New Information from Archival Tags from Bering Sea Tagging, 1998–2004

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Scientists of North Pacific Anadromous Fish Commission nations have cooperated in the deployment of archival data storage tags (DSTs) on salmon in high seas waters since 1994 (Wada and Ueno 1999; Walker et al. 2000a, b; Friedland et al. 2001; Ishida et al. 2001; Tanaka 2003; Tanaka et al. 2005). We report results from archival tagging research under U.S. and North Pacific Research Board (NPRB) programs. Since 1998, 791 salmon have been tagged with DSTs in the Bering Sea, North Pacific Ocean, and Gulf of Alaska (Table 1, Fig. 1). Of these, 72 were recovered and returned, a 9.1% return rate. Funding from NPRB has allowed a larger number of DSTs to be placed on salmon in 2003 and 2004. The return rate has declined in recent years, as more immature fish were tagged. (Immature fish remain at sea at least one additional year and historically have had a much lower chance of being recaptured.) The tags were released during 17 cruises of one U.S. and three Japanese research vessels (Fig. 1). The highest number of tags was placed on chum salmon, which reflects the research priorities, areas, and times of the tagging vessels (Table 2). Forty-one tags were recovered from fish tagged in the Bering Sea, and five tags were recovered in Bering Sea waters from fish tagged in the North Pacific and Gulf of Alaska (Fig. 2). All but three of the recoveries have come from maturing fish that were at large for periods of one day to three months. Because most of the data are from a relatively short period in summer and fall at the end of the ocean phase for maturing salmon, the following observations may apply to only this life history period.

Fig. 1. Areas of U.S. and NPRB-funded high seas salmon tagging, 1998–2004.

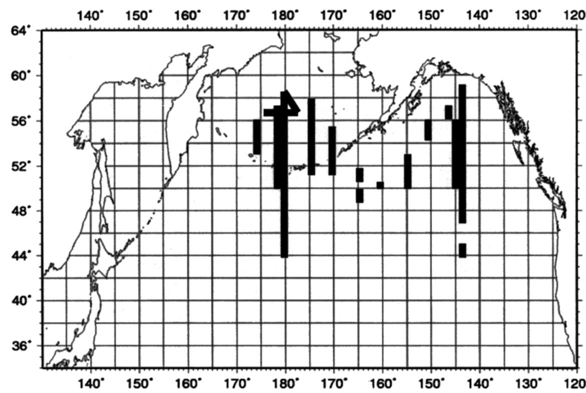

Table 1. Number of U.S. and NPRB-funded data storage tags that were released and recovered and recovery rates, 1998–2004.

Year	Tags Released	Tags Recovered	Recovery Rate
1998	55	8	14.5
1999	89	17	19.1
2000	31	5	16.1
2001	70	2	2.9
2002	73	5	6.8
2003	167	12	7.2
2004	306	23	7.5
Total	791	72	9.1

Table 2. Number of U.S. and NPRB-funded data storage tags released and recovered by species, 1998–2004.

	Sockeye	Chum	Pink	Coho	Chinook	Steelhead
No. Tagged	173	316	130	67	86	19
No. Recovered	17	32	8	11	3	1
Recovery rate	9.8	10.1	6.2	16.4	3.5	5.3

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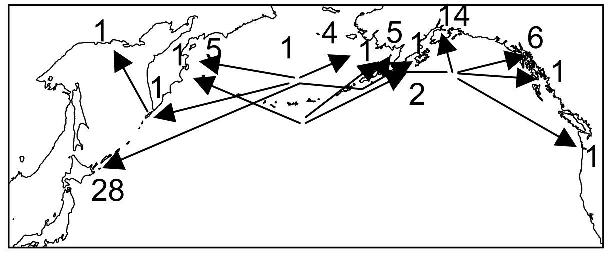
Data from recovered tags have yielded basic information about salmon behavior and migration (Fig. 3; Walker et al. 2000b). Salmon appear to undergo a period of recuperation from the trauma of tagging, when the fish remain at the surface. This period can be brief (on the order of days or hours) or more lengthy (greater than one week). Most fish exhibit a diurnal behavior pattern for some or all of the time they are at liberty. Typically fish remain at or near the surface at night and move vertically in the water column during the day. Most fish return to the surface on these vertical excursions, but individuals of some species may remain below the surface throughout the day. The migration of fish through different water masses can be discerned from changes in surface temperatures and differences in daily temperature ranges. Temperature ranges may vary widely between water masses, while maximum swimming depths remain fairly constant. This indicates differences in thermal stratification and mixing between water masses, and also indicates that during this period fish are choosing maximum depths and not temperature ranges.

Fig. 2. General areas and numbers of recoveries of U.S. and NPRB-funded salmon data storage tags.



