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Site Selection and Feasibility of Enumerating Dolly Varden using Dual Frequency Identification Sonar in the Hulahula River, Arctic National Wildlife Refuge, Alaska, 2006

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Abstract

A study using a fixed-location, Dual Frequency Identification Sonar (DIDSON) was initiated in 2004 to assess the population status of Dolly Varden *Salvelinus malma* in the Hulahula River, Alaska. An abundance estimate from the DIDSON data was generated to describe the variability in run size and timing of Dolly Varden. During 2006 data collection began August 1 and continued through September 20. A total of 1,157 hours of data was collected, providing an estimate of 7,471 Dolly Varden migrating upriver. Species identification was accomplished with hook and line sampling, beach seining, and an underwater camera. A total of 127 fish was captured, identified as Dolly Varden, sexed, and measured. Based on observed swimming pattern, estimated size, and lack of other species observed or captured, all fish enumerated were assumed to be Dolly Varden. Visual observations using an underwater video camera positioned in the ensonified zone detected 125 fish and of these, 68 were identified as Dolly Varden. The remaining 57 fish were too small to identify. No fish were observed during two aerial surveys conducted using helicopter (September 17 and 20) flown from the DIDSON site to the river mouth. Positional data indicated that most fish were detected by the DIDSON with few fish observed near the outer range limits of acoustic detection. Most fish traveled on the river bottom. The peak daily count of 535 fish occurred on September 1. The hourly passage rates of upriver fish showed a slight diel pattern (highest during nighttime hours). The estimate of Dolly Varden migration upriver is conservative because it only included fish that passed while DIDSON was in operation.

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Introduction

The Hulahula River is located approximately 9 km west of Kaktovik, Alaska. It flows north from the Brooks Range through the Arctic National Wildlife Refuge (Refuge) into the Beaufort Sea (Figure 1). This river supports a population of amphidromous Dolly Varden *Salvelinus malma* (McCart 1980). This population appears to be a distinct stock that overwinters, and spawns in the river. They out-migrate and feed in nearshore waters as mixed-stock aggregations. Dolly Varden are an important part of the subsistence diet for the residents of Kaktovik (Jacobson and Wentworth 1982; Pedersen 1990; Pedersen and Linn 2005). They are harvested in mixed-stock fisheries in marine waters and from overwintering areas in rivers. Little information exists on subsistence harvest levels or stock status of these populations. Much of the spawning and overwintering habitat of these fish is located in federally managed waters (Craig 1973; Krueger et al. 1999).

Kaktovik is the center of subsistence fishing activity in the eastern North Slope of Alaska. In 2003, following the 2002-2003 winter season, fishers indicated that greater effort was expended to harvest fewer fish than in previous years from Fish Hole 2 (a popular fishing location on the Hulahula River) (David Wiswar, U.S. Fish and Wildlife Service, personal communication; Figure 1), and that fish caught were smaller. The concerns of Kaktovik residents over reduced harvest and smaller sized fish continue.

Historically, aerial surveys were conducted on river systems of the eastern North Slope to produce an index of Dolly Varden abundance. Weather conditions and fish behavior during flights hampered these efforts, and the surveys were intermittent (Viavant 2001), precluding establishment of population trends. However, the Alaska Department of Fish and Game is funded to continue conducting aerial monitoring of Dolly Varden overwintering abundance through 2008 on several rivers including the Hulahula River (Viavant 2007).

The Fish and Wildlife Service (FWS), through Title III of the Alaska National Interest Lands Conservation Act (ANILCA), has the responsibility for ensuring that subsistence opportunities are maintained. Title VIII of ANILCA requires that a subsistence priority be maintained for rural communities within federal conservation units. With the passage of ANILCA, provisions were developed for collection of biological baseline data to assess populations of fish and wildlife on the coastal plain of the Refuge. These studies were initiated over concerns for possible effects of oil and gas development on fish, wildlife, and their habitats in the Refuge. Possible development activities that could cause impacts include construction of roads, causeways, drilling pads, pipelines, and removal of gravel. To evaluate the potential effects of such development activities on fish and wildlife resources, fishery studies by the Fairbanks Fish and Wildlife Field Office (FFWFO) were conducted during 1981-1991 on the Refuge (Smith and Glesne 1983; West and Wiswar 1985; Wiswar and West 1987; Underwood et al. 1995). Studies conducted throughout and after development of the Prudhoe Bay oil fields have contributed much of the available information on fish utilization of freshwater and nearshore coastal habitats (Winslow and Roguski 1970; Roguski and Komarek 1971; McCart and Craig 1972; Yoshihara 1973; Ward and Craig 1974; Furniss 1975; Craig and McCart 1976; McCart 1980; West and Wiswar 1985; Wiswar and West 1987; Thorsteinson et al. 1991). These studies provided life history information of many freshwater and coastal fish species. Dolly Varden were studied throughout this period because of their relative abundance and importance in subsistence and sport fisheries. Although general life history information was collected, abundance estimates were not obtained for any Dolly Varden stock in the region.

To assess the population status of Dolly Varden in the Hulahula River, a study using DIDSON was initiated in 2004. Throughout that initial year, potential deployment sites were evaluated, and a site was selected. Preliminary operations developed data collection protocols and evaluated target images. In 2005 the study was fully operational and an abundance estimate of 10,424 Dolly Varden was obtained.

This report describes the estimated annual abundance and run timing of Dolly Varden in the Hulahula River using DIDSON data gathered in 2006. Distinguishing between species is an issue inherent to any sonar study where multiple species are present. Consequently, during sonar operation a second method of capture and/or identification of the species being detected with the sonar is necessary. Specific tasks were to: 1) Evaluate the presence of non-target species and identify potential factors such as swimming behavior, size, or spatial or temporal distributions, that could be useful for differentiating species using the DIDSON data; 2) Evaluate biological and physical conditions such as range of target, fish density, and aim/positioning of the DIDSON that could impact fish detection ability and fish enumeration with the DIDSON.

