1989年の新りあす丸によるさけ・ます類のバイオテレメトリー調査の概要

Outline of biotelemetry study for salmon by Shin-Riasu maru, 1989

小倉　未基
遠洋水産研究所
Miki Ogura
Far Seas Fisheries Research Laboratory

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小倉　未基
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要　約

1989年の新りあす丸さけ・ます調査航海において、バイオテレメトリーによるさけ・ます類追跡実験を行った。水深情報発信器を装着したシロザケ1尾及びギンザケ4尾をそれぞれ約58、21、38、24、133時間追跡し、水平・垂直行動データを収集した。

はじめに

海洋生物の生理生態情報を遠隔的に入手する有効な方法としてバイオテレメトリー手法がある。この手法によるさけ・ます類の遊泳行動研究は、沿岸水域ではスモルト及び回帰親魚を用いて数多く行われているが、沖合水域での実施例は少なかった。本年の新りあす丸のさけ・ます調査航海では水深情報発信器を装着したシロザケ1尾及びギンザケ4尾をのべ約273時間追跡することに成功した。得られたデータは現在整理・分析中であり、ここでは生データを使って調査の概要を紹介する。

調査方法の概要

さけ・ます調査船新りあす丸（471.0t）により、1989年6月12日から7月5日まで北緯43～46度、西経175～177度の北太平洋においてバイオテレメトリーによるさけ・ます類の追跡調査を実施した（図1）。

対象魚種としては、日本沿岸で回帰親魚のバイオテレメトリー実験例の多いシロザケと、全て成熟魚で回帰回遊行動を示すと思われるギンザケを選択した。標識放流用はえなわ操業において漁獲した魚のうち体長50 cm以上の健全な魚を標識放流用とは別の水槽に入れ、揚縄及び標識放流作業が終了するまで蓄養した。

使用した発信器は全て長さ65 mm直径15 mmの円筒形で重量23 g（水中重量11 g）、50 kHzのパルス信号が水深に応じて間隔を変化させながら約5日間発信するものである（Vemco, Ltd., Nova Scotia）。

発信器の装着は外部装着法を用いた。発信器の前後に2本づつ計4本のゴムバンドを巻き付け、それらに絡ませた2本のさけます標識放流用ファスナーによって背鰭前方部に固定した。装着時に尾叉長測定及び採鱗を行った。装着に要する時間は通常の標識放流調査による標識札装着時間を少し上回る1分程度であり、麻酔等は使用しなかった。装着後一旦水槽に戻し、約5分間遊泳させ行動が安定した後放流し、追跡を開始した。

追跡には新りあす丸の右舷側に設置したポールの先端、水面下約3mにそれぞれ俯角10°、45°、80°で装備した3つの指向性水中マイク及び受信機（Vemco, Ltd., Nova Scotia）を用いた。追跡中、3つの水中マイクは魚の遊泳水深にあわせて随時切り替え最良の受信状態が得られるマイクを選択し、ポールの上端のハンドルを回転させ、水中マイクの方向を変化させて魚の方位を確認した。

垂直方向の動きについては、受信機から5秒毎に時間及び遊泳水深のデジタル信号を出力し、船上に設置したパーソナルコンピュータ上のフロッピーディスクに記録した。バイオテレメトリーによる追跡実験では魚の水平位置を追跡中の船の位置で代用するため、なるべく高い精度での船位測定が必要である。新りあす丸は、沖合水域ではNNSS、オメガ及び一部の海域でロランCの利用が可能である。今回は標識放流調査により海域が指定されていたため、ロランCの精度が充分でない海域であったが、NNSS及び5分毎のロランCによって追跡中の船位を記録した。

追跡の前後には、MBTによる250mまでの水温測定、追跡中は適宜XBTによる各層水温の測定を行い、さらに5分毎に船底の電気水温計による水温を記録した。また、1時間毎に天候、風向、風力、気圧及び大気温を記録した。

なお、各追跡実験直前に使用する発信器の水深較正実験を行った。MBTと共に約200、100、50mの各深度まで垂下しMBTの表示する最大水深と発信器情報の最大水深を比較した。また、10m以浅ではロープで0.5、2、5、7、10mに垂下し発信器情報と比較した。

結果の概要

追跡に使用した魚の魚種、尾叉長、年令、追跡開始・終了の時間及び位置を表1に示した。水平移動としてNNSSによる追跡中の船の航跡を図2に示した。水深較正実験によると、今回使用した発信器の水深情報の精度はかなり高いことが確認された。従って詳細な遊泳水深の解析が可能であるが、ここでは、垂直移動として異常値を除く30秒毎の生の水深情報をプロットし図3に示した。

1回目の追跡は、尾叉長631mmのシロザケを用い、6月12日、5：54に45°-33'N, 175°-35'W地点から放流した。魚は最初北東方向へ向かったがその後南下した。追跡開始から約57時間後の6月14日、14：10、イシイルカ型イシイルカ10頭が船につき、その約10分後から水深情報が一定速度で急速に深くなり、発信器の耐圧水深350mを超え580mを示した後発信音が途絶え、追跡を終了した。放流地点から長距離の水平移動は見られなかった。垂直移動については、放流直

後に水深約150 mまで潜行した後は20 mから100 mの間の上下移動を繰り返し、6月12日の日没時に220 mまで潜行し、夜間は150 mまでの潜行を含めて10 m付近から60 m付近を上下移動した。6月13日の日出時からは10～20m付近を遊泳し、12：00頃から少し遊泳水深が深くなり、15：30頃には90 mの潜行が見られた。6月13日の夜間は1度120 mまでの潜行が見られたものの40 m付近を中心に遊泳した。6月14日の日出時頃からは表層から50 m付近までの上下移動を繰り返した。

2回目からは充分な大きさのシロザケが捕獲出来なかったためギンザケを用いた。2回目の追跡は、尾叉長511 mmのギンザケを用い、6月17日、4：28に44°-33'N, 175°-27'Wから放流した。魚は概ね東へ移動したが、天候悪化のために開始から約21時間で追跡を終了した。垂直移動については、放流直後に水深60 m付近までの潜行がみられたが、その後は5～30 m間で頻繁な上下移動をみせた。放流約8時間後の6月17日、12：00頃からは時折30～70 mの潜行をみせながらほぼ10 m付近を遊泳した。

3回目の追跡は、尾叉長571 mmのギンザケを用い、6月23日、5：05に43°-31'N, 175°-27'Wから放流した。魚は最初北東へ、その後6月24日には北へ移動した。追跡開始から約38時間で天候が悪化したため終了した。垂直移動に関しては、放流直後には水深45m付近までの急潜行がみられたが、その後も最大70 mまでの潜行を含めて頻繁に上下移動を繰り返した。6月23日、22：00頃の50 m付近までの潜行以降は上下移動は減少し、6月24日の日出時までは10 m以浅、その後は時折30～50 mの潜行を見せながら10 m付近を遊泳した。

4回目の追跡は、尾叉長537 mmのギンザケを用い、6月26日、4：38に44°-29'N, 176°-28'Wから放流した。魚は概ね東へ移動したが、追跡は悪天候のため24時間で終了した。放流直後に水深20 mまでの潜行を見せた後、7：00、10：00及び22：00頃に連続した上下移動が見られた以外は、6月26日の日中は10 m付近に、夜から翌6月27日の日出後までは5 m付近を遊泳した。

