The Responses of Adult Sockeye Salmon *(Oncorhynchus nerka)* to a Commercial Purse Seine

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ABSTRACT

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Depth-sensing ultrasonic transmitters provided information on the vertical and horizontal movements of 5 adult sockeye salmon (Oncorhynchus nerka) being captured by a commercial purse seining vessel in the waters between Vancouver Island and the mainland of British Columbia. Vertical excursions by the fish on the order of 5-10 m/min were common both before and after the boat approached and set the net. In general, the boat and net did not seem to trigger the rapid diving or horizontal swimming responses that would have been necessary for the fish to escape capture.

RESUME

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Des sondeurs-transmetteurs à ultrasons ont fourni des donées sur les déplacements verticaux et horizontaux de cinq saumons rouges (Oncorhynchus nerka) adultes au moment de leur capture par un senneur commercial dans les eaux entre l'Île de Vancouver et la partie continentale de la Colombie-Britannique. Avant et après l'approche du navire et le mouillage de la senne, les saumons ont effectué des déplacements verticaux de l'ordre de 5-10 m/min. En général, il semble que le navire et la senne n'ont pas déclenché la descent rapide ou les déplacements horizontaux qui auraient été nécessaires pour que le poisson puisse s'échapper.

INTRODUCTION

Man has devised an extraordinary variety of methods for catching fish (von Brandt 1984). The effectiveness of these methods is often influenced by the three-dimensional configuration of the gear and the behavior of the target species. For example, the optimal design of Japanese setnets depends greatly upon differences in behavior of the fishes that may be caught (Nomura 1980). Wardle (1983) reviewed studies of the responses of fishes to towed nets and concluded that behavior plays a major role in catchability when the fish can see the gear.

Ultrasonic transmitters can provide useful information on fish behavior in relation to fishing gear. In their simplest form they indicate the horizontal position of the fish. Leggett and Jones (1971) tracked 13 American shad (Alosa sapidissima) in the vicinity of commercial drift gillnets on the Connecticut River. In 39 approaches to nets, only one shad was captured, and precise net avoidance was documented. Similarly, Westerberg (1982) reported that telemetered Atlantic salmon (Salmo salar) often avoided stationary net traps. Information on the vertical movements of chum salmon (Oncorhynchus keta) in coastal waters relayed by depth-sensing ultrasonic transmitters helped assess the efficacy of various set net designs (Ichihara and Nakamura 1982).

In the course of a study on adult sockeye salmon (O. nerka) vertical movements (Quinn and terHart 1986), we had occasion to recapture five telemetered salmon with a commercial purse seine vessel. This note reports the vertical movements of the salmon during the seining operation and describes the changing three-dimensional structure of the net in relation to the fish's opportunities for escape.

METHODS

Sockeye salmon were initially captured by the drum seine vessel Sea Luck. Each salmon was anesthetized with tricaine methanesulfonate (MS-222) and a 74 mm cylindrical ultrasonic transmitter was placed in its stomach. The fish was allowed at least 40 min to recover before release (see Quinn and terHart [1986] for additional details). For various reasons, we decided to recapture five of the salmon later in the day (Table 1). We attempted to maintain a record of the fish's vertical movements in relation to the progress of the seining operation. Seining took place in Johnstone Strait (salmon No. 5), Discovery Passage (Nos. 7 and 9), and the Strait of Georgia (Nos. 11 and 14), between Vancouver Island and the mainland of British Columbia, during the summer of 1985. All 5 salmon were recaptured on the first attempt by the Sea Luck.

DETAILS OF THE SEINING OPERATION

The Sea Luck is an aluminum drum seiner, 18 m in length and 2.8 m in draft, powered by a 365 hp, CAT D433 engine and equipped with bow thrusters. It is typical of the salmon seine boats in the waters around Vancouver Island, Canada. It used a seine measuring 400 m long by 52 m deep, with a bunt end mesh size of 76 mm and lead line weighing 3 kg/m (Fig. 1). A small aluminum rowing skiff was used in the setting of the net, as motorized skiffs are not permitted for salmon seining between Vancouver Island and the British Columbia mainland.

Many commercial sets in this area are made from tie-off points along shore owing to the regulation against power skiffs, tidal velocities and concentrations of salmon near shore. Fishermen also commonly employ rapid offshore circle sets that do not utilize tie-off points, and this was the type of set used to recapture our salmon. Details of the seining operation are as follows. The bunt end of the net was attached to the skiff with a skiff line and to the seiner with a running line. The skiff and net were then released from the seiner while it was underway at a speed of up to 6 km/h. The net freewheeled off the drum as the seiner ran in a circle until the entire net was set and the circle closed off (Fig. 2A). For the 5 sets made to capture the sockeye, this phase of the operation occupied between 3 and 5 min (average 4 min).