Study Area

The Hulahula River is a third-order glacial river, draining from the northern slope of the Brooks Range (Daum et al. 1984; Figure 1). In the lower reaches, the river is braided with many channels. The DIDSON site was located 300 m upriver from this braided area located at river kilometer 37 (Figure 2). Requirements for site selection included: 1) single channel; 2) uniform non-turbulent flow; 3) gradually sloping bottom gradient; 4) location downriver from known spawning and overwintering areas; and 5) active fish migration past the site (no milling behavior). Upriver from the site, the Hulahula River is confined to a single channel with steep tundra-covered cut-banks alternating with large gravel bars. Water turbidity is highly variable; depending on glacial melt. Surface runoff usually decreases early in July resulting in lower discharges. The discharge fluctuates throughout the summer due to rainfall and glacial melt (McCart 1980). Overwintering Dolly Varden in the Hulahula River concentrate in three areas known as “Fish Holes” (Jacobson and Wentworth 1982; Daum et al. 1984; Figure 1).

Methods

Site Selection and DIDSON Deployment

Determining a site specific river profile is essential before initiating any sonar operation even when operating a DIDSON (Daum and Osborne 1995). The DIDSON site (the area to be ensonified) was originally located during the feasibility phase of the study in 2004. In 2006 the DIDSON site was redefined from cross-sectional river profiles constructed of the area (Figure 3). Profiles were constructed using a laser rangefinder and depth sounder. River bottom irregularities, which could allow fish to pass undetected, were identified and avoided by running transects perpendicular to river flow. The following conditions were evaluated: river width, river depth, channel morphology, and proximity to overwintering/spawning grounds. Additional site evaluation consisted of deploying the DIDSON to further define the bottom profile and collect target data to make observations of both fish behavior and image quality of the river bottom. Artificial targets were deployed out from shore at various distances from the DIDSON. Placing targets not only on the river bottom but throughout the vertical column allowed us to identify the bottom profile and verify that the DIDSON was aimed to prevent fish from passing undetected under and over the ensonified zone.

The DIDSON was installed on the right bank and aimed perpendicular to river flow (Figure 2). It was moved inshore or offshore throughout the season as the water level changed. A boulder weir constructed 1 m downriver and extended 3 m past the DIDSON forced fish offshore before they passed through the ensonified zone. The river was ensonified to 26 m from the DIDSON. The DIDSON was mounted to an aluminum stand secured with large boulders and sand bags.

Equipment Description

A standard DIDSON, developed by the University of Washington's Applied Physics Lab (APL) and manufactured by Sound Metrics Corporation (Belcher et al. 2001; Belcher et al. 2002), was used to monitor the upriver migration of Dolly Varden in the Hulahula River. The DIDSON system is a high frequency (1.0 and 1.8 MHz), 12 x 29 degree multiple beam sonar. Component descriptions and operations are detailed in the DIDSON Operation Manual V5.02 (APL 2006). Specifications of the standard DIDSON deployed in the Hulahula include: 1) frequencies, 1.8 MHz with 96-0.3 x 12 degree beams that range offshore to 12 m, or 1.1 MHz with 48-0.6 x 12 degree beams that range offshore to 35 m; 2) an acoustic lensing system which creates and focuses the multiple beams; 3) range-dependent pulse widths from 4-64 μS; 4) frame rates of 5-20 frames/s; 5) a focus range of 1-24 m; 6) digital storage of data using the same software (which resembles digital video software) for control and playback; 7) software menus to convert the DIDSON data to either .jpg or .avi files. Data were output to a laptop computer with an Ethernet connection for management and analysis.

Data Processing

DIDSON data were collected in 30 minute sample periods and saved to files on two external hard disk drives. Data from the hard disk drives were downloaded to an analysis computer and analyzed at the field camp, using echogram view in the DIDSON control and display software (version 4.53). When a potential target was encountered, it was evaluated in normal view to determine: 1) if it was a fish, and 2) the direction of travel. Data from these files were exported to ASCII files, which were compiled and summarized using a Microsoft Excel VBA macro. Initial enumeration and adjustments were made in the field, and reanalyzed post season.

Data Analysis

Count adjustments were made for time lapses in data acquisition during equipment shutdown. Partial hourly counts (≥ 15 and < 60 min) were standardized to 1h, using

$$E_h = (60 / T_h) \bullet C_h \,, \qquad (1)$$

where E_h = estimated hourly upriver count for hour h, T_h = number of minutes sampled in hour h, and C_h = upriver count during the sampled time in hour h. Counts for hours with < 15 minutes were discarded and treated as missing hours.

Partial daily fish counts (days with missing hours) were standardized to 1 d using

$$E_d = (24 / T_d) \bullet C_d \,, \qquad (2)$$

where E_d = estimated daily upriver fish count for day d, T_d = number of hours sampled in day d, and C_d = upriver count during the sampled time during day d.

Species Evaluation

While sonar (DIDSON included) is capable of identifying fish that are present in the ensonified area, it is rarely possible to determine size or species of fish (Gunderson 1993). Ideally, species of fish can be differentiated by unique echo patterns (traces) resulting from their swimming or schooling behavior (Osborne and Melegari 2002). Identification of these patterns requires considerable experience by the operator, and it also requires a method to confirm that the pattern observed is produced from the particular species. Several methods were considered as means to evaluate the presence of non target species and our ability to differentiate species with the DIDSON. These included beach seining, angling, underwater camera, and visual observations.

Netting was limited by river conditions. Seining with a 30 m x 1 m, with 2 cm mesh, beach seine was hindered by high water and safety concerns. Later in the season as water levels dropped visibility increased considerably and net avoidance by fish became a problem. The increased visibility did however allow sampling by angling and visual surveys on foot.

Angling with artificial lures, when water clarity allowed, was used to determine species presence. Angling was conducted in and around the ensonified zone when fish were observed in real time DIDSON images. All angling was done with effort to minimize stress of any fish captured.

When visibility of the water column was good (>1m) an underwater video and holding station was deployed in the ensonified zone. This was used to confirm the DIDSON data with a visual image. The holding station was a boulder of known size positioned 1.5 m from shore within the ensonified zone (Figures 2 and 3). The boulder created a slower current where fish rested. It also created a reference target of known size in the DIDSON data. When fish held behind it, the fish's image in real time DIDSON data was matched with the video image of fish for identification and recording.

Two aerial surveys were conducted, by helicopter flown from the DIDSON site to the mouth of the Hulahula River on September 17 and 20. These surveys were conducted to determine if Dolly Varden that migrated downriver past the DIDSON were leaving the immediate area.