5回目の追跡は、尾叉長560 mmのギンザケを用い6月30日、4：30に45°-35'N, 176°-33'Wから放流した。6月30日には東へ移動し、7月1日には南下、7月2日には南西方向へ移動しその後南下し、全体では放流地点から南へ直線距離で約83 Km移動した。追跡は約133時間で天候悪化のため終了した。放流直後には顕著な急潜行は見られず、6月30日の日没時までの経過では、12：00頃に水深40 mまでの何回かの潜行があったものの、表層から20 m付近までの頻繁な上下移動を繰り返した。6月30日の夜間には時折30 m付近まで潜行しながらも多くの時間は表層を遊泳した。7月1日、6：00頃から30 m付近まで潜行しそのまま留まることが多くなった。翌7月2日の日出時前からは、時折30～50 m付近まで潜行するものの10 m以浅を遊泳することが多かった。この後7月2日、15：00頃から7月5日、3：00頃までの約60時間は、途中7月4日の昼間にかなりの時間50 m付近まで潜行したものの、ほとんど水面付近を遊泳していた。その後は時折30 m付近まで潜行しながら5 m付近を遊泳した。

おわりに

以上、沖合水域におけるさけ・ます類のバイオテレメトリー調査により魚種による遊泳行動の差異が示唆された。今後データを細かく分析することによって、沖合生活期のさけ・ます類の水平・垂直遊泳行動を明らかにできると考えている。さらにこの種のデータを蓄積することにより、時間帯、魚種間及び生活段階での遊泳行動の差異、漁具に対する行動シミュレーション及び回遊メカニズム等の解明に有用な知見が得られる事が期待される。

謝　辞

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Table 1. Species, fork length, and age of 5 salmon tracked in 1989 and date & time (J.S.T.) and position at the start and end of tracking.

Tracking No.	Species	F.L. (mm)	Age	Tracking			
				Date & Time		Position	
				Start	End	Start	End
1	Chum	631	0.4	June 12, 05:54	June 14, 14:40	45°-33'N,175°-35'W	45°-31'N,175°-30'W
2	Coho	511	1.1	June 17, 04:28	June 18, 01:17	44°-33'N,175°-27'W	44°-32'N,175°-14'W
3	Coho	571	1.1	June 23, 05:05	June 24, 18:50	43°-31'N,175°-27'W	43°-50'N,175°-12'W
4	Coho	537	1.1	June 26, 04:38	June 27, 05:00	44°-29'N,176°-28'W	44°-29'N,176°-21'W
5	Coho	560	2.1	June 30, 04:30	July 5, 18:00	45°-35'N,176°-33'W	44°-51'N,176°-38'W

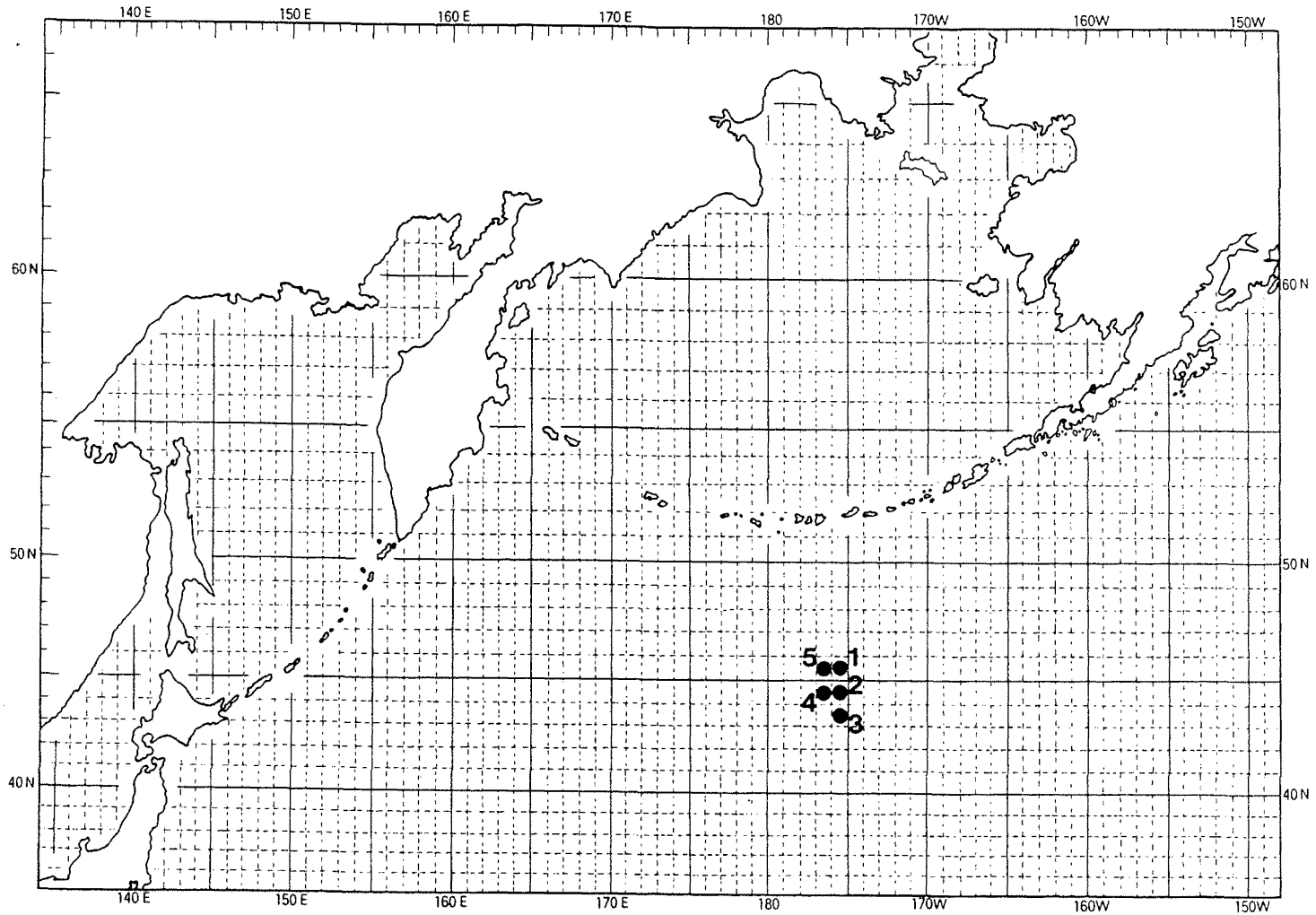
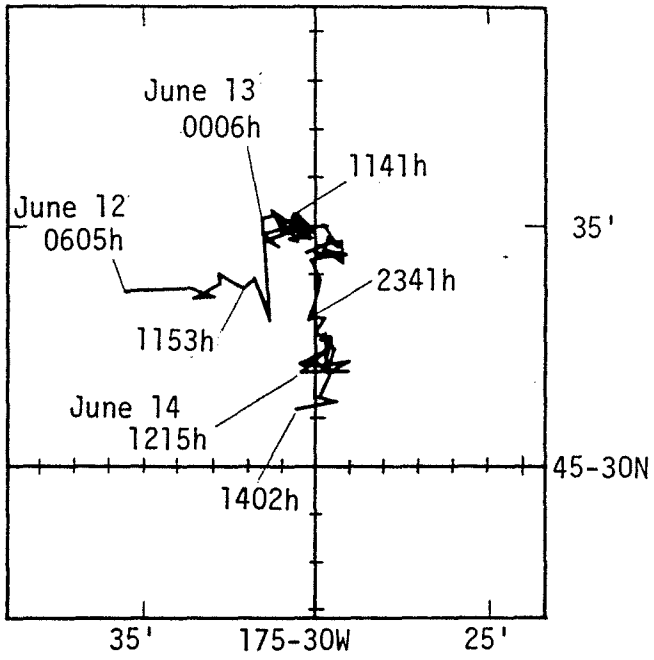
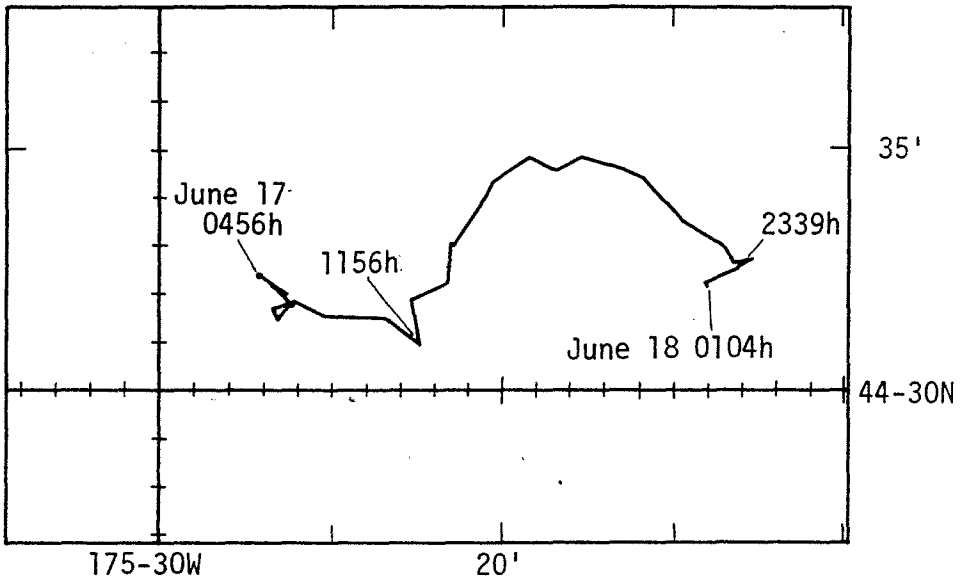


