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Prediction of shooting trajectory of tuna purse seine fishing

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ABSTRACT

Purse seine fishing is very effective in catching large volumes of pelagic fish. In Korea, as in many other countries, it is frequently used in catching tuna, a fish with high added value. To make a successful catch in purse seine fishing, it is important to choose the initial gear shooting position and trajectory for the purse seine based on the speed and direction of the swimming fish and the speed of the ship. In the field, the initial shooting position typically depends on the experience of the captain. With increasingly strict global regulations for fish aggregating devices (FADs), greater precision in predicting the purse seine shooting trajectory is required to improve the catch success rate for unassociated (FAD-free) schools. In this study, we propose trajectories with high potential for application in purse seine fishing, based on the speed and direction of the fish school. Two distinct gear shooting methods are proposed according to the speed of the fish. The first gear shooting method is applicable for fish moving at a moderate speed and with less changes in direction; the second method can be applied to fast-swimming schools. In addition, when the depth covered by the sinker line is known through the analysis of the gear behavior, the gear shooting trajectory can be modified according to the depth of the sinker line. The results from this study may be used as a technological alternative to FAD operations by assisting in tuna resource management and reducing the capture of non-targeted species.

1. Introduction

Purse seines are used in areas of maximum fish concentration since they are more effective than other gear for catching pelagic fish. Thus, purse seining is one of the most efficient advanced fishing methods because relatively few vessels are needed to harvest resources that are suitable for exploitation (Ben-Yami, 1994). However, deploying purse seines efficiently is also a complicated process that depends on the correct setting of the net relative to the fish school's swimming direction, swimming speed, and depth, as well as on the prevailing environmental conditions, such as waves, wind, and current.

A purse seine is large wall of netting used to surround the aggregated fish from the sides and from underneath, thus preventing them from escaping by diving downward. Apart from a few exceptions, purse seines are surface nets. Each netting wall is framed by a floatline at the top and a leadline at the bottom. The tuna school is sensitive to the presence of the net during the fishing operation. The school or any other collection of fish upon which the seine is set may be stationary (mainly when attracted to light or to a fish aggregating device (FAD)) or mobile. In general, fish schools captured by purse seining can be divided into unassociated (FAD-free) schools and FAD-associated schools (Hare et al., 2015). The operation for unassociated schools is performed for fish schools at the surface and for schools that are feeding on baitfish. Meanwhile, the operation for associated schools is performed for log schools, FAD schools, and whale shark schools (Bromhead et al., 2003; Lee, 2016).

The Western & Central Pacific Fisheries Commission (WCPFC) limits FAD operations because of bycatch problems with juvenile bigeye tuna and yellowfin tuna when FADs are operated in tuna purse seine fishing (WCPFC, 2017). FAD regulation is expected to be further strengthened in the future based on the distance and the kind of school to be caught. Currently, the FAD set of purse seine fishery operating on the Pacific Ocean is regulated under the related Conservation and Management Measures (CMM) and resolutions by WCPFC and Inter-American Tropical Tuna Commission (IATTC). In the case of Korea, fishing activity using FAD is only applied by WCPFC CMM, because there is no operation in the IATTC convention area. In addition, there are two types of regulations for major purse seining countries in the Pacific Ocean; FAD operation by purse seining countries is prohibited from July to September and fishing operations are limited to a total number per year. Second, FAD operation is prohibited from July to October with no limit on the total number of fishing operations per year.