Results

Site Selection and DIDSON Deployment

On July 31, 2006 the DIDSON was deployed at the same site as in 2005, 37 km upriver from the mouth. No changes in physical conditions were observed at the deployment site. A suitable river channel profile was selected. The physical characteristics of the site, included a gradually sloped boulder/cobble bottom on the right bank, when facing down river, out 36 m to a steep cut left bank (Figure 3). Maximum river depth was 2.7 m. Maintaining the boulder weir to direct the fish through the beams worked well. Therefore operations were conducted with a weir throughout the season.

Abundance Estimate and Run Timing

For the season, over 1,157 hours of DIDSON data (95% of 1,224 possible hours) were collected, and 9,386 fish were counted (Table 1). Of these, a total of 8,134 were identified as fish migrating upriver. The remaining 1,252 fish were migrating downriver. Fish were clearly visible as images in the DIDSON data even during high water events. Partial hours/days were missed due to equipment malfunction, maintenance, and/or movement of DIDSON. Adjusting the data for the missed time yielded estimates of 8,808 fish migrating upriver and 1,337 migrating downriver. The total net estimate (upriver fish minus downriver fish) from August 1 to September 20, 2006 was 7,471 (Table 2 and Figure 4).

Dolly Varden migrating upriver exhibited a weak pattern in hourly passage rates throughout the season with the exception of a short time period of high passage rates from August 27 through September 2. The high passage rates occurred during late night/early morning hours and low numbers throughout the day (Figure 5). The mean hourly passage rates among fish migrating upriver showed a weak diel tendency for the entire season (Figure 6). Dolly Varden were ensonified out to 26 m from the right bank (Figure 7).

Species Evaluation

Seventy hours of catch and release fishing effort were conducted. A total of 95 Dolly Varden were caught. Lengths ranged from 120 to 750 mm FL ($\overline{x}$ = 385; SE = 15).

Fourteen hours of underwater video were compared to corresponding DIDSON data while in the field. Of the 124 fish viewed on the video, 67 were identified as Dolly Varden. The remaining fish were too small (70 – 130 mm) to identify.

Water levels and suspended solids dropped by September 20 and visibility improved, allowing for visual observations of fish. Two surveys flown by helicopter were conducted from the DIDSON site to the mouth of the river. No fish were observed downriver from the DIDSON site during the aerial surveys.

Discussion

Site Selection and DIDSON Deployment

Dolly Varden using the Hulahula River for spawning or overwintering were moving upriver past the DIDSON deployment site. This was confirmed from the DIDSON data as well as aerial surveys conducted on the river later in the season. Selecting a site at the narrowest section of the channel free of abrupt changes and large objects allowed coverage of the entire river. The bottom profile at the DIDSON site was linear out from the left bank with a slight flat spot in the thalweg allowing ensonification of the full channel from the right bank.

A similar pattern in milling behavior (fish moving back and forth in the area of the DIDSON) was observed in Dolly Varden during 2006 as observed in 2005. Later in the season downriver movement of fish increased. In preparation for the potential of milling fish during the 2006 counting season, an alternate site, approximately 150 m downriver from the original site, was mapped. The DIDSON was then redeployed at the alternate site to reduce counting milling fish later in the season.

An increase of downriver fish movement was seen toward the end of the 2006 season. We found that we needed to make visual confirmation of Dolly Varden that were moving downriver during this time. This was not difficult, because the increased visibility and lower water levels allowed for visual observations. The milling fish moved downriver but did not leave the immediate area. We believe this downriver movement was a result of increased milling behavior due to crowding in Fish Hole 1 and not an out migration event. Later in the season as more fish moved into Fish Hole 1 crowding occurred creating increased milling of fish. Before this time period most fish moved steadily upriver through the beam. Aerial surveys conducted from the DIDSON site (ensonified zone) downriver 2 km to the river mouth confirmed that downriver moving fish were staying in the immediate area.

Abundance Estimate and Run Timing

The net abundance estimate of Dolly Varden for the Hulahula River in 2006 was 7,471 compared to 10,412 in 2005. The median passage date was September 9, 8 days later than during 2005. The observed diel patterns in upriver fish passage were weaker than patterns seen during 2005.

Fish range data collected with the DIDSON were similar to data collected during 2006 and suggested that most upriver fish passing the DIDSON site were within the ensonified zone. Upriver fish were found on the river bottom with few fish near the range limits of acoustic detection. The DIDSON does not obtain vertical position data. However the much larger vertical angle of the DIDSON's beams reduced the potential of fish passing above or below the beams. This is further supported by the field data, where surface waves were sometimes detected with the DIDSON on windy days, and the river bottom was visible throughout all of the range.

Two distinct types of aggregations of Dolly Varden were observed migrating past the DIDSON site. These aggregations contained Dolly Varden that appeared to be in spawning-condition (dark red) and non-spawning condition (silver colored). Each aggregation appeared to number from 10 to 20 fish. The larger aggregations contained Dolly Varden in spawning condition and had larger fish. A number of smaller aggregations contained fish that appeared silver and were possible non-spawners.

Species Evaluation

DIDSON images were reliable for the enumeration of passing fish, but the image produced was inadequate for estimating the size or species of the fish. Fish images produced from our DIDSON data were true to the actual shape of the target fish moving in the river. The data were evaluated for patterns in diel, range distribution and size grouping that could suggest another species in the river during Dolly Varden enumeration. No evidence of another species was found from the data.

Differentiating between species is not always possible with the DIDSON data alone especially when fish species are morphologically alike (Weiland and Carlson 2003). The only other species known to be present during the study with morphological similarities include Arctic grayling *Thymallus arcticus,* but only in small numbers. Consequently they would collectively make up only a small percentage of the fish present relative to Dolly Varden. Current classification and identification of fish images to species requires matching the DIDSON image to the actual fish in the river with another sampling method. By using underwater video, netting, angling, or visual observations species identification could be achieved.

Angling and visual observations were the methods used in 2006. Early in the season, high water and high turbidity made netting unsafe and visual observations and underwater video unusable. Angling conducted in and around the ensonified zone was used to determine species presence. All fish caught were identified as Dolly Varden. As water visibility improved throughout the last weeks of operation, visual observations of fish in the DIDSON beam were made from shore. All fish sighted were Dolly Varden.