Fig 1. Circle and number attached show position and number of tracking.

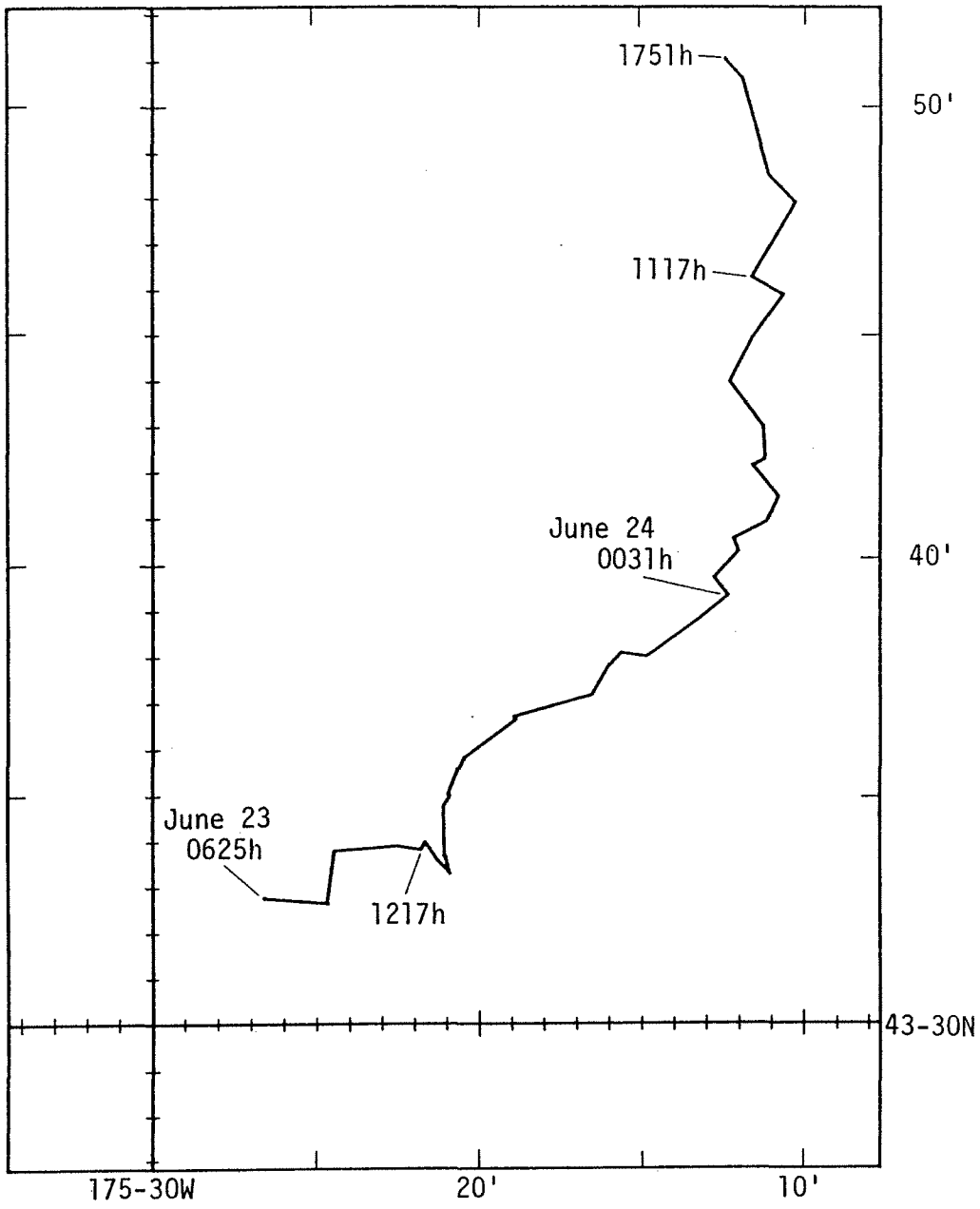
Fig 2. Tracks of R/V Shin-Riasu maru by NNSS during tracking of salmon fitted with transmitter.



