An investigation of reactive behavior of yellowfin tuna schools to the purse seining process

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Abstract

The movement parameters of yellow fin tuna schools were analyzed by means of scanning sonar in tuna purse seine capture situations in the Oman Sea in June 2010. There was significant difference in swimming speed and radial swimming direction between the escaped and captured schools. In escaped cases, the fish schools swam faster with mostly horizontal avoidance behavior to the sound stimuli from the surrounding vessel and escaped capture under the sinking net at last. The swimming speed of the schools in two occasions was correlated to the vessel's speed. Some alternatives of new constructions of the nets with regard to the sinking speed are discussed that may reduce the potential problem of escape capture during purse seining process.

Keywords: Purse seining, Reactive behavior, Sound stimuli, Scanning sonar

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Introduction

Fish schools reaction to the purse seine gear configuration during the fishing process largely determines the success in catch as the sinking speed of purse seines falls within a low range (Misund, 1992). The precise positioning of the purse seine gear relative to the fish schools is a significant issue in this respect. The decisive parameters resulting in the successful operation include the fish school size, the distance at which the fish can detect the purse seine wall under the fishing condition, the swimming behavior of fish school (their speed and direction) with respect to the size of purse seine, and the speed and direction of setting in combination with the speed of net sinking and pursing (Iitaka, 1971; Ben-Yami, 1994). In some cases fish descend to the full depth of the seine and can escape underneath the leadline or change direction of movement during shooting. Research on swimming behaviour of schools can be found on rare occasions because of difficulty in their studies.

Computerized sonar equipment which is commonly installed on board purse seiners can display the horizontal extent and movements of recorded schools as distinct intensity spots, although its function is not simply to detect underwater schools concentrations and their swimming behavior. By such instruments, useful information can be predicted for the behavior of pelagic fish schools in capture situation using purse seine nets.

The purse seine gear is usually set at a safe distance of at least 250-300 m to the fish school (Ben-Yami, 1994), laying far beyond the range of the maximum visual perception distance of fish, which covers around 40 m (Tyler, 1967).

When purse seining, however, the vessel is being actively operated and it may generate stimuli influence and modify the behavior of nearby target fish schools (Olsen, 1971). Moreover, operating purse seiners generate low-frequency sounds with their peak around 100 Hz within the frequency range of teleost fishes (Chapman and Hawkins, 1969).

The noise sources result from propeller cavitations and engines, which together produce a continuous sound spectrum that may have the noise patterns with different line frequency (Misund, 1993). The sound from the vessel is directive with lobes of higher intensity athwartships and minimum sound intensity in front of the vessel (Urick, 1967).

The moving tracks of fish schools of Atlantic mackerel in response to the noise of the fishing vessel was recorded by the analysis of the sonar images taken during the purse seining (Misund, 1992,1993). Escaping behavior of fish schools through the gape at wing ends was observed by a model purse seine in the experimental tank (Park et al., 1997).

Example of reactive behavior of skipjack schools to the purse seining are found in Shimozaki et al. (1975). The changes in swimming behavior between herring schools were evidenced during the purse seine process whereas the swimming pattern of individual schools remained constant (Misund, 1992).

The data on the reactions of fish schools to stimuli from the purse seine gear and the vessel can be used as a basis to set a model of fish behavior as indicated by Olsen et al. (1983). According to the model, fish start reacting to the approaching vessel by turning and swimming radially away from the sound source.

The purpose of this study was to investigate the swimming behavior of the yellowfin schools to the purse seine operation as quantified by changing in swimming speed and radial direction in relationship between stimulus and response based on sonar observations in the Oman Sea.

Materials and methods

Horizontal movement of yellowfin schools were recorded by color scanning sonar (Furuno FSV-30) from purse seine operations on board M/V "Parsian Shila" (1800 G/T), a typical Iranian tuna purse seiner, during the period of 5-30 June 2010 in the Northern Oman Sea.

The gear used was a typical tuna purse seine and had a length of 1886 m along the floatline and of 2026 m along the leadline. The full stretched depth measures 210 m.