Continued effort in 2007 on species verification using methods previously mentioned will be a top priority. *In situ* information gathered using these methods will be compared to the DIDSON images. Developing DIDSON image patterns from fish behaviors will confirm fish species present. Behavior characteristics that will be considered are: location in the river, swimming speed, body movement, schooling, and run timing.

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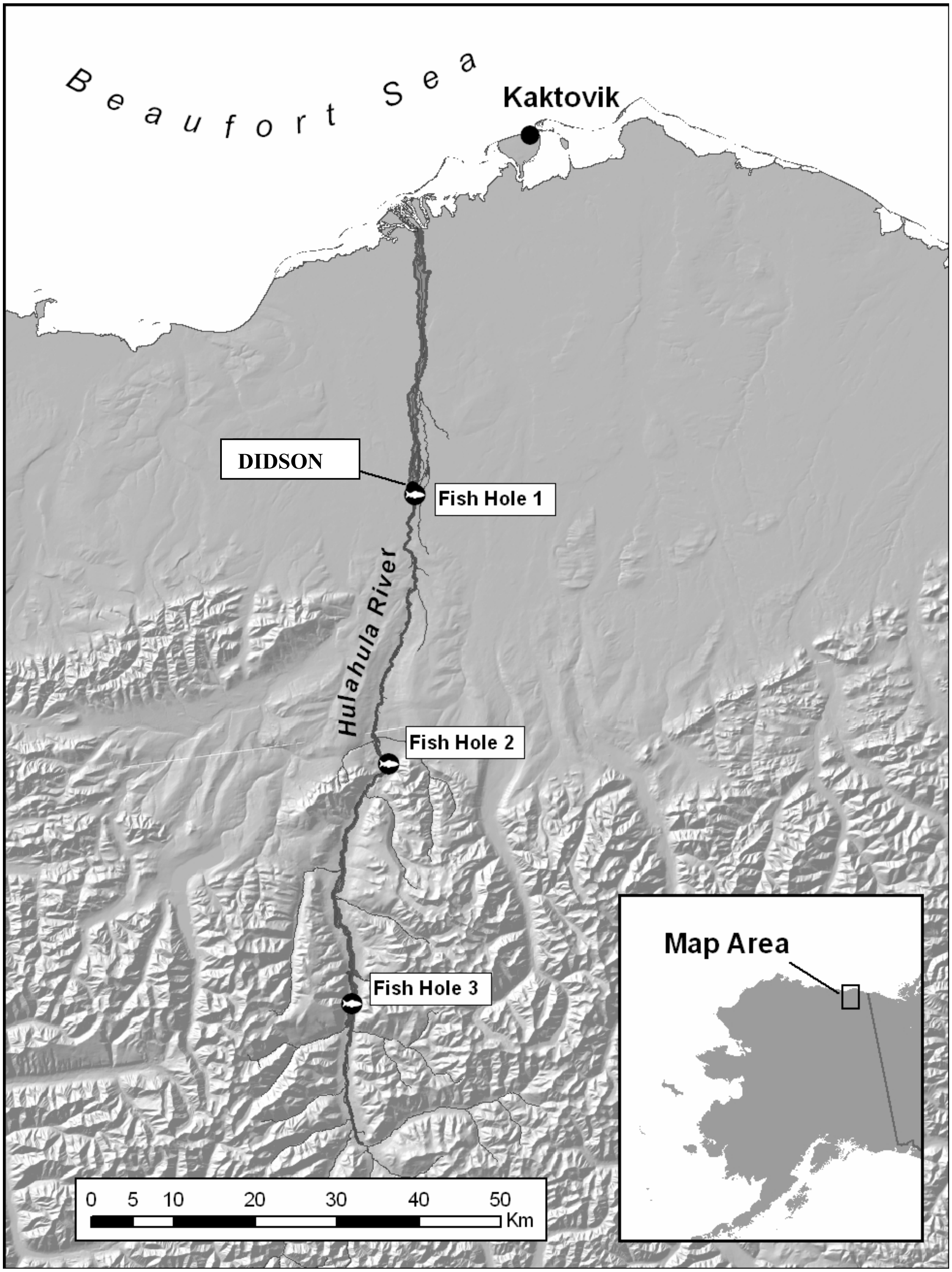

Figure 1.− DIDSON deployment location and known fish over-wintering locations (Fish Hole 1-3 heading up river) Hulahula River, 2006.

Figure 2.– Map of Hulahula River DIDSON study area showing ensonified zone the numbers represent the early and late season deployment.

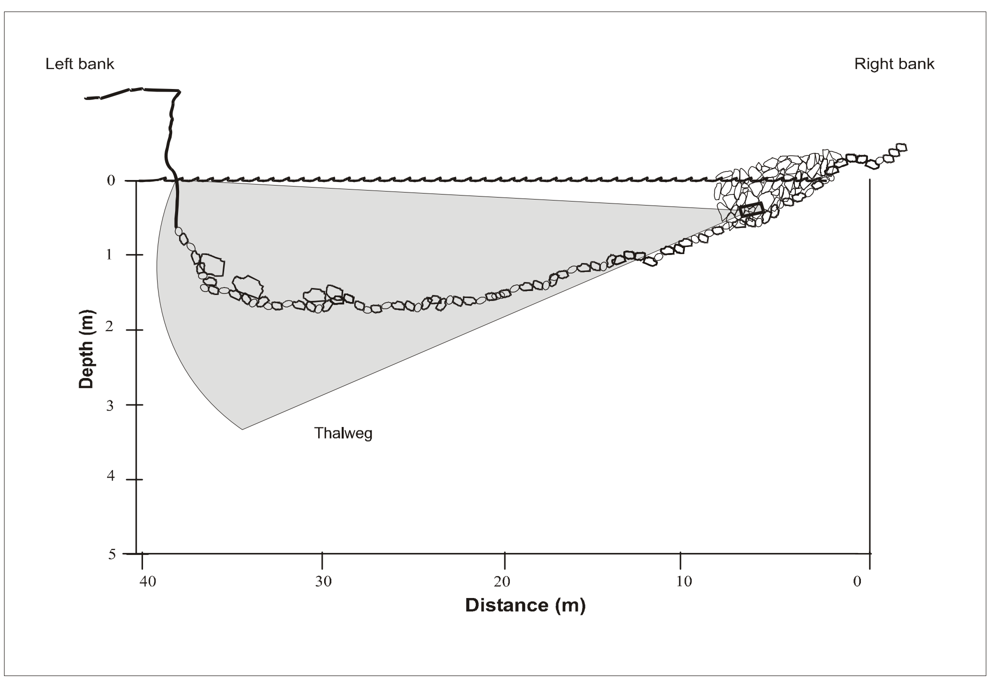

Figure 3.– River channel profile and estimated ensonified zone of the Hulahula River, 2006.