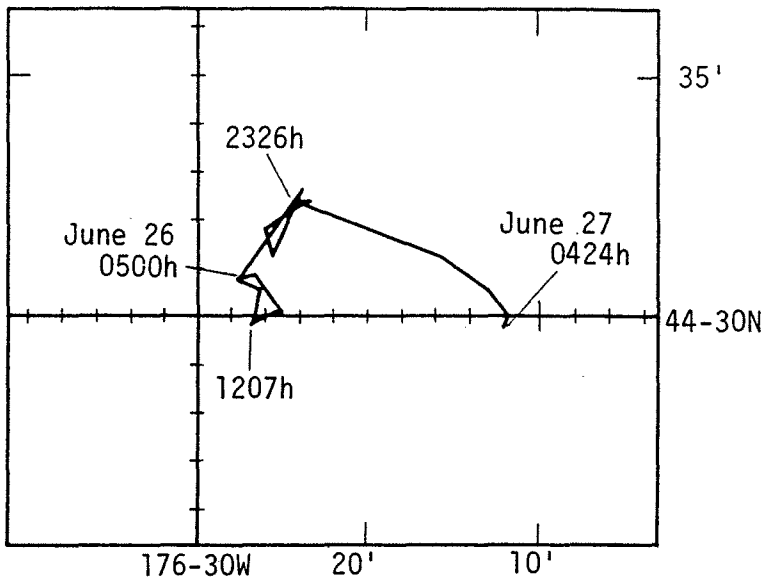
2-1 Chum salmon (Tracking No. 1)



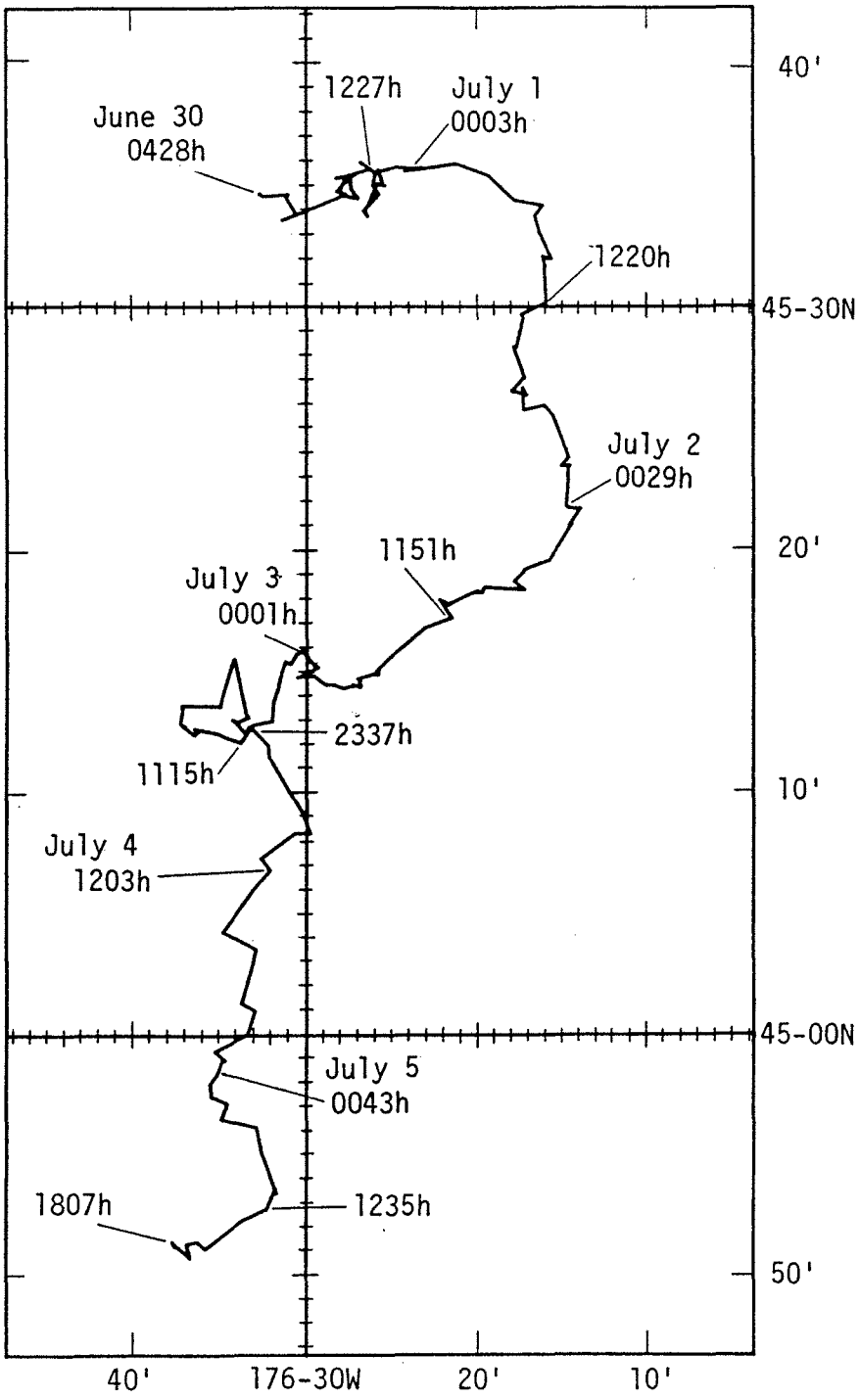
2-2 Coho salmon (Tracking No. 2)



2-3 Coho salmon (Tracking No. 3)