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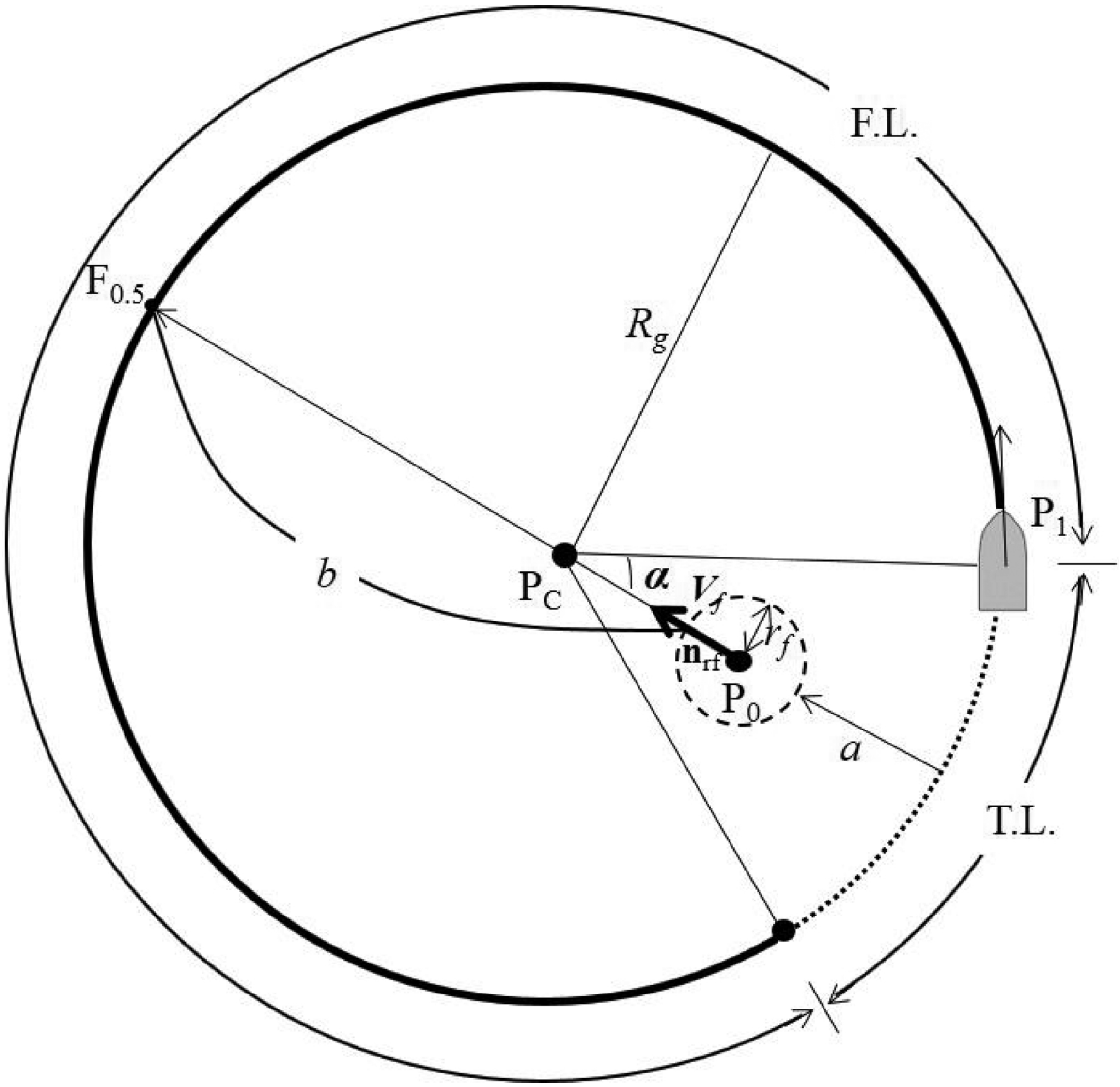

Fig. 1. Movement of fish school and shooting trajectory of purse seine shooting method 1 (F.L.: floatline length; T.L.: tow line length; R_g: gear radius; α: angle between the school direction and the line abeam of the ship; a: distance between the school and the shooting circle; b: distance to be moved by the school; r_f: radius of the school; $\boldsymbol{V}_f$: speed of the school; $\mathbf{n}_{rf}$: unit vector of the school velocity; P_0: position of the school; P_1: initial shooting position; P_c: center of the shooting circle; $F_{0.5}$: center of the net).

FAD operations have a high success rate because the target fish remains almost stationary. Meanwhile, the operation for unassociated fish schools has a higher failure rate because of errors in judgment regarding the fish school as well as unexpected fish behavior and inaccurate gear shooting trajectory prediction. The operation to be performed is selected by setting the shooting trajectory and initial shooting position, according to the accurate assessment and prediction of fish school movement.

From previous research (Lee, 2016) on the Korean purse seine fleet, a fishing operation is considered a failure if the total catch is less than 15 metric tons. The fishing success rate with FAD is 70%, whereas that for unassociated fish schools is 44%. The above fishing restriction affects Korean tuna purse seine fishing only slightly, as Korea has a relatively low FAD operation ratio. However, it presents a significant obstacle for countries with relatively high FAD operation ratios. Therefore, the efficiency of fishing operations for unassociated fish schools must be improved. A potential way to do so is to predict the seine shooting trajectory through scientific calculations by considering the direction and speed of fish schools. However, research on the calculation of seine shooting trajectory is rare. Fridman (1973, 1986) attempted the theoretical calculation of the length of the purse seine by considering the vessel speed and fish school speed.

Here, we propose two shooting trajectories for the purse seine net, which were calculated based on the speed vector of the fish school by combining the empirical knowledge of skilled skippers and mathematical principles. This study proposes two purse seine shooting methods according to the speed of the target fish school. These shooting methods can be applied to both unassociated and associated fish schools. Shooting trajectories are presented under different scenarios along with sample calculations. In addition, a shooting method based on the sinking depth of the leadline is presented. The sinking depth of the leadline can be obtained through numerical calculation or field measurement; Using the numerical method presented here.