Adult Chinook Salmon Behavior and Survival after Catch and Release from Purse-Seine Vessels in Johnstone Strait, British Columbia

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Abstract.—In British Columbia, chinook salmon Oncorhynchus tshawytscha are commonly taken in purse-seine fisheries directed at other salmon species, but the need to conserve chinook salmon may reduce the opportunities for such fisheries to operate. To test the feasibility of a nonretention fishery (i.e., release) for chinook salmon, we used ultrasonic telemetry to estimate the survival rates of chinook salmon caught and released from purse-seine vessels in Johnstone Strait, British Columbia. From 1990 to 1992, we tracked 47 fish for durations ranging from 2 h 1 min to 32 h 48 min (mean, 16 h 48 min). For the first 24 h after release, the survival rate for all years combined was estimated to be 77% with 95% binomial confidence limits of 62% and 87%. Mortality was positively associated with longer landing time. Chinook salmon that survived spent between 57–64% of the next 24 h at depths less than 50 m where they were vulnerable to recapture by commercial purse-seine gear.

The overlapping feeding distributions and migration routes of Pacific salmon Oncorhynchus spp. often result in multispecies fisheries. The species commonly differ in abundance or productivity, hence conservation of the weaker species may constrain fishing the stronger species to below its maximum yield. Among the more abundant and productive stock complexes in British Columbia is the Fraser River sockeye salmon O. nerka. Between 1988 and 1991, these populations averaged 14.1 million adults (PSC 1994).

Sockeye salmon return to the Fraser River by migrating either through Johnstone Strait or along the west coast of Vancouver Island and through the Strait of Juan de Fuca (Verhoeven and Davidoff 1962). In Johnstone Strait and the Strait of Juan de Fuca they are subject to gill-net and purse-seine fisheries. These fisheries also catch pink O. gorbuscha and chum O. keta salmon, but bycatch is minimized by the tendency of the pink and especially chum salmon to migrate later than sockeye salmon (Verhoeven and Davidoff 1962; Hourston et al. 1965; Anderson and Beacham 1983). However, significant numbers of chinook salmon O. tshawytscha have been taken in the seine fisheries. Commercial sales records indicated that from 1980 to 1994, between 17,000 and 80,000 chinook salmon were caught annually in southern British Columbia seine fisheries (Wong 1983; Department of Fisheries and Oceans, unpublished data). One management option to increase the catch of sockeye salmon without overfishing chinook salmon is to live-release the chinook salmon caught in the seine nets. However, the survival of chinook salmon caught and released from seiners is uncertain.

On the basis of external tagging studies, Cole (1975) estimated 50–100% mortality of sublegal (<66 cm) chinook salmon caught by purse seines in Puget Sound. To assess mortality of chinook salmon releases from purse seines in the southeast Alaska fishery, Van Alen and Seibel (1986, 1987) assigned an injury category to the fish before tagging and release. They estimated the overall mortality of released chinook salmon to be between 27 and 47% (1986) and between 68 and 75% (1987) for fish greater than 53 cm, but conceded that there was no way of determining if mortality had occurred at the rates projected after the fish were released. In subsequent years of this study, a 70% mortality estimate was applied to all fish released alive (Rowse and Marshall 1989; Rowse 1990). From the limited available data, the Chi-
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FIGURE 1.—Map of Vancouver Island, British Columbia, showing the study area in Johnstone Strait where the chinook salmon were tracked.

To improve estimates of the proportion of released chinook salmon that survive, we used ultrasonic transmitters to track fish after capture and release from commercial seine vessels. We tested the hypotheses that fish size, landing procedure, landing time, tagging time, catch size, and degree of external injury influenced chinook salmon survival, inferred from vertical and horizontal movements of the fish. Few studies have used telemetry to estimate salmonid survival after release from fishing gear (Bendock and Alexandersdottir 1993). By using telemetry, we avoided the potential additive stress of the artificial conditions of holding experiments which may bias mortality estimates (Wright 1970) and the confounding effect of tag loss or nonreturn inherent in external tag-and-release studies. In addition, we obtained information on chinook salmon movements after release that was important for determining the potential for recapture following release.

