). About 72% of recaptures moved to the northern part of the study area. No shrimp was recaptured or reported outside of the study area.

Discussion

In the present study more than 48% of the marked shrimps (males and females) moved to deeper waters, 34% to the shallow waters and 18% were recaptured in the same depth that they were released. These findings suggest the seasonal movement of *P. semisulcatus* from inshore to offshore waters. As mentioned in the previous section, this movement is for spawning purposes and depicted two main directions of travel; either to the northern or southern part of the Bushehr waters. The majority of *P. semisulcatus* traveled to spawning grounds in the Ganaveh and Heleh areas (Fig. 7). One recapture that was released near the spawning ground moved only 20 km after 381 days at liberty, which may represent an annual return to the site.

Information on shrimp movement has been published by several authors in different areas (Frusher 1984; Yimin and Mohammad 1999 and Siddeek et al. 2001). Based on the objectives of any of the various studies, the results cover different aspects of the life history of shrimp species. Although the information available for *P. semisulcatus* is very scarce, the data emphasizes similar components to the objectives of the present study.

The movements of *P. semisulcatus* are determined by different behavioral and biological requirements. Sheridan et al. (1989) noted that *P. semisulcatus* migration may be related to feeding , substrate preference or spawning. Prevailing bottom currents may also influence the observed patterns in recaptures of tagged shrimp. Also, up current migration has been reported for the king prawn (*P. plebejus*) to spawning areas on the Australian continental shelf (Ruello 1973). Frusher (1984) noted the extensive migration of *Fenneropenaeus merguiensis* to commercial fishing grounds that can be located a considerable distance away (80-150 km) from nursery grounds.

In Kuwait waters (Persian Gulf), tagging experiments of *P. semisulcatus* showed that adult migration was generally limited with a maximum recorded distance of 85 km and most movements were much shorter (Mohammad et al. 1979; Farmer and Al-Attar 1981). They also reported some north-south movements along the coast in this area. Movements as far south as Saudi Arabia and Bahrain were insignificant, however further investigation at this point would be beneficial (FAO 1982). Although the migration pattern of *P. semisulcatus* in waters off Kuwait is still not clear, the pattern of catchability strongly indicates that this species may return to Kuwait waters, in pre-spawning aggregations (Yimin and Mohammad 1999). There is also the possibility that *P. semisulcatus* not originating from Kuwait migrate into Kuwait waters (Yimin and Mohammad 1999). El-Musa (1982) analyzed mark-recapture data and concluded that the *P. semisulcatus* released close to the border of Saudi Arabia, exhibited a strong northward movement. The timing of such a migration (February) could be affected significantly by environmental conditions associated with a spawning migration, resulting in an apparent increase in catchability earlier in some years than in others.

Siddeek et al. (2001) reported that the tag-recaptures of *P. semisulcatus* in the Gulf of Masirah (Oman) exhibited very restricted movements <100 m and none of the shrimps tagged and released within the bay were subsequently recaptured outside the bay. Likewise, none of the shrimps tagged and released outside the bay were recaptured inside the bay. This suggests the possibility of two separate populations.

In the northern Gulf of Mexico, mark-recapture experiments of shrimp species, *Farfantepenaeuse aztecu*s and *Litopenaeus setiferus*, indicated that the average distance moved 180 days after release was only 31 km (Klima 1963). In this study less than 3% of 2973 marked shrimps were recaptured.

In a study of *P. semisulcatus* in the Gulf of Carpentaria, movement was reported to be 10-30 km (Somers and Kirkwood 1984). In contrast, tagged brown shrimp, *F. aztecus*, moved up to 620 km during 430 days at liberty, while pink shrimp *Farfantepenaeus duorarum* moved a maximum 428 km during 446 days at liberty (Sheridan et al. 1990). In further studies, banana prawns *Fenneropenaeus merguiensis* exhibited maximum distance moved; 167 km in males and 190 km in females (Frusher 1984).