After the set was closed off, the skiff was released from the bunt end. The running line was winched aboard which hauled the net up against the seiner amidships. A wind line was also secured to the bow of the seiner as an additional means of holding the bunt against the ships hull. At this point, about 5 min after the beginning of the set, the net was essentially hanging vertically in the water to its maximum fishing depth of about 45 m, alongside the seiner. Under ideal conditions of wind and tide, the net would be in a cylindrical configuration with a diameter of about 125 m. The only way for a fish to escape at this stage is to dive under the net or swim through the wedge-shaped opening directly under the boat (Fig. 2A).

During the pursing stage of the operation, the opening at the bottom of the net was closed and the net's shape changed from a cylinder to a hemisphere. The purse line leads from the running line through a series of rings along the leadline for about 3/4 of the net's length. Retrieval of the purse line constricted the rings, reducing the diameter of the bottom of the net and elevating it. As the net was being pursed, it was simultaneously wound onto the drum, reducing the net's horizontal expanse. These procedures continued until the rings were brought to the surface alongside the boat, completely encircling the fish in the fully pursed net (Fig. 2B). In the sets made by the Sea Luck to recapture the fish, an average of 10 min elapsed from the beginning of the set to the recovery of the rings. The net's maximum depth at this point would be approximately 20-25 m, and under ideal conditions the diameter would be about 50 m. The net was then rolled onto the drum until only a small pocket remained in the water. At this time the net was manually hauled on deck until the fish could be removed by dip nets. In our sets, the fish was usually on deck about 15 min after the set began.

RESULTS

Prior to the approach of the Sea Luck, the sockeye salmon occupied depths from the surface to about 30 m (Fig. 3; Table 1). This seemed to be typical of sockeye in these waters (Quinn and terHart 1986). Vertical excursions were common and depth changes of over 10 m/min were observed. If sufficiently motivated, sockeye can dive over 20 m/min, and some sockeye descended to 70 m upon release from the holding tank (Quinn and terHart 1986). The approach of the seiner was not associated with diving by the first two sockeye, which were near the surface prior to the set (Fig. 3A, B). The third fish made a rapid descent from the surface to 23 m 2 min after the set began (Fig. 3C). While this might have been triggered by the boat or the net, we note that this fish also made a steep dive 8 min prior to the approach of the Sea Luck, and indeed had often descended from the surface to about 15-20 m during the previous 12 h of the track. The fourth sockeye was swimming at 24 m when the set began but only descended to 29 m before ascending to the surface (Fig. 3D). Similarly, the fifth sockeye was swimming at 12 m when the set began but did not dive below 19 m and was at 10 m when the net was pursed (Fig. 3E). Thus dives and ascents occurred before and after the net was set, and we could not ascribe any of the dives to the appearance of the boat or release of the net. The patterns of vertical excursions continued until the net's rings were recovered, after which the salmon seemed to be gradually forced to the surface by the rising net. In terms of horizontal movements, the salmon did not accelerate noticeably when in the net, but often seemed to swim along the edge of the net.

DISCUSSION

In rapid circle sets such as the Sea Luck employed to catch these fish, an individual salmon has relatively little chance to escape. Two opportunities are present: a horizontal dash before the net encircles the fish or a deep dive below the net before it is fully pursed. The typical cruising speed of adult sockeye salmon is about 2 km/h or 30-40 m/min, but speeds up to 4 km/h (70 m/min) have been reported (Madison et al. 1972; Stasko et al. 1976; Quinn and terHart 1986). If the boat requires only 5 min to set the net in a 100 m diameter circle, the fish must react quickly to effect a horizontal escape. If the set is made so that the direction of fish movement is into the net rather than away from it, a fish might require 1-2 min to encounter the net even if it swam in a straight line. If it then reversed its direction, it might require another 2 min to recross the net, by which time it would be nearly encircled. After the net's circle is closed, about 5 min remain for the fish to dive under the net before it is pursed. Since the fish can dive up to 20 m/min, escape is certainly possible. However, the opening at the bottom of the net grows progressively smaller and closer to the surface until it is about 20 m deep when pursed. At this time, escape is not possible and the maximum depth to which the fish can descend decreases as the net is retrieved.