Methods

Capture, tagging, and tracking.—The purse-seine fishery for sockeye salmon in Johnstone Strait operates from mid to late summer (Figure 1). Chinook salmon were obtained for tracking from commercial seine vessels during the fishery, from Department of Fisheries and Oceans (DFO) test fishing operations, and from vessels chartered specifically to catch chinook salmon. The number of salmon and species composition in the sets from which we used chinook salmon were estimated by DFO observers in 1990 (Nagtegaal and Riddell 1994) and by us in 1991 and 1992. The DFO Fisheries Branch provided catch sizes and species composition from test fishing sets.

We recorded landing procedure, catch size, and species composition for each set from which a chinook salmon was taken for tracking. Two types of landing procedures were evaluated: “stern,” in which chinook salmon were taken from the deck after the catch was pulled over the stern of the vessel (typical of smaller commercial sets), and “side,” in which fish were dipnetted from the seine net when it was held alongside the vessel once a majority of the catch had been released over the corkline (test fishing sets) or brailed aboard (large commercial sets). From stern-landed sets, we selected a chinook salmon that was large enough to carry a transmitter (>50 cm). From side-landed sets, we dipnetted a chinook salmon using a knotless soft mesh bag to minimize descaling. We did not attempt to recover chinook salmon from the hold once they had been brailed aboard. Landing time was defined as the interval from the commencement of net retrieval to the moment when the chinook salmon was dipnetted from the pursed net or landed on the deck of the vessel. We measured fork length, took scales for age determination, and assessed degree of capture-induced injury. Injury was categorized as minimal (0–5% scale loss and no injury), slight (5–25% scale loss, minor injury such as abrasions, fin damage, net marks, or both), or substantial (>25% scale loss, major injury such as slashes through the flesh and bleeding from gills, or both). A pressure-sensitive ultrasonic transmitter (74 mm long, 16 mm diameter, weighing 13 g; Vemco Ltd.) then was inserted through the mouth into the stomach with a 1.3 × 30-cm dowel. Tagging time was defined as the end of the landing time to when the fish was released. Except for the potential of tag regurgitation, insertion of the transmitter into the stomach appears to be the best method of tag attachment, with minimum effect on swimming performance and behavior (Mellas and Haynes 1985). A uniquely numbered Floy spaghetti tag was tied posterior to the dorsal fin to identify the fish and enable transmitter recovery if the fish was recaptured.

We tried to minimize additional handling stress associated with tagging which would not occur if the fish were simply released. The first two fish (9001, 9002) were anesthetized with MS-222 (tricaine methanesulfonate) before tagging and then
allowed 10–20 min to recover before being released. We then discovered that chinook salmon could be successfully tagged without use of anesthetic, thus eliminating the recovery period and reducing handling time. For the first year (1990), chinook salmon taken from capture vessels were transported by rigid-hull inflatable boats to a holding tank on the tracking vessel where each fish was measured and tagged. In subsequent years, we further reduced handling by tagging and releasing fish directly from the inflatable boats.

In most cases, chinook salmon were released in the vicinity of the capture site. We followed the tagged fish up to a maximum range of 400 to 500 m with a directional hydrophone and Vemco VR-60 receiver-decoder. The extent of horizontal sea surface area where transmitter signals could be received aboard the tracking vessel was inversely proportional to transmitter frequency, ocean current velocity, and sea state. The ultrasonic tags had a maximum life expectancy of 3 d and transmitted at a pulse rate proportional to depth at a fixed frequency of 50–76.8 kHz. After the first year, the transmitters with 50-kHz frequency were avoided because of signal interference with depth sounders on the tracking vessel and other vessels in the vicinity. Transmitters were calibrated to ±1 m for transmitters with 0–100-m depth range (1990) and ±2 m for transmitters with 0–200-m depth range (1991, 1992). To ensure the accuracy of over-range data, we had a transmitter pressure-tested. It showed a linear response between pressure and pulse frequency to 100% over full scale. Time and depth readings were recorded at approximately 1-s intervals by a microcomputer or logged internally by the receiver-decoder. Vessel position was determined by locally corrected Loran C readings, and in 1992, with a Magellan Nav5000 Plus GPS unit. Vessel latitude and longitude coordinates, depth, and time (PST) were recorded at 5-min intervals.

In 1990, we used the F/V Seabound and DFO F/V Walker Rock as the tracking vessels. We increased the number of tracks in 1991 by dedicating an inflatable boat for tracking as well as the Walker Rock. The inflatable boat was useful for following the fish through shallow reefs or into the middle of the seine and gill-net fleet but was restricted to tracking during daylight hours. The addition of the F/V Caligus to the program in 1992 gave us the capability of tracking two fish simultaneously, even at night.