Table 1.− Hydroacustic data collected from the Hulahula River, 2006.

Date	Sample time (h)[a]	Missed time (h)	Upriver count	Downriver count	Total count
Aug 1	23.00	1.00	0	0	0
2	22.96	1.04	1	0	1
3	23.63	0.37	0	0	0
4	23.83	0.17	1	0	1
5	23.87	0.13	0	0	0
6	23.42	0.58	5	2	7
7	23.90	0.10	10	0	10
8	21.49	2.51	0	0	0
9	23.92	0.08	5	2	7
10	23.50	0.50	248	6	254
11	22.78	1.22	137	6	143
12	22.95	1.05	108	6	114
13	23.20	0.80	95	3	98
14	19.94	4.06	17	0	17
15	22.22	1.78	3	0	3
16	23.80	0.20	10	1	11
17	23.72	0.28	52	0	52
18	23.89	0.11	289	4	293
19	23.90	0.10	122	2	124
20	20.23	3.77	66	3	69
21	23.90	0.10	60	0	60
22	23.52	0.48	19	2	21
23	23.90	0.10	6	0	6
24	23.54	0.46	19	1	20
25	23.88	0.12	43	3	46
26	23.95	0.05	25	0	25
27	20.53	3.47	25	11	36
28	23.49	0.51	69	20	89
29	23.08	0.92	252	33	285
30	23.42	0.58	320	40	360
31	23.82	0.18	221	40	261
Sep 1	21.44	2.56	188	39	227
2	23.73	0.27	187	26	213
3	23.80	0.20	143	37	180
4	23.85	0.15	139	67	206
5	23.81	0.19	165	38	203
6	22.02	1.98	262	53	315
7	16.15	7.85	237	32	269
8	16.14	7.86	306	43	349
9	23.81	0.19	432	47	479
10	23.75	0.25	327	65	392
11	23.72	0.28	436	89	525
12	23.83	0.17	395	77	472
13	23.82	0.18	433	66	499
14	23.78	0.22	333	47	380
15	22.04	1.96	323	62	385
16	23.24	0.76	321	69	390
17	23.83	0.17	531	62	593
18	23.82	0.18	361	84	445
19	23.77	0.23	289	47	336
20	9.95	14.05	98	17	115
Total	1,157.48	66.52	8,134	1,252	9,386

[a] Times are recorded to the nearest second and converted to decimal hours by the computer.

Table 2.− Daily adjusted Dolly Varden counts, Hulahula River, 2006.

Date	Upriver		Downriver		Upriver
	Count	Cumulative	Count	Cumulative	Net Count
Aug 1	0	0	0	0	0
2	1	1	0	0	1
3	0	1	0	0	0
4	1	2	0	0	1
5	0	2	0	0	0
6	5	7	2	2	3
7	10	17	0	2	10
8	0	17	0	2	0
9	5	22	2	4	3
10	253	275	7	11	246
11	148	423	6	17	142
12	116	539	6	23	110
13	95	634	3	26	92
14	21	655	0	26	21
15	3	658	0	26	3
16	10	668	1	27	9
17	53	721	0	27	53
18	290	1,011	4	31	286
19	122	1,133	2	33	120
20	75	1,208	6	39	69
21	60	1,268	0	39	60
22	19	1,287	2	41	17
23	6	1,293	0	41	6
24	19	1,312	1	42	18
25	43	1,355	3	45	40
26	25	1,380	0	45	25
27	26	1,406	13	58	13
28	70	1,476	20	78	50
29	255	1,731	34	112	221
30	329	2,060	41	153	288
31	224	2,284	41	194	183
Sep 1	202	2,486	42	236	160
2	191	2,677	27	263	164
3	145	2,822	37	300	108
4	140	2,962	67	367	73
5	166	3,128	38	405	128
6	302	3,430	56	461	246
7	396	3,826	48	509	348
8	488	4,314	63	572	425
9	437	4,751	47	619	390
10	331	5,082	66	685	265
11	442	5,524	90	775	352
12	398	5,922	78	853	320
13	436	6,358	67	920	369
14	337	6,695	47	967	290
15	373	7,068	63	1,030	310
16	327	7,395	71	1,101	256
17	535	7,930	63	1,164	472
18	365	8,295	85	1,249	280
19	292	8,587	47	1,296	245
20	221	8,808	41	1,337	180
Total	8,808		1,337		7,471