In slower sets, the fish would have more time to escape if they become alarmed. While our transmitters did not allow us to pinpoint the fish's horizontal position, there was no evidence of sudden bursts of swimming when the fish encountered the net. Underwater observations by remote camera or diver would be needed to more precisely ascertain the responses of isolated or schooled salmon in the net. Another factor that might influence escape is schooling behavior but only the fourth fish was caught with any significant number of sockeye (58). The others were either alone (Nos. 5, 7 and 11) or with 2 other sockeye and one chinook salmon, *O. tshawytscha* (No. 14). However, observations from the *Sea Luck* during its commercial operation generally indicated that schools of sockeye seldom made rapid reversals of direction upon encountering the net, and they could sometimes be seen circling along the edge of the net.

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Table 1. Summary of data on five telemetered sockeye salmon recaptured by commercial purse seine (see Quinn and terHart [1986] for details).

Fish	Date	Duration of track prior to recapture (hours)	Time (PST) of recapture	Depth distribution during 1 h prior to recapture			
				Mean	StD.	Max.	Min.
5	19 July	6:00	17:59	7.3	8.5	33	1
7	26 July	3:32	11:13	5.1	4.6	25	1
9	1 Aug	12:20	19:55	8.3	8.1	26	1
11	7 Aug	7:55	19:15	23.9	6.3	36	4
14	16 Aug	9:49	17:14	10.7	4.0	22	2

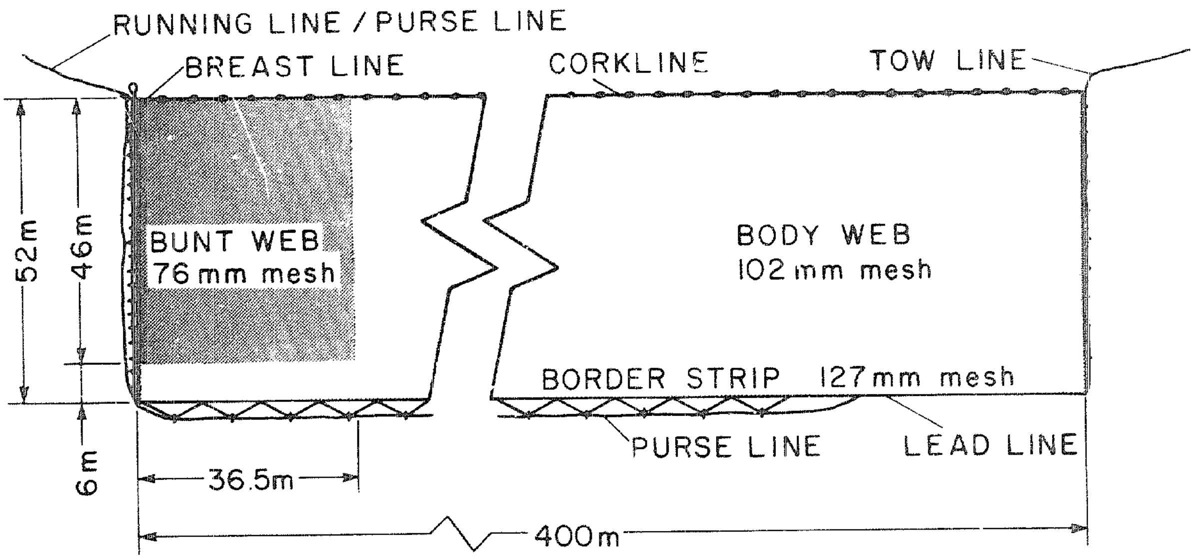

Fig. 1. Diagram of the purse seine used by the Sea Luck to capture sockeye salmon.