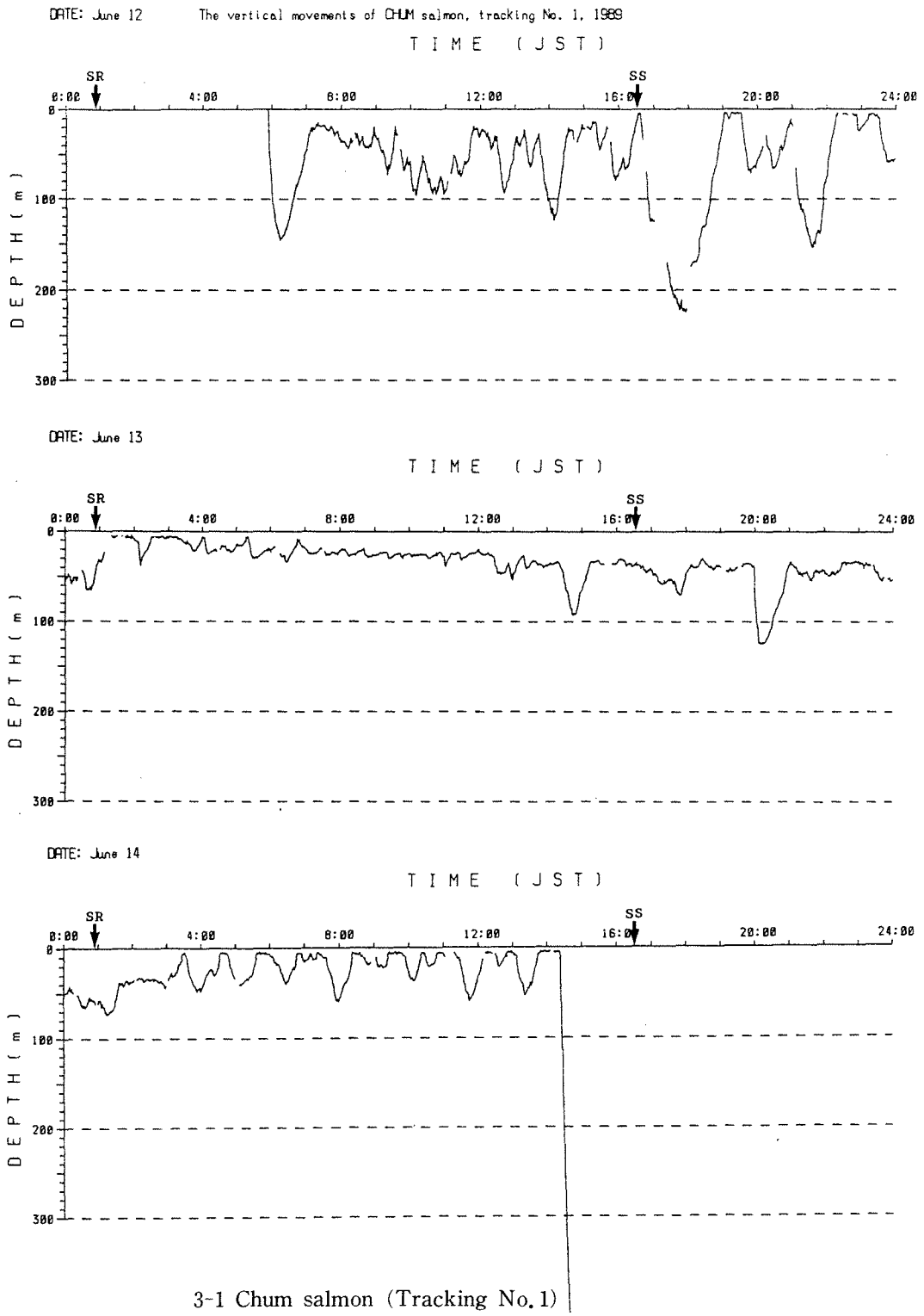


2-4 Coho salmon (Tracking No. 4)

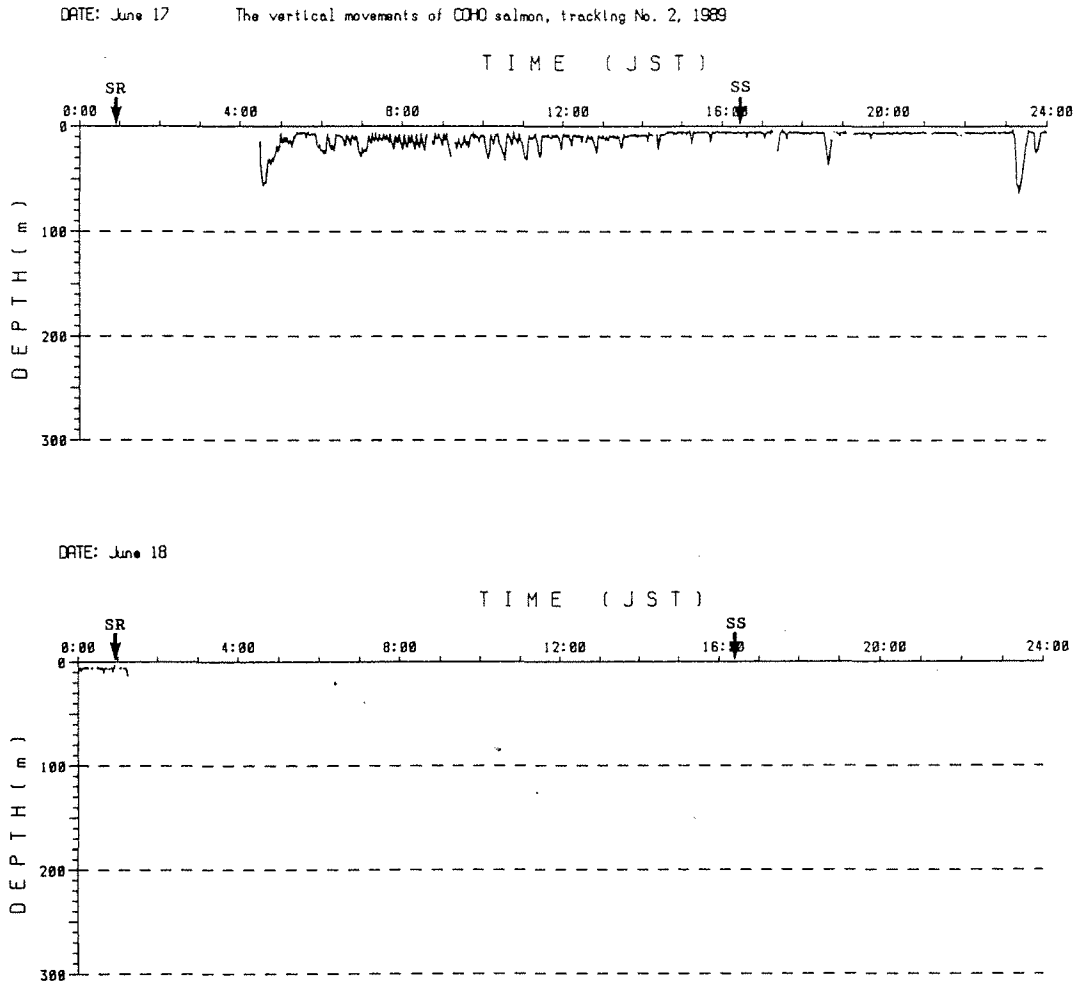


2-5 Coho salmon (Tracking No. 5)

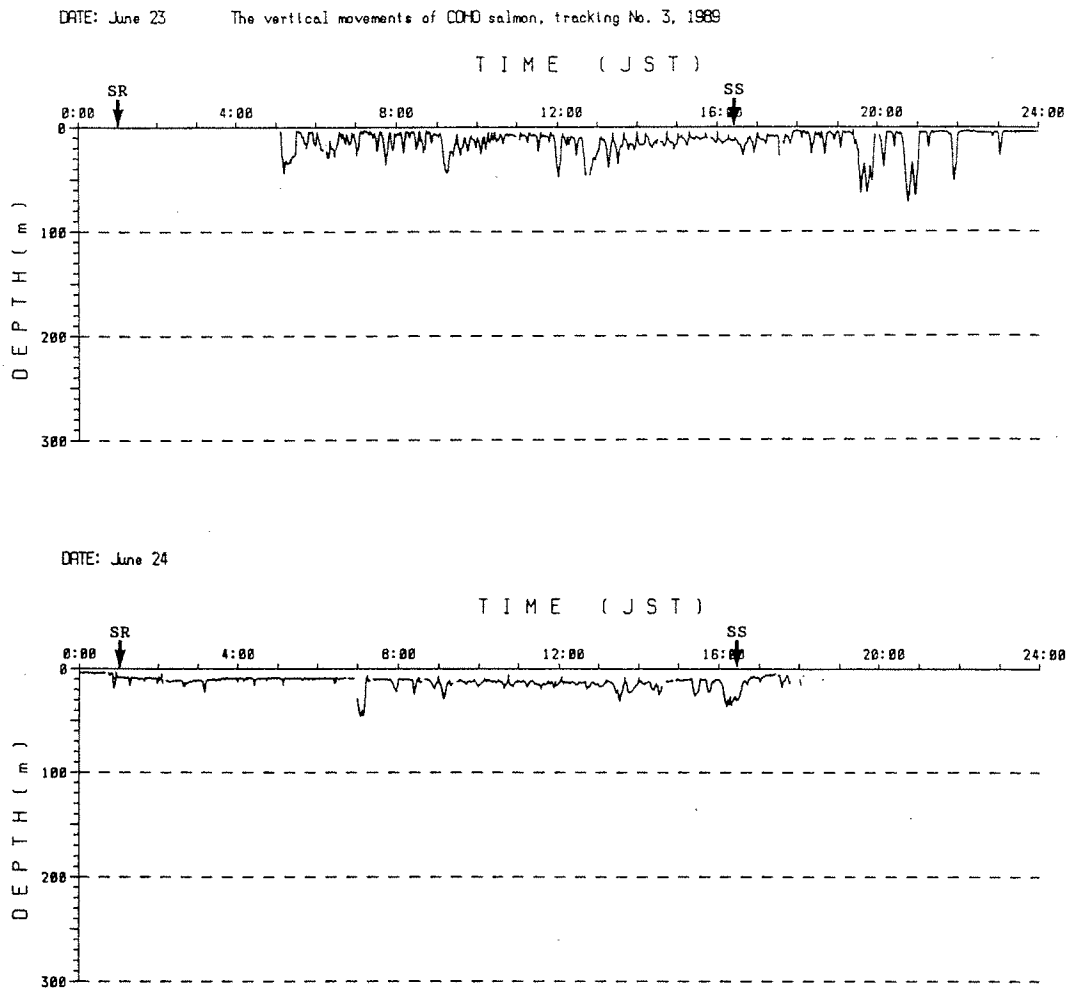
Fig. 3 The vertical movements of salmon tracked. SR and SS indicate sunrise and sunset time, respectively.