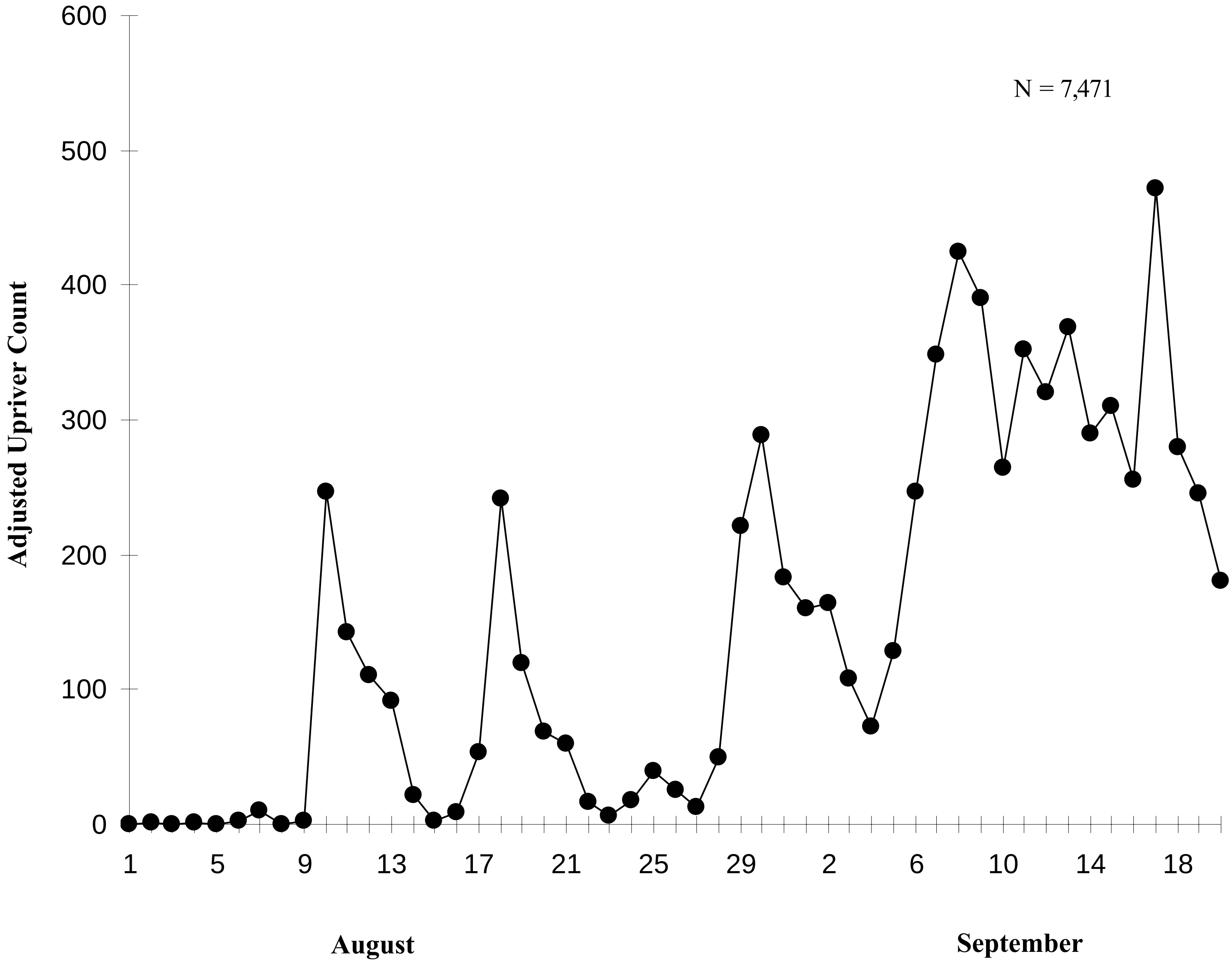

Figure 4.− Daily net upriver counts of Dolly Varden, Hulahula River, 2006.

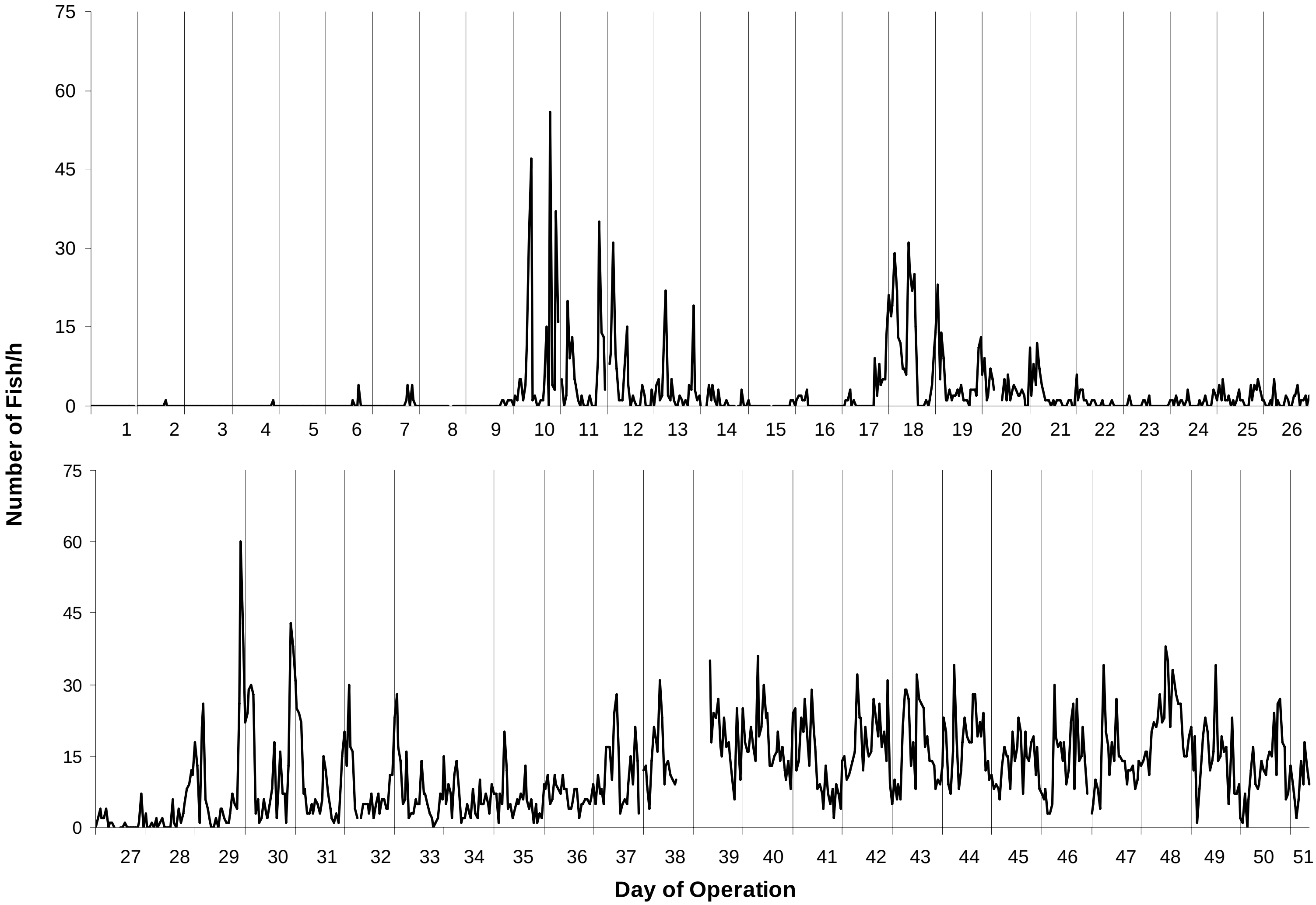

Figure 5.– Diel distribution of upriver traveling Dolly Varden, Hulahula River, August 1 through September 20, 2006. Area within a date represents 00:00 – 24:00 hours. Gaps in the line represent time when no data were collected.