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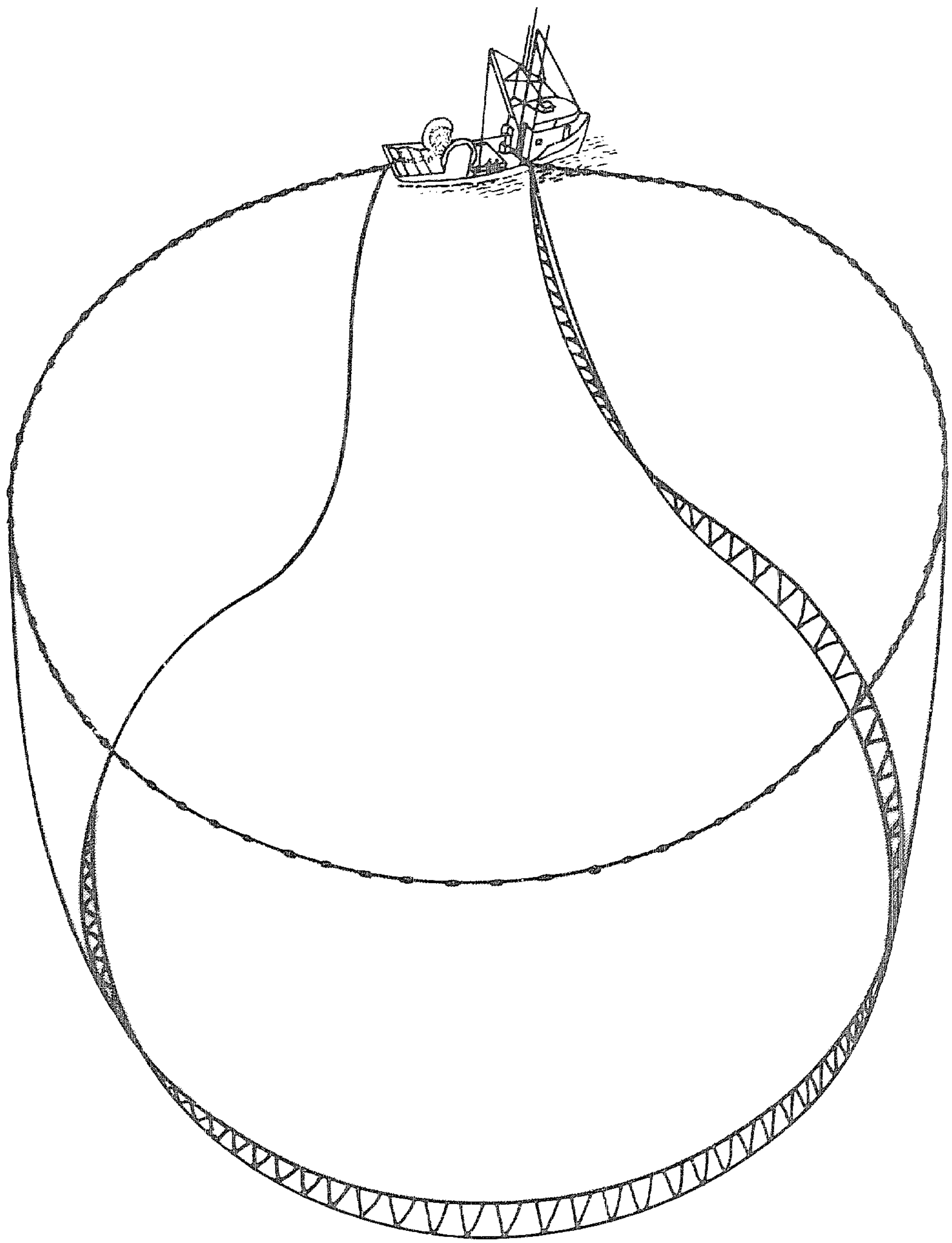

Fig. 2. Operation of a purse seine to capture sockeye salmon. A) The net is set in a circle by action of the seine vessel and its skiff. The net hangs vertically in the water with a wedge shaped opening directly under the boat. B) The net is pursed by retrieval of the purse line through rings at the bottom of the net. The rings are brought to the surface alongside the seiner completely encircling the fish in the fully pursed net.