**Mortality.**—We inferred survival or mortality of each fish from its horizontal and vertical movements. We assumed that the fish had died if it slowly sank to a depth corresponding with the bottom, and then remained there for at least 2 h. We attempted to relocate these apparently dead fish 12–24 h later at the same Loran or GPS coordinates. Our goal was to track live fish for at least 24 h, but some tracks were suspended due to signal loss or hazards such as inclement weather, shallow water, and difficulty maneuvering through the gill-net fishery at night.

**Analysis.**—Survival was estimated for all years combined by using the number of fish still alive that were tracked into each hour interval from time of release. A probability of mortality was calculated for fish that were lost or abandoned during an interval. For example, if a fish was lost in the 10th hour, that hour was defined as interval $t$. Three time periods result: intervals previous to $t$, $t$, and future intervals. The probability of mortality in $t$ was

$$\text{Prob Mort}_t = \frac{\sum t_n \text{Mort} + \text{Surv}_{tn}}{\sum t_n \text{Mort} + \text{Surv}_{tn}};$$  

$$\text{Mort} = \text{number of confirmed mortalities}; \text{Surv} = \text{fish tracked through the 24th hour}; t = \text{time interval}; \text{and } tn = \text{end of the 24-h tracking period.}$$

The cumulative mortality for a time interval $t$ was estimated as

$$\text{Cum Mort}_t = \text{Cum Mort}_{t-1} + \text{Mort}_t + (\text{Number abandoned}_t \times \text{Prob Mort}_t).$$

Confidence limits (95%) were calculated for the estimate of the proportion surviving (Fleiss 1981).

For analysis, data were pooled into two groups, mortalities (confirmed and suspected) and survivors (known survivors and lost fish). Continuous data were divided into the following classes: fish size, less than 70, 70–85, more than 85 cm; tagging time, less than 10, 10–20, and more than 20 min; landing time, less than 15, 15–30, and more than 30 min; and catch size, less than 200, 200–500, and more than 500 fish. The interactions of fish size, landing procedure, landing time, tagging time, catch size, degree of external injury, sampling year, and mortality were tested with the log-likelihood ratio or $G$-test (Sokal and Rohlf 1981).

**Results**

**Capture, Tagging, and Tracking**

Most chinook salmon were captured in beach sets (one end of the net secured to land) on the
TABLE 1.—Mean (SD) for landing time, tagging time, catch size, and fish size, and numbers of fish by landing procedure, injury category, and survival status for chinook salmon tracked in Johnstone Strait, 1990–1992.

<table>
<thead>
<tr>
<th>Year</th>
<th>Measurement</th>
<th>1990</th>
<th>1991</th>
<th>1992</th>
<th>All</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Landing time (min)</td>
<td>23 (8)</td>
<td>24 (7)</td>
<td>19 (9)</td>
<td>22 (8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tagging time (min)</td>
<td>19 (8)</td>
<td>11 (5)</td>
<td>8 (4)</td>
<td>12 (7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Catch size (number of fish)</td>
<td>259 (445)</td>
<td>199 (200)</td>
<td>381 (564)</td>
<td>276 (416)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fish size (cm)</td>
<td>82 (10)</td>
<td>76 (13)</td>
<td>85 (12)</td>
<td>80 (12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Numbers of fish</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Landing procedure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stern</td>
<td>9</td>
<td>14</td>
<td>13</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Side</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Injury category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minimal</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slight</td>
<td>4</td>
<td>9</td>
<td>8</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Substantial</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Survival status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dead</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alive</td>
<td>12</td>
<td>12</td>
<td>14</td>
<td>38</td>
<td></td>
</tr>
</tbody>
</table>

Vancouver Island side of upper Johnstone Strait (Figure 1). The target species, sockeye and pink salmon, dominated the catches. Chinook salmon were taken from seine catches that varied from 2 to 2,006 fish (mean, 276 fish; Table 1). Approximately half of the seine hauls contained only one chinook salmon.