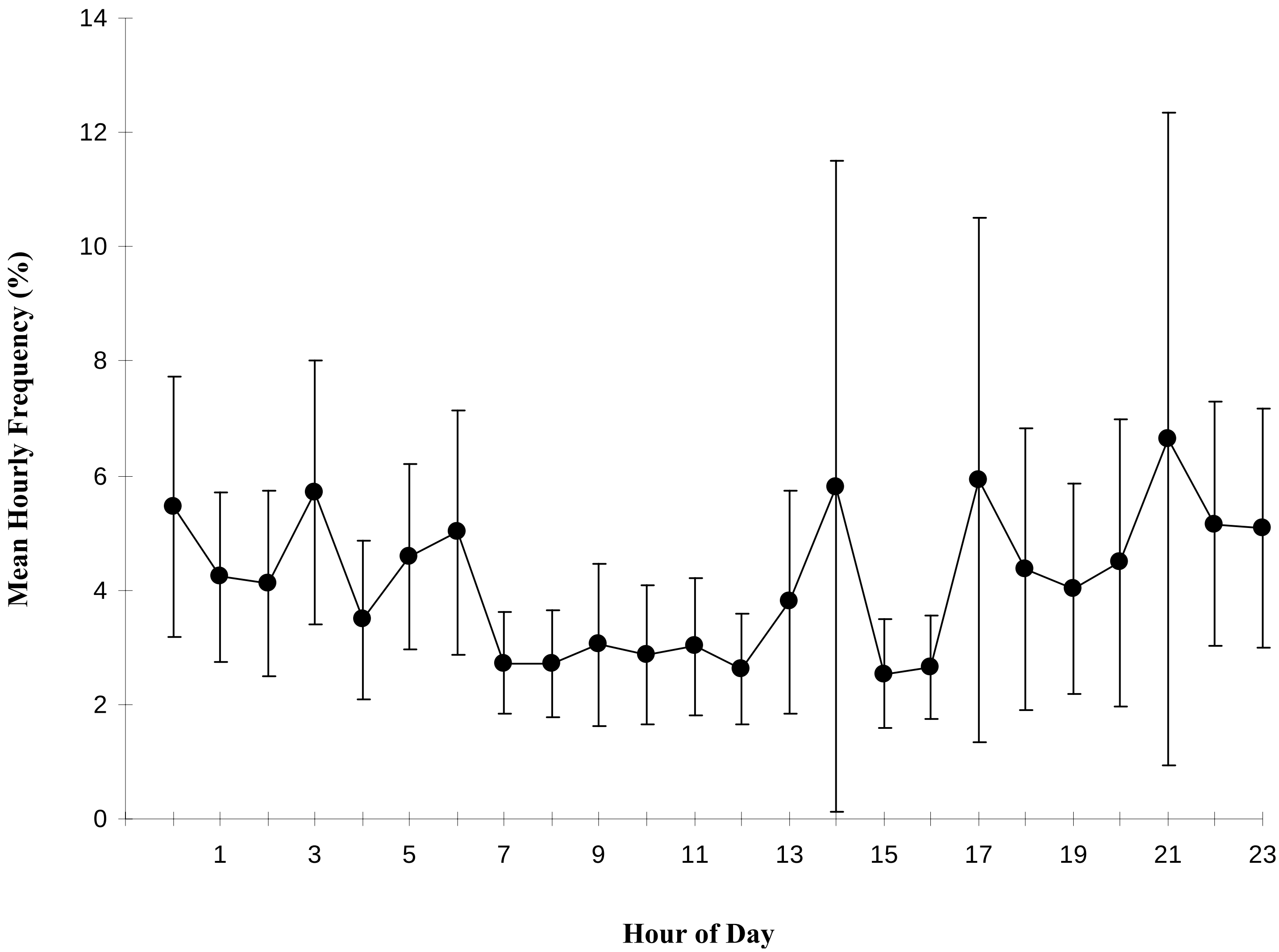

Figure 6.− Mean (±2 SE) hourly frequency of upriver traveling Dolly Varden, Hulahula River, 2006. The data represents 34 d of continuous 24 h collection.