Different areas had different effects on movement of shrimp. In the Gulf of Mexico, Sheridan et al. (1990) reported that *F. duorarum* released in Tamaulipas moved faster (1.67-2.34 km/d) than those released in Texas (1.04-1.25 km/d). Movement of the shrimp *Litopenaeuse setiferus* was recorded along the coast of the United States at 657 km traveled after 95 days (Anderson 1956).

Various tag types affect shrimps differently. The total length of time that a tag remains attached to a shrimp is unresolved. Generally, it is expected that the level of attachment would decrease with time, due to tag shedding or removal by predators. Frusher (1984) noted that mortality increased in tagged *F. merguiensis* less than 17 mm CL. Also, Ruello (1970) showed a significant difference in recapture rate of large and small (<22 mm CL) *Penaeuse plebejus* using Atkins tags. Tags have also been suggested to increase predation rates, either through changing behaviour, attracting predators, or inducing cannibalism by other prawns (Howe and Hayt 1982 and Hill and Wassenberg 1985). There have also been indications that tag colour may influence mortality due to bird predation. Johnson (1981) suggested that higher bird predation on orange-tagged prawns occurred in his study of *F. aztecus*, because 78% of the tags recovered from bird droppings were orange and only 22% were black . Primavera and Caballera (1992) showed in a laboratory experiment on streamer tagged juvenile *Penaeus monodon* that there was no effect of tagging on growth rate.

Reported recovery rates of tagged shrimps from various studies differ appreciably. For example, shrimp tagging studies in different regions have reported a range from <1% to 13 percent (Sheridan et al. 1989; Klima 1963; Somers and Kirkwood 1984; Silas et al. 1984; Ulmestrand and Eggert 2001; Sideek et al. 2001).

The recapture rates reported for other programs that tagged substantial numbers of penaeid shrimps are more or less similar to the present study. Overall, the recapture rates for marine tagging experiments are generally quite low, often much lower than the present study. For instance, Holts and Prescott (2001) report 0.58% recovery for sailfish, while Bullen et al. (2000) reported a recovery rate of 1.24% for sailfish in South Africa.

Low tag recoveries may be caused by predation, stress, attack of tagged shrimp by untagged shrimp and increased nature mortality. In the present study, a lack of tag recoveries during the 10 month closed season contributed to a low number of recaptures. Consequently, the movement and behaviour of *P. semisulcatus* during the closed season in not well understood.

Water current can assist shrimp movement. The predominant sea current in the Persian Gulf is generated by the influx of water at the Strait of Hormuz. There is a surface inflow with velocities at the Strait of Hormuz reaching 15 cm/sec, then running along the Iranian coast at speeds of ~10 cm/sec (Al-Majed et al. 2000). This flow drags the deeper water in the same direction (Landner et al. 1993). The pattern of surface velocities around the northern coast of Iran is anti-clockwise. According to the schematic circulation model described by Reynolds (1993) for the Persian Gulf, the flow is driven from the Strait of Hormuz up the Iranian coast and stagnates east of Qatar, where high evaporation and sinking forms a dense bottom flow to the northeast, exiting out the Strait of Hormuz. All of these findings are similar to the observed movements of

P. semisulcatus detected by tagging experiments; thus suggesting that water current has a direct affect on *P. semisulcatus* movement.

The observed movement speed of *P. semisulcatus* in the present study is higher than other species reported elsewhere. As previously stated, during the open fishing season *P. semisulcatus* move to deeper waters for spawning. Hunter (1982) reported that the inflow from the Strait of Hormuz to the Iranian coast is stronger in summer (~20 cm/sec) and weakest (~10 cm/sec) in spring and autumn. As mentioned, the open fishing season for *P. semisulcatus* in the study area is in summer and all of the tag recaptures were done during this period. Because of the *P. semisulcatus* fishery is closed most of the year, it was not possible to identify the annual cycle of the movements. In this study, no marked shrimp were recaptured and reported outside of the open fishing season or the study area.

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