Landing time ranged from 7 to 38 min (mean, 22 min; Table 1). For a single fish that was reseined (9113), the stress associated with the reseining was assumed to be additive, so the landing time for this fish was combined with the landing time from the first seining. Tagging time ranged from 3 to 34 min (mean, 12 min). Tagging time was significantly reduced over the 3 years of sampling due to changes in our tagging methods (i.e., tagging directly from the inflatable boats rather than returning the fish to the tracking vessel; \( G = 24.13, df = 4, P < 0.01 \)). Side landings were slower (\( G = 14.61, df = 2, P < 0.01 \)) and catches were larger (\( G = 12.50, df = 2, P < 0.01 \)) than stern landings. The condition of fish ranged from nearly unmarked to deep net-induced gashes on the belly and heavy bleeding from the gills. Estimated scale loss ranged from 0 to 65%. Stern-landed fish showed a greater degree of external injury than side-landed fish (\( G = 7.91, df = 2, P < 0.05 \)), but no relation was detected between injury category and mortality.

Fish were tracked from 4 July to 31 August 1990, from 5 August to 2 September 1991, and from 2 to 27 August 1992. We tracked 49 chinook salmon but data from 2 fish that were lost within the first hour of tracking were not analyzed (Candy et al. 1995). The remaining 47 fish were tracked for a total time of 789 h 47 min. Track durations ranged from 2 h 1 min to 32 h 48 min (mean, 16 h 48 min).

Once released, chinook salmon showed a range of escape responses from an initial deep dive near the release site to rapid or slow horizontal movement near the surface. The fish in Figure 2a is an example of one of five fish that dived to at least 300 m. This fish survived, retaining its transmitter, and was caught 35 d later in a sport fishery on the west coast of Vancouver Island (an estimated minimum distance of 500 km). The fish in Figure 2b is an example of a fish that remained near the surface (<80 m) for the duration of the track. This fish with its transmitter returned to the Quinsam River hatchery in the Strait of Georgia 34 d after release (estimated minimum distance of 130 km). Of the 49 chinook salmon tagged and tracked, 4 were recovered at hatcheries, 2 from sport fisheries, and 2 from commercial fisheries.

**Mortality**

The first confirmed death was tracked for about 7 h at the same location and depth before the track was terminated (Figure 2c). To use time more efficiently and to complete more tracks, we confirmed suspected mortalities by returning to the Loran or GPS coordinates where the track had been terminated and attempted to relocate the fish the following day. We were successful with three tracks (9113, 9119, 9120) but failed to relocate two others (9117, 9202) that terminated in mid-Johnstone Strait near the maximum range of the transmitters. Possibly we were unable to reposition the tracking vessel precisely enough to relocate the transmitter signal from this depth, or the transmitter’s rapid pulse may have drained its battery. On the basis of horizontal and vertical movements, we inferred that six fish died: two died immediately (9120, 9202) and the others died at 2.0 h (9113), 8.3 h (9119), 8.7 h (9117), and 12.0 h (9108). Fish were judged to have died at the start of the last abrupt descent toward the bottom.

Three additional fish were likely to have died at 0.0 h (9102), 9.0 h (9204), and 9.3 h (9103), but these fish were lost at depth near the limit of
FIGURE 2.—Depth plots from six chinook salmon tracked in Johnstone Strait, 1990–1992, showing examples of three fish of known fate and three suspected mortalities: (a) a surviving fish (9213) that recovered from a deep dive (>300 m); (b) a surviving fish (9212) that remained nearer the surface (<80 m); (c) a fish (9108) that died after 12 h, sinking to the bottom at approximately 114 m (curved depth profile of fish on the bottom is due to changing tidal height); (d–f) three fish (9103, 9102, and 9204, respectively) tracked to depths below 300 m and assumed to have died. Note that the axes vary in scale.

the transmitters before they could be confirmed on the bottom for more than 2 h (Figure 2d,e,f). The fish in Figure 2d was tracked for over 9 h before it started a steady descent to 379 m and the track was terminated. This fish was judged unlikely to have recovered because all other dives exceeding 300 m were at time of release, not more than 9 h later. The fish in Figure 2e showed a slow, steady descent for 2.5 h before the track was terminated at 314 m. The fish in Figure 2f was tracked to a depth of 364 m and was thought to be on the bottom for the last 4 h of the track, but for part of this time the signal was lost. In addition, we failed to confirm the bottom depth with the ship’s sounder, possibly due to a steeply sloping bottom profile.