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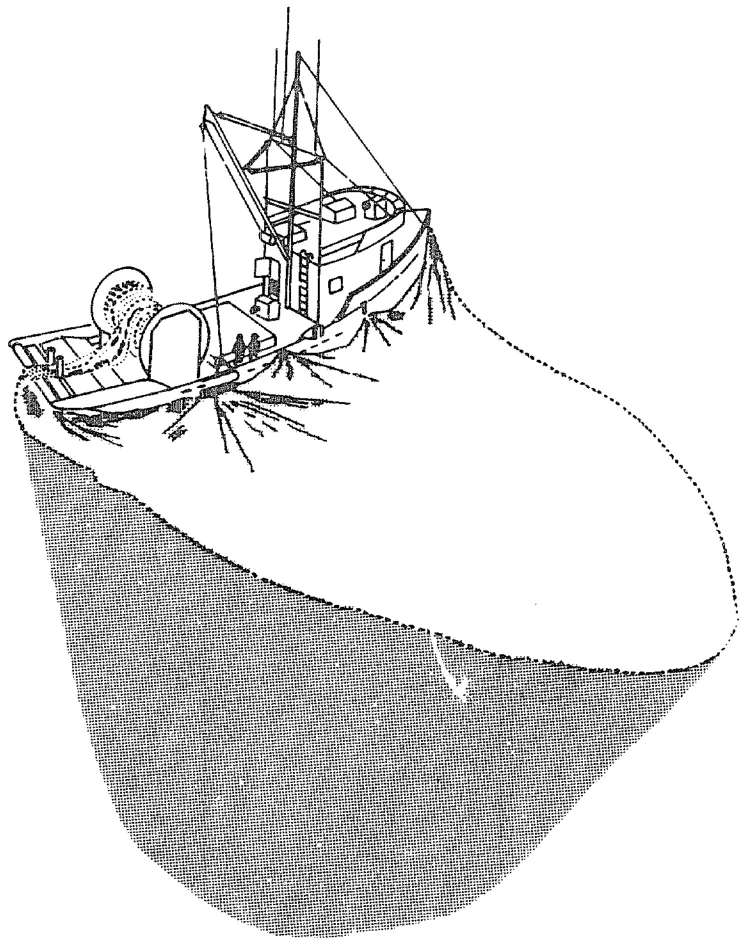

Fig. 2B.

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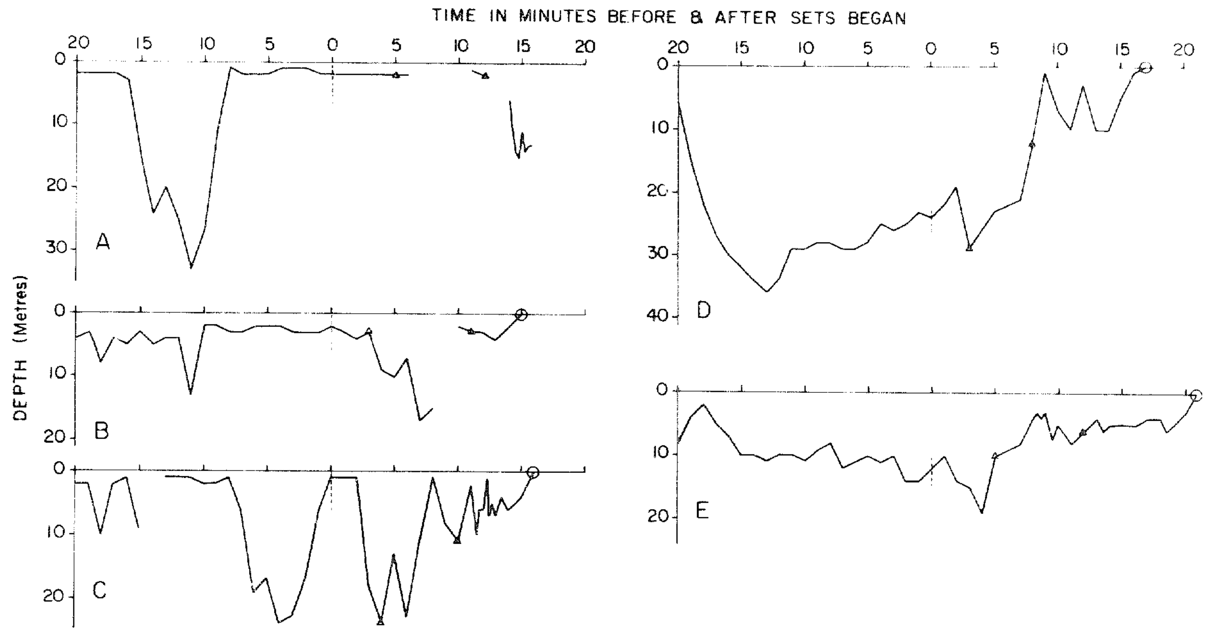

Fig. 3. The vertical movements of 5 sockeye salmon during the 20 min prior to the setting of a purse seine, and during the fishing operation. The time when the net completely encircled the fish is indicated with a Δ, the time when the net was pursed (rings on board the vessel) is indicated with a ▲, and circle indicates the time when the fish was brought on board the Sea Luck. A) salmon No. 5, B) salmon No. 7, C) salmon No. 9, D) salmon No. 11, and E) salmon No. 14 (see Table 1 and text for additional details).