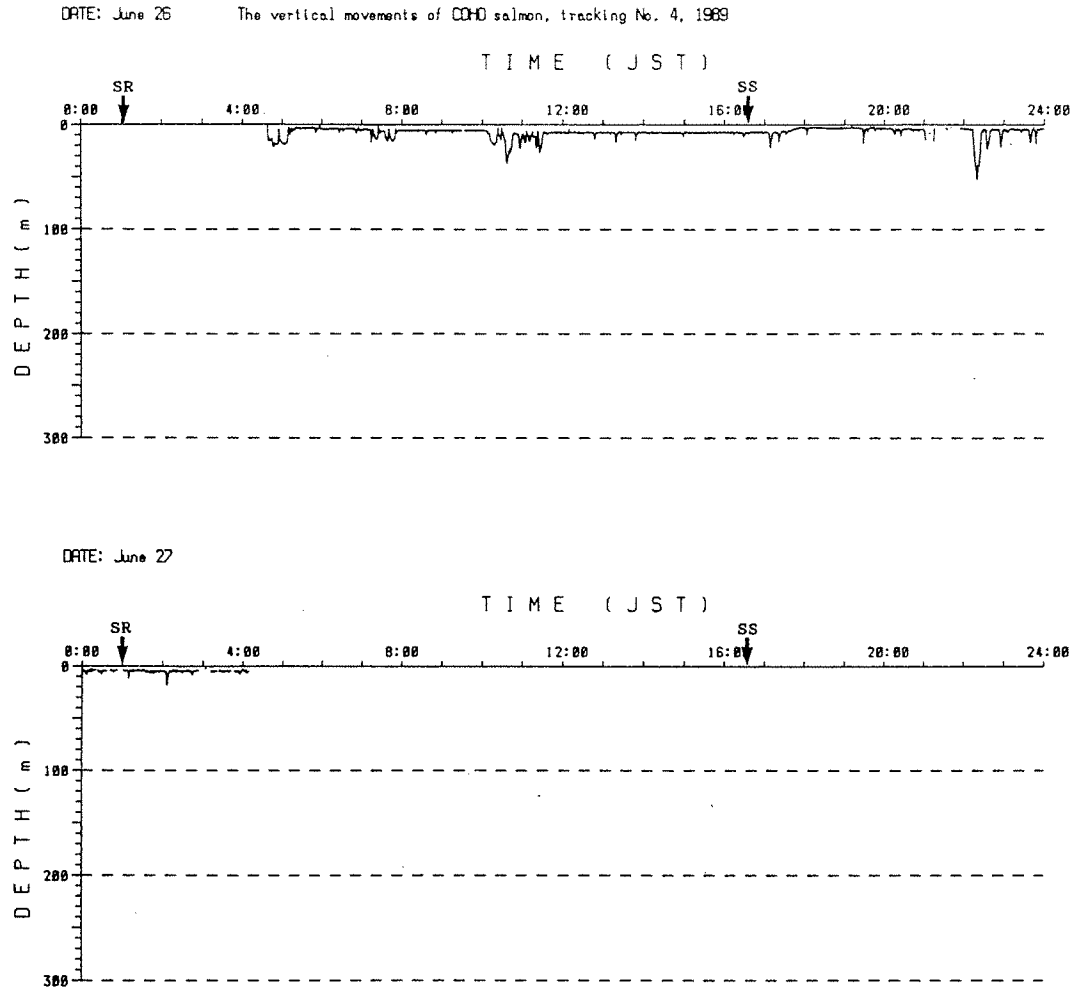
3-1 Chum salmon (Tracking No. 1)



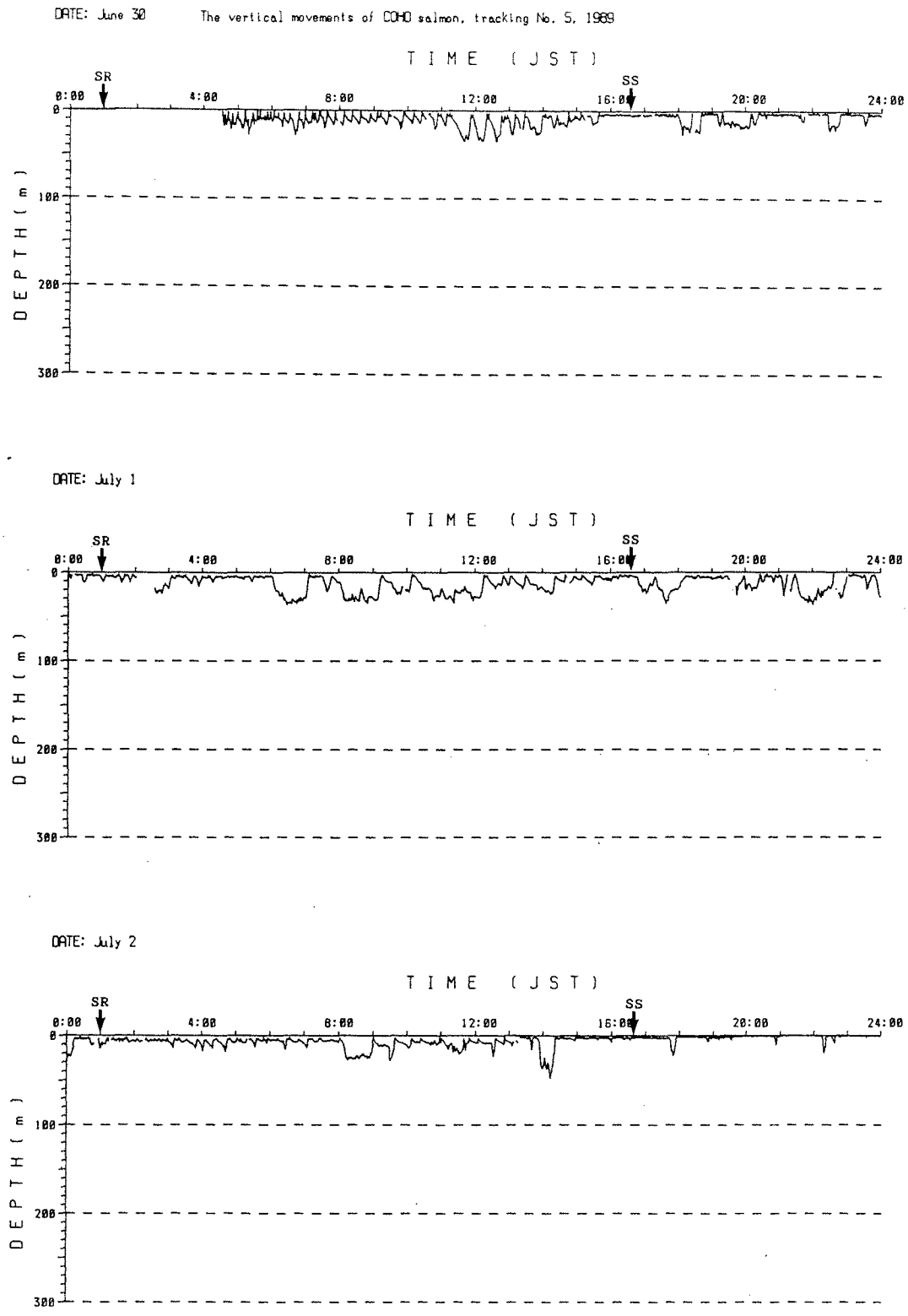
3-2 Coho salmon (Tracking No. 2)