For the analysis we pooled the data into two groups, mortalities (confirmed and suspected) and survivors (known survivors and lost fish). Survival rate varied among sampling years (100%, 1990; 64%, 1991; 88%, 1992; G = 8.84, df = 2, P < 0.05). We also tested the interactions of fish size, landing procedure, landing time, injury category, and seine catch size on survival. The only significant effect was that mortality increased with longer landing times (G = 6.34, df = 2, P < 0.05; Table 2).

A survival curve was calculated with 47 fish, of which 9 (6 confirmed and 3 probable) were assumed to have died. Five fish (9001, 9004, 9007, 9011, 9106) that were abandoned or lost between 20 and 24 h but showed no indication that they would die were assumed to have survived to 24 h because we detected no mortalities after 12 h. The overall survival estimate was 77% at 24 h with 95% binomial confidence limits of 62 and 87% (Figure 3).

Movements After Release

Although several chinook salmon passed beside and below seine nets, only one fish (9113) was resinned by the commercial fleet during tracking. Maximum depth for seine nets in Johnstone Strait is 52 m (Canada DFO 1993). For the first 3 h after

<table>
<thead>
<tr>
<th>Landing time* (min)</th>
<th>Live</th>
<th>Dead</th>
<th>Percent survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15</td>
<td>8</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>15–30</td>
<td>23</td>
<td>5</td>
<td>78</td>
</tr>
<tr>
<td>&gt;30</td>
<td>4</td>
<td>4</td>
<td>50</td>
</tr>
</tbody>
</table>

* Landing times were available for only 44 fish.
release, fish spent 57% of the average tracking time at depths above 50 m where reseing would be possible (Table 3). This increased to approximately 65% after 6 h as some of the deep-diving fish ascended. Of 30 fish tracked for 7 h or more, 60% moved northwestward up Johnstone Strait (50% beyond the northern fishing boundary), 26% moved southeasterly down Johnstone Strait, and 13% remained within 2 km of the release site. Of these 30 fish, 27% spent between 4 and 12 h in bays. Johnstone Strait has a constant northward flow of surface water to about 100-m depth, capable of moving a passive object at approximately 20 cm/s (Thomson 1981). The higher frequency of fish movement in a northwesterly direction up Johnstone Strait probably was due in part to water transport.

**Discussion**

Catch-and-release studies have used either the confinement of net-pens and live-boxes or external tagging to observe fish after release from fishing gear. The stress caused by net-pens and live-boxes may bias the mortality estimates (Wright 1970). The results of external tagging are uncertain due to the confounding effects of tag loss, nonreporting, and mortality. The use of ultrasonic telemetry avoids "pen effects" but still allows observation of individual fish. Although there always will be differences between the experiment and the fishery, we assume that transmitter application created little additional stress on the fish. Several studies have found that insertion into the stomach is the best method of transmitter attachment and has little effect on survival and behavior (Stasko and Pincock 1977; Mellas and Haynes 1985; Quinn et al. 1989). Our recovery of transmitters from fish up to 64 d after release indicates that chinook salmon could carry the transmitters for a long time without ill effects.

We assumed that the vertical and horizontal movements seen from the telemetry data reflected chinook salmon behavior. It is possible we could have collected false tracking data if the fish had been eaten by a predator or regurgitated the transmitter. Killer whales *Orcinus orca* prey on chinook salmon in Johnstone Strait (J. K. B. Ford and others, DFO, unpublished). At times they were seen passing near the fish but never attacked a tagged chinook salmon during tracking. If a tagged fish were eaten by a whale, it would have been readily apparent from muffled or lost signal, rapid increase in horizontal speed, or surface depth data corresponding with a whale sighting. A surviving fish could have been misidentified if the transmitter was regurgitated and sank to the bottom while the fish swam off. However, Olson and Quinn (1993) found that regurgitation of transmitters was not a problem in their study of chinook salmon tracked in the Columbia River estuary. Two fish (9120, 9202) that apparently were dead at release had descent rates of 0.08 m/s and 0.11 m/s, very close to the 0.10 m/s descent rate of the transmitter alone in a test. These fish presumably were dead when released, so without any swimming, the descent rate could be similar to that of the tag alone. One fish (9119) died in a kelp bed near the surface, so there was no associated descent rate. The final descent rates of the remaining "dead" chinook salmon (mean = 0.04 m/s, \( N = 6 \)) were less than half the descent rate of the tag alone, indicating that regurgitation probably had not occurred.