13 favorable shooting operations out of 20 shootings were selected for the movement parameters of yellowfin tuna schools during purse seining. The vessel circled the schools counter-clockwise when the duration of the entire purse seine process varied with fishing condition; an average of 6 min was required to set the seine and 22 min to haul in the purse line completely at an average speed of 12 knots. The sonar recordings were taped via a JVC video camera and latter displayed on computer. The images of the sonar monitor were prepared for every 1 min at each purse seine operation. Subsequently, the horizontal position of the midpoint of the yellowfin school center and the purse seine operation course with surrounding net wall were tracked on transparency at 1- min intervals. The vessel heading and horizontal distance of the yellowfin school to the vessel or the purse seine wall, all displaced by the sonar when used in target tracking mode, were measured for each interval. The main movement parameters were investigated as swimming speed, radial swimming direction (α_f) (Fig. 1), the same way as it was used by Misund (1993) with some modifications, and distance to the vessel with fishing time from shooting to the pursing end. When circling the schools, the sonar was mostly operated manually with a tilt ranged from 2 to 14°. All the swimming speeds of yellowfin were recorded during shooting operation, so no separation between simple circling and shooting is made in the investigation.

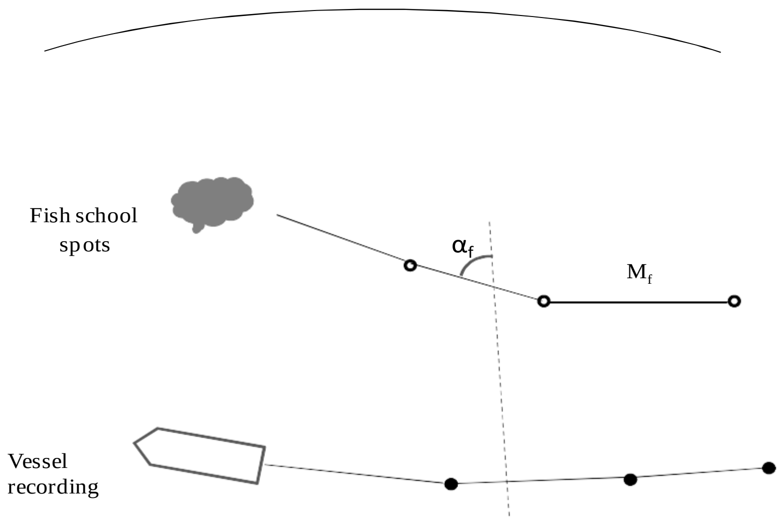

Figure 1: Analysis of the sonar recording. M_f, fish school movement in a time interval; α_f, radial swimming direction.

Results

The school size (visually approximated by the fishing master) per set differed considerably, ranging from 30 tons to around 100 tons, with majority being approximately 30-40 tons as shown in Table 1. A total of 53% of 13 yellowfin schools recorded during the survey seemed to react to the vessel with more than 70% swimming out under the sinking net during shooting and pursing. Two of the escaped schools avoided being encircled during shooting with swimming away from the vessel.

Table 1: Characteristics of fishing operations and catch of yellowfin school as observed in captured and escaped status (the catch size visually approximated by the fishing master).

Type	Shooting	Shooting period	Location (Lat & Long)	Catch	Remarks
Captured	170º	11:20 – 11:30 am	25:47 N , 57:13 E	100	
	190 º	14:30 – 14:36 pm	24:72 N , 59:12 E	30	
	335 º	10:30 – 10: 34	24:85 N , 59:37 E	30	
	185 º	9:25 – 9:31	24: 72 N, 58: 75 E	35	
	215 º	8:20 – 9:29	24: 90 N, 57: 92 E	45	
	195 º	16:21 – 18:28	24: 83 N, 58: 67 E	55	
Escape	210 º	16:45 – 16: 53	24:80 N , 59:07 E	50	During pursing under the net
	50 º	15:20 – 15: 27	24:68 N , 59:50 E	30	During shooting under the
	115 º	17:15 – 17: 21	24:81 N , 59:02 E	30	Avoided being encircled
	120 º	07:15 – 07: 23	25:02 N , 58:43 E	35	During shooting under the

Continue table 1:

121 º	11:10 – 11: 21	25:27 N , 57:82 E	43	Avoided being encircled
315 º	13:20 – 13: 29	25:22 N , 57:62 E	23	During shooting under the
130 º	11:00 – 11:07 am	25:02 N , 58:53 E	100	During pursing under the net

An example of the horizontal movement track of a herding yellowfin school of 50 tons during purse seining is shown in Figure 2 which led the schools to be caught at last. Two cases of the escape under the leadline are indicated in Figure 3 for the schools of 30 tons and 50 tons during shooting and pursing situations respectively. It is evident in the Figure 3a that during shooting the school avoided the vessel and fled downward under the lead line mostly in opposite direction to the vessel. As for pursing case (Fig. 3b), the school guided by the vessel (0-4) and then clearly avoided the vessel with escape out under the netting wall.