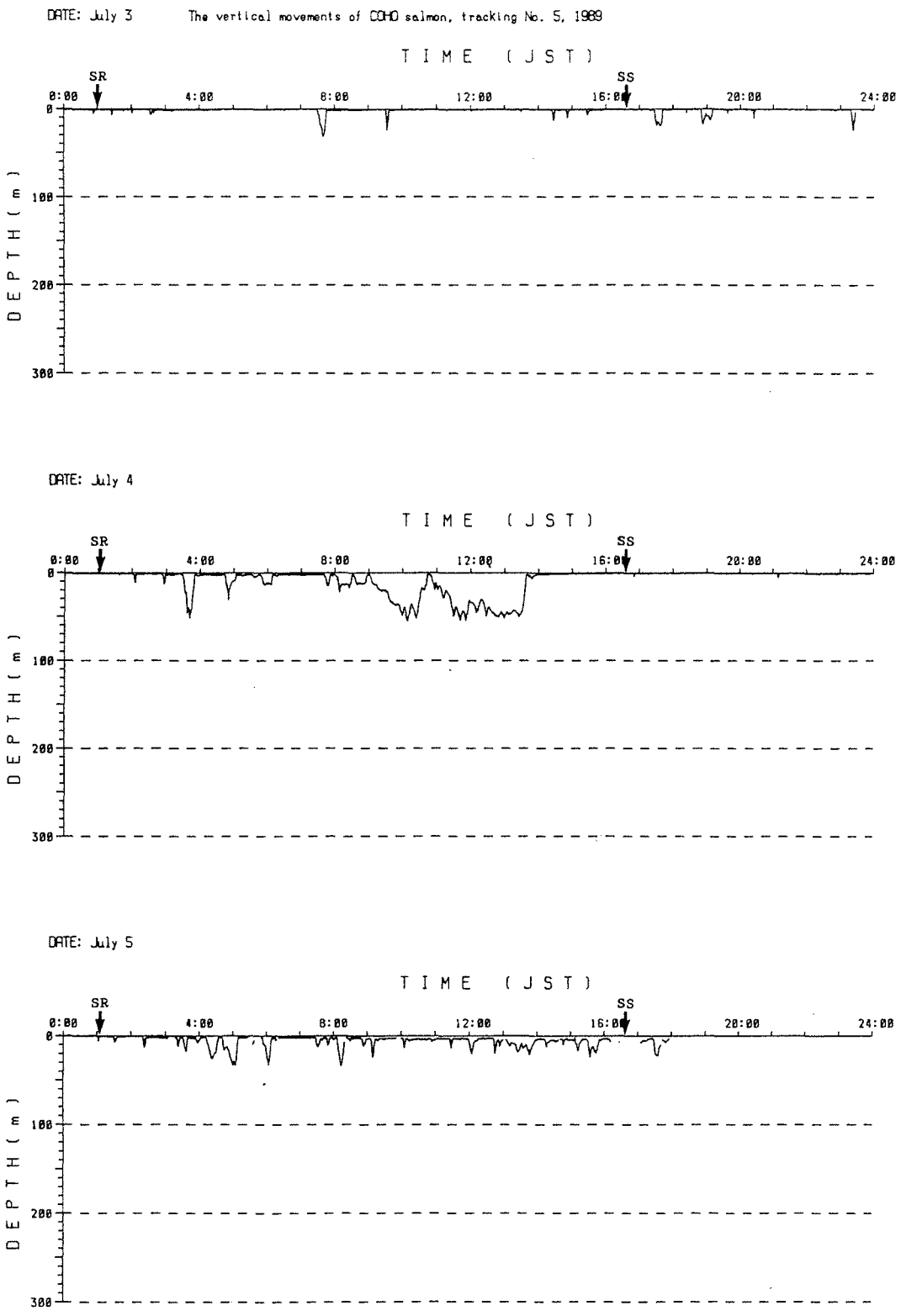
3-3 Coho salmon (Tracking No. 3)



3-4 Coho salmon (Tracking No. 4)



3-5-1 Coho salmon (Tracking No.5), 30 June, 1 July, 2 July



3-5-2 Coho salmon (Tracking No.5), 3 July, 4 July, 5 July

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Miki Ogura
Far Seas Fisheries Research Laboratory

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Fisheries Agency of Japan

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Outline of biotelemetry study for salmon by Shin Riasu maru, 1989

Miki Ogura
Far Seas Fisheries Research Laboratory

ABSTRACT

The survey of tracking salmon using biotelemetry was conducted on board Shin Riasu maru as a part of its 1989 salmon research cruise. A depth information transmitter was attached to one chum and 4 coho salmon and the fish were tracked for about 58, 21, 38 and 133 hours respectively and data on horizontal and vertical behavior were collected.

Introduction

One effective method to obtain remote information on physiology and ecology of marine life is biotelemetry. The study on swimming behavior of salmon with this method has been common in coastal areas using smolts and returned spawners, however, the use of this method is rare in the offshore waters. The author succeeded in tracking one chum and 4 coho salmons, to which depth information transmitters were attached, for a total of some 273 hours on board the salmon research cruise of Shin Riasu maru in 1989. Data obtained are now being tabulated and analyzed. This report presents an outline of the survey using new data.

Outline of survey method

The tracking survey using biotelemetry was conducted on board the salmon research cruise of Shin Riasu maru (471.0 GT) from June 12 to July 5, 1989 in the area of 43°-46°N and 175°W-177°W of the North Pacific (Fig. 1).

Chum and coho salmon were selected as target species because many biotelemetry experiments have been conducted on returned chum salmon in the Japanese coastal areas and because all coho salmon may return as mature fish and may show their migrating behavior. Viable fish of more than 50 cm in fork lenght caught by longline operation for tagging were separated from fish for tagging and stored in another tank until longline hauling and tagging were completed.

All transmitters used were cylindrical in shape, 65 mm in length and 15 mm in diameter, and each weighed was 23 g (underwater weight: 11 g). It changed pulse intervals according to water depth and transmitted 50 kHz pulse for 5 days (Vemco, Ltd., Nova Scotia).