The complex interaction of mechanical injury (internal or external) and physiological stress induced by capture and handling influences whether or not a chinook salmon survives purse-seine catch and release. Of the six factors hypothesized to affect mortality (fish size, landing procedure, degree of external injury, catch size, landing time, and tagging time), only landing time showed a signif-

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>0-3 h (( N = 38 ))</th>
<th>&gt;3-6 h (( N = 35 ))</th>
<th>&gt;6-12 h (( N = 33 ))</th>
<th>&gt;12-24 h (( N = 20 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-50</td>
<td>57</td>
<td>59</td>
<td>65</td>
<td>64</td>
</tr>
<tr>
<td>&gt;50-100</td>
<td>24</td>
<td>18</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>&gt;100-200</td>
<td>12</td>
<td>8</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>&gt;200</td>
<td>7</td>
<td>15</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

![Figure 3.—Cumulative survival of ultrasonically tracked chinook salmon released from purse-seine vessels in Johnstone Strait, 1990-1992. Dotted lines indicate 95% confidence limits.](image-url)
When survival could be determined, we assumed that mortality due to shortened track lengths can overestimate survival.

In addition to providing information on postrelease survival, the telemetry data allowed us to estimate the likelihood that the released fish would be recaptured in the purse-seine fisheries. Reseining requires that the released fish remain both horizontally and vertically vulnerable to the fishing fleet. For a portion of the fish tracked, reseining was unlikely during the first 24 h. These chinook salmon either remained below seining depths or moved horizontally away from the area of fishing. Their capability for rapid movement may allow some of these fish to escape from the fishery during an opening, but this same capability allows the fish to move back into a vulnerable position between seine openings. For example, one fish (9110) was tracked northward beyond the fishing boundary but was caught 2 weeks later approximately 40 km south after having moved back across the fishing boundary. Site-specific geographic and oceanographic features such as proximity to fishing boundaries, availability of refuge bays, the strength and direction of current, fleet distribution, and patterns of vertical movements will influence the likelihood of reseining.

The success of a catch-and-release fishery in Johnstone Strait would depend on the cooperation of fishermen. For our estimated survival rate, we assumed that the fish were quickly and carefully released after being landed. We dipnetted fish from the pursed net which may not be practical during a commercial fishery. If fish were retrieved from the hold after being bailed onboard or roughly handled before release, mortality might be much higher. However, mortalities may be minimized if handling time is reduced, particularly from sets with small catch sizes (<100 fish). The observer program determined that from 1986 to 1990, an average of 68% of the purse seine sets in upper Johnstone Strait that caught at least one chinook salmon caught fewer than 100 salmon of all species (D. Nagtegaal, DFO, unpublished data). If mortality is related to landing time and associated with catch size, then survival could be quite high for these chinook salmon.

Assuming responsible handling by their captors, chinook salmon mortality due to incidental catch in the Johnstone Strait seine fishery could be considerably reduced if a nonretention policy were implemented. However, it would have drawbacks such as the difficulty in determining accurate seine
fishing mortality and the lost opportunity to sample fish for biological information such as size, age, and stock composition.

Finally, our study indicates that ultrasonic telemetry provides an alternative to external tagging or net-pen techniques for estimating survival after capture. It is relatively costly in terms of labor, equipment, and vessel operations, but postrelease survival can be directly observed under more natural conditions.

Acknowledgments

We thank John “Butch” Aleksich who provided his seiner, F/V Seabound at cost to test procedures and equipment before the 1990 fishing season. Alvin Sewid was tremendously helpful with his knowledge of upper Johnstone Strait and operation of the Walker Rock in 1990. We also thank skippers Alfred “Hutch” Hunt (F/V Marc Alan) and Julian “Moon” Stauffer (F/V Western Moon), both on charter to DFO, who provided us with fish to track between fishery openings. We also thank David Bain who kindly shared his tracking data with us. We gratefully acknowledge the field crew: Mark Chapman, Valentyne Deleeuw, Bryan Flucke, Ed Siu, Laura Smith, Paul Smith, Cameron St. John, and Julian Sturhahn who operated the vessels and equipment day and night. We also thank Dick Nagtegaal and Terry Beacham for reviewing this manuscript and making many helpful comments and suggestions.

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