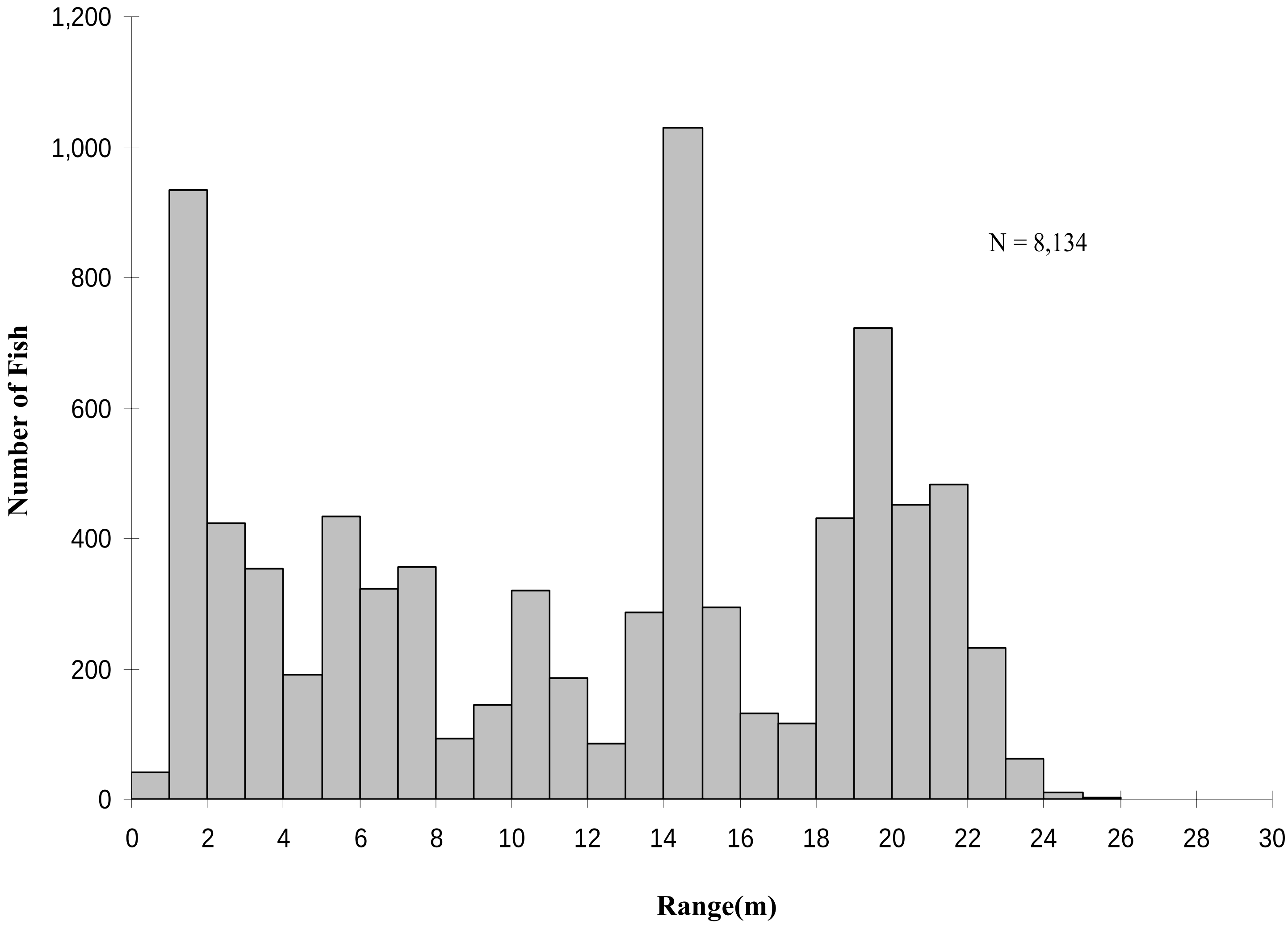

Figure 7.− Range (horizontal distance from transducer) distribution of upriver traveling Dolly Varden, from DIDSON data collected on the Hulahula River, August 1 to September 20, 2006.

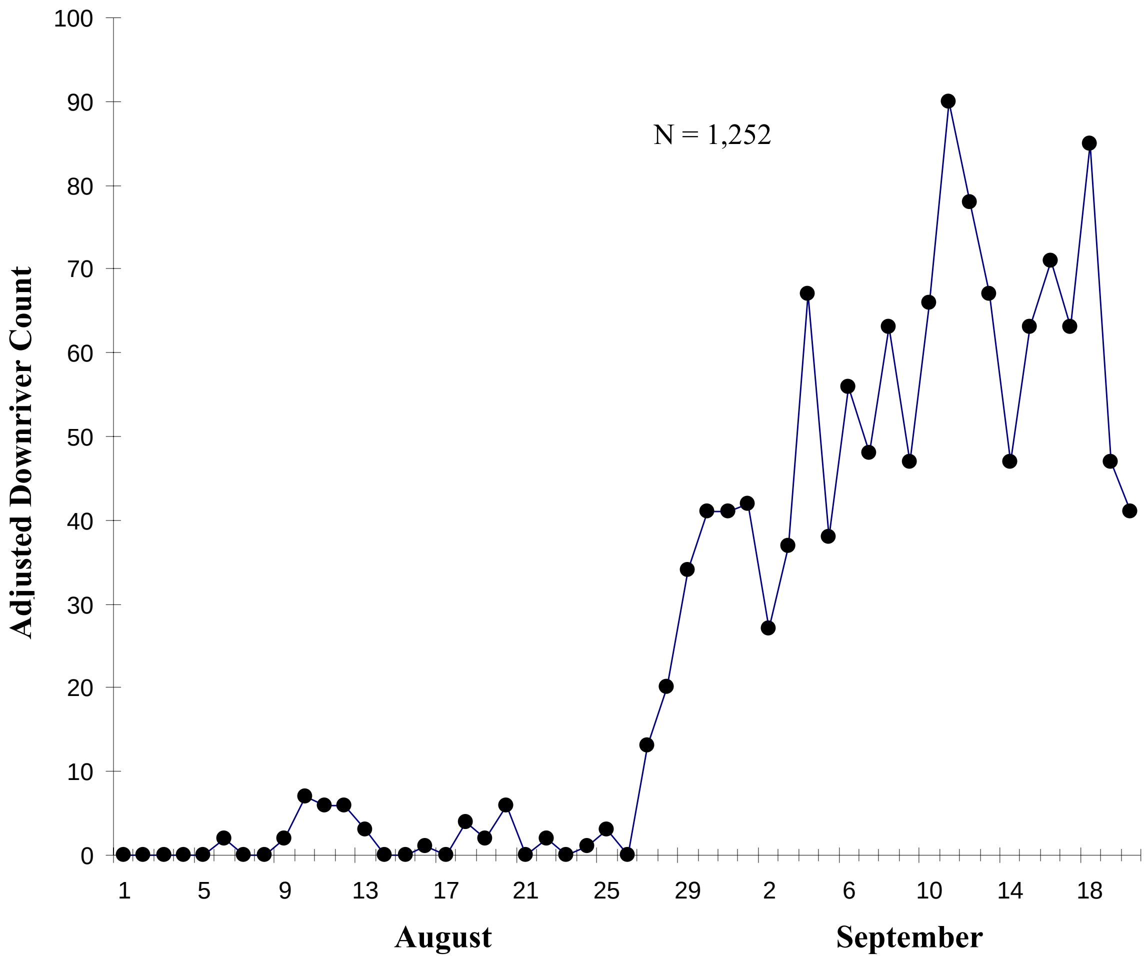

Figure 8.− Adjusted counts of downriver traveling Dolly Varden, Hulahula River, 2006.