An external attachment method was used for the attachment of the transmitters. A total of 4 rubber bands, 2 in front and 2 in the back were fastened around the transmitter and two fasteners for salmon tagging were attached to them. Then the transmitter was fixed in front of the dorsal fin with two fasteners. Fork length was measured and scales were sampled at the time of attachment. Time needed for the attachment was about one minute, which was a little longer than that needed for a tag attachment in the normal tagging research, and no anesthesia was used. After the attachment, the fish was returned to the tank and kept for about 5 minutes to stabilize its behaviour, and then it was released and the tracking survey was started.

The tracking survey was conducted with three directional hydrophones at the top of a pole, which was equipped on the starboard of the Shin Riasu maru and submerged 3 m under the surface, with 10°, 45° and 80° of depression respectively and with a receiver (Vemco, Ltd., Nova Scotia). During the tracking, three hydrophones were switched periodically in accordance with the swimming depth of the fish and the microphone of the best receiving condition was selected. Direction of the fish was confirmed with changing the direction of hydrophone by turning a handle at the upper end of the pole.

Regarding vertical movement of fish, the output of a digital signal on time and swimming depth was at 5 second intervals from the receiver and was recorded on a diskette of a personal computer on board the vessel. An accurate determination of the vessel location is required for the tracking survey using biotelemetry because the location of the vessel tracking the fish is regarded as the horizontal location of the fish. The Shin Riasu maru can use NNSS, Omega and, in certain areas, Loran C in offshore waters. The accuracy of Loran C in this survey was not sufficient because the survey area was previously determined in accordance with the tagging research program, however the vessel locations while tracking the fish were recorded by NNSS and Loran C at 5 minutes intervals.

Water temperature measurements up to 250 m in depth were conducted by MBT before and after tracking the fish. While tracking a fish, XBTs were used properly for the measurement of water temperature of each depth layer, and in addition to XBT, water temperature was also recorded at 5 minutes intervals by electric thermometer for water temperature attached to the bottom of the vessel. Weather, wind direction, wind force, atmospheric pressure and air temperature were also recorded at one hour intervals.

The depth calibration test of a transmitter which would be used was conducted immediately before the beginning of the tracking survey. The transmitter hung down to the depth of 200, 100 and 50 m with a MBT and the deepest depth shown by the MBT and that obtained by the transmitter was compared. In addition, when the depth was less than 10 m, the transmitter hung down to the depth of 0.5, 2, 5, 7, 10 m with rope and compared the depth information obtained by the transmitter with the actual depth.

Outline of results

Table 1 shows species, fork length and age of fish used for the tracking survey, and time and location of beginning and ending of trackings. Tracklines during tracking fish obtained by NNSS are shown in Fig. 2 to illustrate the horizontal movement of fish. The result of depth calibration test showed that the accuracy of depth information obtained from the transmitter was very high. Therefore the detailed analysis of swimming depth is possible, and the raw data at a depth at 30 seconds intervals are plotted in Fig. 3, however, some extraordinary values are excluded.

A chum salmon of 631 mm in fork length was used for the first tracking survey and released at 5:54 on June 12 at the location of 45°33'N, 175°35'W. The fish swam first to the northeast and then turned toward the south. AT 14:10 on June 14, 57 hours after the beginning of the tracking, 10 dalli type Doll's porpoises were attracted by the vessel, and after 10 minutes of that incidence, depth information obtained became deeper rapidly at a constant speed and exceeded 350 m, the submersible limit of the transmitter, and after 580 m was obtained, pulse transmission was stopped and then the survey was finished. For the vertical movement, fish swam down to 150 m in depth immediately after the release and then repeated the up and down movement between 20 m to 100 m. At the time of sunset on June 12, it swam down to 220 m and during nighttime it repeated the up and down movement between some

10 m to 60 m including swimming down to 150 m. After the sunrise of June 13, it swam around 10-20 m, the swimming depth became slightly deeper at around 12:00 and a swimming down to 90 m was observed at around 15:30. During nighttime of June 13, the fish swam down to 120 m but mainly swam around 40 m. Around and after the sunrise of June 14, it repeated the up and down movement between the surface and 50 m.

After the second survey coho salmon were used because chum salmon of large size could not be captured. A coho salmon of 511 mm in fork length was used for the second survey and released at 4:28 on June 17 at the location of 44°33'N and 175°27'W. The fish generally moved toward the east, however the tracking survey was stopped after 21 hours of starting the tracking because of foul weather. For the vertical movement, a swimming down to 60 m was observed immediately after the release. Then the fish moved frequently up and down between 5 m and 30 m. At around 12:00 on June 17, 8 hours after the release, the fish swam around 10 m and sometimes swam down to 30-70 m.

A coho salmon of 571 mm in fork length was used for the third tracking survey and released at 5:05 on June 23 at the location of 43°31'N and 175°27'W. The fish first moved to northeast and then moved northward on June 24. The survey was stopped after 38 hours of starting the tracking because of foul weather. For the vertical movement, a rapid swimming down to 45 m was observed immediately after the release. Then the fish repeated up and down movement frequently including a swimming down to the deepest depth of 70 m. At around 22:00 on June 23, it swam down to 50 m and since then the up and down movement was decreased, and by the sunrise of June 24, it swam shallower than 10 m and then it swam around 10 m and sometimes swam down to 30-50 m.

A coho salmon of 537 mm in fork length was used for the fourth survey and released at 4:38 on June 26 at the location of 44°29'N and 176°28'W. The fish generally moved toward the east, however the tracking survey was stopped after 24 hours of starting the tracking because of foul weather. The fish swam down to 20 m immediately after the release and then it swam around 10 m during daytime of June 26 and swam around 5 m from the night to after the sunrise on June 27 except for the cases it moved up and down continuously at around 7:00, 10:00 and 22:00.

A coho salmon of 560 mm in fork length was used for the fifth survey and released at 4:30 on June 30 at the location of 45°35'N and 176°33'W. The fish moved to the east on June 30, to the south on July 1, and to the southwest and then to the south on July 2, and it moved a total distance of about 83 km in a straight line from the point of release to the south. The chase was stopped after 133 hours because of foul weather. Remarkable rapid swimming down was not observed immediately after the release, and it repeated up and down movement frequently between the surface and around 20 m by sunset on June 30 although some swimming down to 40 m was observed at around 12:00. During nighttime of June 30, the fish swam mostly in the surface layer and sometimes swam down to around 30 m. On July 1, the fish swam down to 30 m at around 6:00 and after that it tended to stay at that depth layer. Before sunrise on July 2, the fish tended to swim in the layer of less than 10 m although it sometimes swam down to 30-50 m. During a total of 60 hours from 15:00 of July 2 to 3:00 of July 5, the fish swam mostly near the surface with

an exception that it swam down to 50 m for a fairly long time in the daytime of July 4. After that the fish swam around 5 m and sometimes swam down to 30 m.

Conclusion

As mentioned above, the biotelemetry survey on offshore salmon suggested that there were differences in swimming behaviour by species. The author believes that the horizontal and vertical swimming behaviour of salmon during offshore stage may be determined by analyzing the data in detail in the future. The accumulation of this kind of data is expected to provide useful information for the determination of differences of swimming behavior by time of day, by species and by life stage, for the simulation of fish behavior to nets and for the determination of migration mechanism etc.

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Figs. 1 to 3 are in English in the Japanese document.