Maturing chum salmon generally swim at maximum depths between 50 and 100 m below the surface, but can swim at depths over 300 m as they approach coastal areas. These extensive vertical movements may be thermoregulatory to avoid high surface temperatures. Diurnal behavior patterns are well-pronounced. Recoveries of Japanese and Sakhalin chum salmon indicate the fish migrate through an area of cold water with surface temperatures of 4°C or less on their return (Fig. 3). This area is likely in the Kuril Islands.

Maturing pink salmon also have strong diurnal behavior patterns, but may remain below the surface at depths of 40–60 m throughout the day. Maturing sockeye salmon generally swim at shallower maximum depths, between 20 and 30 m. They encounter small temperature ranges, because surface waters are usually well-mixed to these depths. Diurnal behavior patterns are not as strongly expressed as in chum and pink salmon. Maturing coho salmon have more variable diurnal behavior. In some fish, it is strongly expressed, while it is weaker in others. This difference may relate to stage and location of returning migration. Like pink salmon, coho salmon sometimes remain below the surface throughout the day, but they may remain there for more than a day. The maximum swimming depths of coho salmon are slightly deeper than those of pink salmon.

We have depth data from only one chinook salmon, but the pattern it displays is remarkable (Fig. 4). This fish was tagged in July 2002 in the Bering Sea and recovered in the Yukon River in June 2004. In spring and early summer the fish swam at depths over 350 m below the surface, the maximum depth the tag could record. During the first winter recorded on the tag, the fish remained at approximately 125 m for three months, where the temperature was a fairly uniform 4°C. During the second winter, the fish remained at or near the surface, while the temperature declined from 4°C to 1°C. The salmon exhibited differing diurnal behavior patterns at different times during the two years.

Fig. 3. Information about salmon behavior obtained from high seas salmon data storage tags. Chum salmon tagged in the Bering Sea (July 9, 2002) and recovered on the Nemuro coast of Hokkaido, Japan (September 24, 2002).

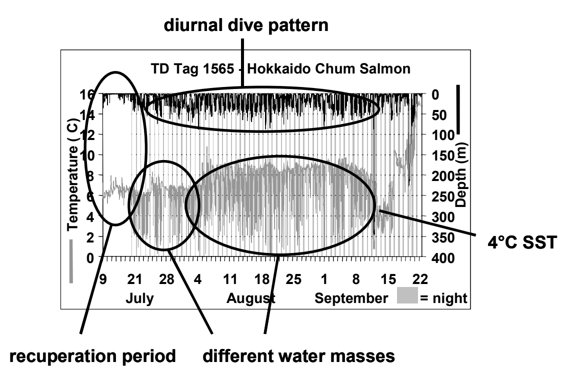
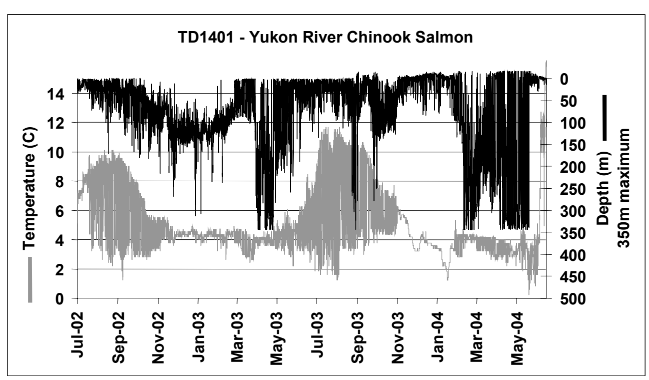


Fig. 4. Temperature and depth data record of a chinook salmon tagged in the Bering Sea July 2, 2002 and recovered in the Yukon River June 16, 2004.



Differences between species are summarized in Table 3. These differences are based on observations from a relatively small number of tag recoveries (n = 3 to 15) and all come from the last part of the ocean life of maturing fish, except for one chinook salmon.

Future research with DSTs should include more tagging of immature salmon to discover how behavior changes at different life history periods. Tagging in fall may increase chances of recovery of immature fish. Tagging in spring should provide access to maturing stocks that return earlier than stocks tagged during previous cruises. Geographic locations of salmon as estimated from tags which record and interpret light data could provide useful general information on distribution and migration routes.

Table 3. Summary of salmon swimming depth below the surface and behavior obtained from data on archival tags.

Species	'Usual' Depth (m)	Max Depth (m)	Diurnal Pattern	N
Sockeye	20–30	30–85	weak to moderate	15
Pink	40–60	60–85	strong	6
Coho	30–70	80–120	weak to strong	11
Chum	60–70	100–345	strong	15
Chinook	variable	350+	variable	1
Steelhead	no data	no data	strong	1

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