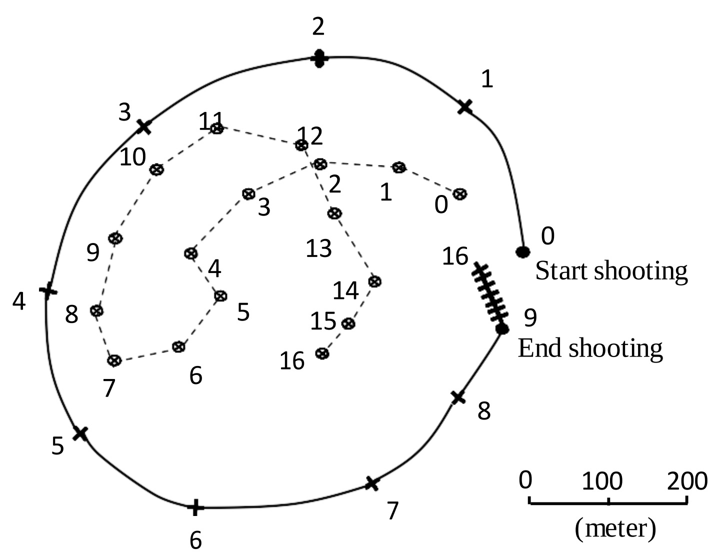

Figure 2: Horizontal movement of yellowfin as centers of school in purse seine process when school of 50 tons captured (circle and dotted line) in relation to net setting (circle and solid line). Similar numbers refer to the track of the school and the vessel in 1 min interval.

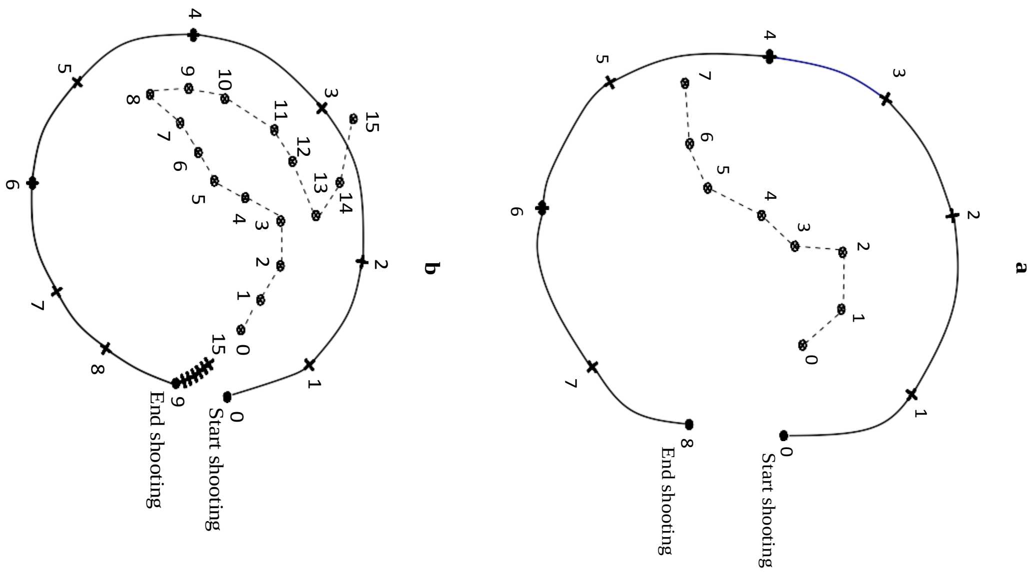

Figure 3: Horizontal movement of yellowfin as centers of school in purse seine for escaping under the leadline. School of 30 tons (circle and dotted line) in relation to the net setting (circle and solid line) (a), and of 50 tons during pursing (b). Similar numbers refer to the track of the school and the vessel in 1 min interval.

The distribution of the swimming angle (α_f) from the sonar recoding indicated an average value of 53º and 315º for escaped and caught yellowfin schools respectively (Fig. 4).

Apaired t-test was performed to indicate the difference between caught and escaped schools at every 20º of the heading which was sufficient from 0 to claim significance (*p<.008*).

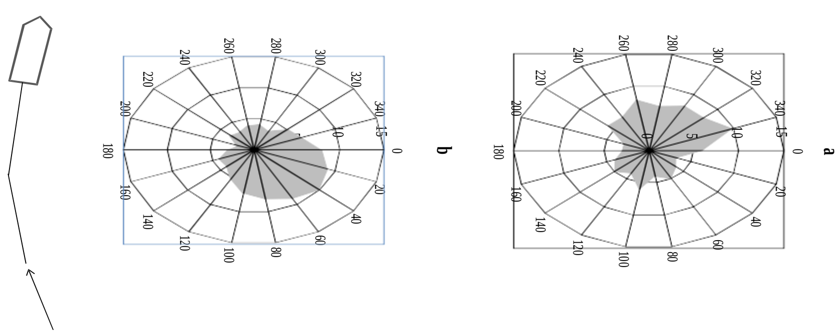

Figure 4: Frequency (%) of radial swimming direction, α_f, for caught (a) and escaped (b) yellowfin schools in relation to the vessel heading.

The relationship between the distance, D in m, from the center of the school to the vessel and swimming speed of fish, V_f , of yellowfin school during setting the net was not significant for caught schools (n=77, r^2= 0.048, *p>.06*), while it was significant for escaped schools (n=74, r^2= 0.25, *p<.00001*) (Fig. 5). The significant rank correlation between the distance of escaped fish school to vessel and swimming speed would imply that the avoidance was faster at a greater distance from the vessel. However, our results may alternatively be affected by the most avoiding schools preserving greatest distance from the vessel. The average distance of the school center (±SD) to the vessel was 427 ±116 m for escaped schools and 404±97 m for caught schools which was not significant statistically (*p>.2*).

The 13 schools of yellowfin observed represented a range in swimming speed of 1.19 to 4.42 m/s. The mean horizontal swimming speed of escaped schools was recorded as 2.88 ± 0.79 m^{-s} while this was 2.44±0.73 m/s for caught schools which was significantly different between caught and escaped schools (*p<.005*).

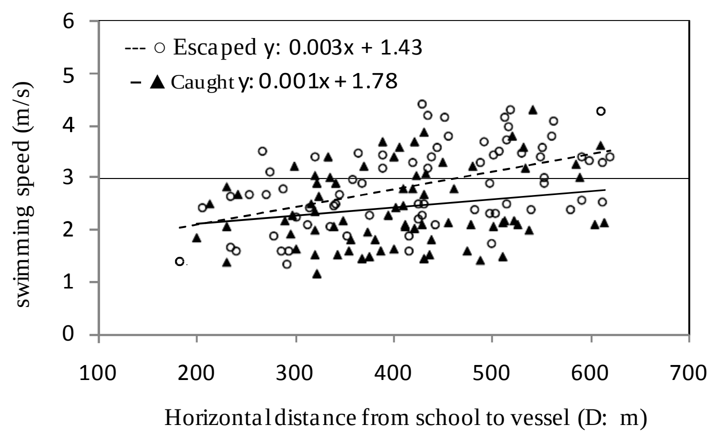

Figure 5: Distance from yellowfin school the vessel related to the swimming speed of the fish for caught situations (triangle and solid line) and escaped ones (circle and dotted line).

The correlation between the setting speed and horizontal swimming speed of the fish is shown in Fig. 6 which performed significance for escaped schools (n=86, r^2=0.37 *p<.000001*) and caught ones (n=94, r^2=0.31, *p<.00001*). This tendency was relatively apparent for escaped schools.

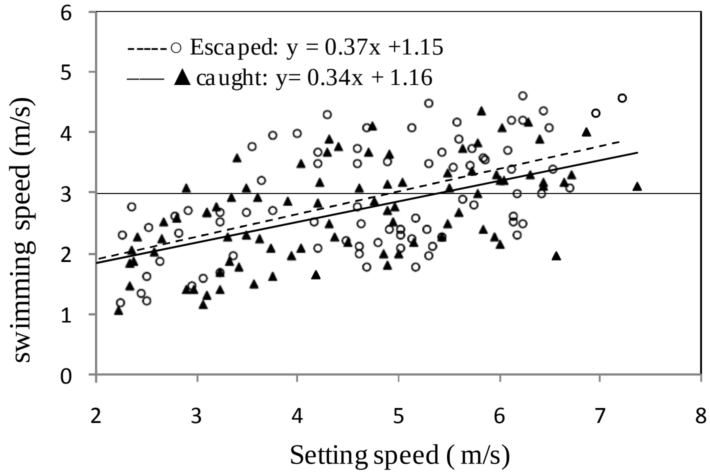

Figure 6: Setting speed of the seiner related to the swimming speed of yellowfin schools for caught situations (triangle and solid line) and escaped ones (circle and dotted line) in 1 min interval.

Discussion

The behaviour of the fish schools during pursing may be changed as swimming towards the gear when the sound level is increased simultaneously by the intensive vessel manoeuvring. Therefore, the horizontal avoidance behaviour may be the result of directional orientation. In this case, fish reacting to the surrounding vessel by adjusting the swimming direction away from it seemed to be explained by an increasing sound level of vessel with direction of bearing nearly perpendicularly towards the schools routs, as sound coming out of the vessel is a “butterfly”-like pattern with a minimum in front and lobes of higher intensity on both sides (Urick, 1969). There was an obvious difference of swimming angle between the escaped and caught schools of yellowfin tuna. On the basis of the swimming tracks, the escaped schools can therefore be judged as avoiding while schools from those of herded into the circled seine as non-reacting.

In yellowfin schools, whose reaction to the sound stimuli includes an increase in swimming angle, variations in swimming angle among the swimming schools probably reveal variations in motivational state and thereby reaction threshold, and variations in sound intensities omitted from the vessel.

Olsen et al. (1983) argue for the avoidance reactions of the fish by an instantaneous increase in the pressure gradients of low frequency sound stimuli generated from an approaching vessel.

There is evidence of variations in the swimming behaviour from sonar observations of schooling herring and mackerel during purse seining with clockwise shooting Misund (1993); some schools induced no reaction to the encircling purse seiner, some schools partly guided by the vessel, while others consistently avoided the vessel with mostly guided in an inner circle by the vessel.

The direct correlation between the setting speed and horizontal swimming speed, especially for the escaped schools, probably indicates a connection between the reaction and the sound emission of the vessel for both schools. Erickson (1979) found that tuna vessels omitting smooth sound spectra had apparently higher catch rates than vessels producing higher intensities with distinct line frequencies.

Our samples showed a swimming speed of 1.19 to 4.42 m/s for yellowfin tuna schools which showed less variation than the previously reported 1.6 to 5.4 m/s (Yuen, 1966) from underwater motion pictures of feeding yellowfin schools at Sea. The difference may be attributed in part to difference in the nature of activity of fish.

The highly failed sets of the tuna catch (around 62% based on the cruise and around 51% from the logbook records of whole purse seiners) in EEZ waters of Iran compelled the designers of these nets to establish their goals of improving tuna purse seines in terms of building costs and standardization of net construction appropriate for the rapidly swimming fish schools.

The potential problem of escape capture by swimming out under the sinking net is decreased alternatively by using faster sinking purse seines. The latter objective is achieved by utilizing large-meshed panels in combination with denser netting materials in main body of the net considering the escape of capture through the meshes when selecting the appropriate mesh size (Hosseini et al., 2011). The advantage of the large-meshed sections is that the deceased bulk and weight of the net require less powerful purse winches and smaller power blocks, and the seine maintains a good operative shape even during high tidal currents. Although the sinking speed of a seine is proportional to the square root of the lead weight (Iitaka, 1971), too heavily weights result in practical limitations such as gear damage and strain on the gear-handling equipment.

Apart from vessel noise, other natural stimuli such as temperature (Blaxter, 1969), dissolve oxygen levels (MacFarland and Moss, 1967) and parameters of prey and predators, as has been stressed already by Ben-Yami (1994), influence strongly on the reactive behavior of yellowfin schools in relation to the purse seining process. Purse seining on the feeding schools of skipjack leads to successful catch when there is no risk of predatory and they move in stable condition without panic behavior (Menard and Marshal, 2003). Additional noise generated by the leadline running through the purse rings may explain the tendency of schools to change the swimming heading with a downward component during shooting of purse seine (Misund, 1992). On some occasions, the schools swimming towards and under the noisy vessel explains that the visual stimuli from moving gear impact stronger on fish behavior as compared to the sound stimuli generated by the vessel and gear (Misund, 1994).

In conclusion, such basic findings of swimming behavior of yellowfin school in tuna purse seine presented here need to be extended in further study by consideration of more parameters affecting the movement as mentioned above.

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