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MANAGEMENT BRIEF

A Lightweight Battery for Backpack Electrofishing

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Abstract
A lithium ion battery was modified to replace the conventional sealed lead acid battery used to operate a backpack electrofishing unit. Specifications and performance of the lithium ion battery were compared with those of a lead acid battery of similar capacity. The lithium ion battery was 76% lighter in weight than the lead acid battery, reducing the overall weight of a Smith-Root model 12 backpack electrofishing unit and battery by 55%. Including the cost of a charger and parts to make the battery compatible with an electroshocking unit, the lithium ion battery and charger cost was 26% less than that of the lead acid battery and charger. Bench tests indicated the lithium ion battery provided 91% and 98% of the operating time of the lead acid battery per charge when the settings were 300 V at 90 Hz and 500 V at 90 Hz, respectively. The fuel gauge (battery discharge indicator) on the lithium ion battery, which was absent in the lead acid battery, provided the ability for a user to assess the remaining charge level while in the field. The lithium ion battery provided similar performance with a significant reduction in weight and cost compared with a conventional lead acid battery for backpack electrofishing. The lighter weight of the backpack electrofishing unit using the lithium ion battery can reduce fatigue and the risk of fatigue-related injuries to field crews.

Backpack electrofishing is a common technique for actively sampling small streams (Onorato et al. 1998). Modern backpack electrofishing units typically use pulsed DC and are powered by either a battery or gasoline generator (Reynolds 1996). Battery-powered models are preferred to generator-powered models because they are quieter, can be used in restricted use areas such as National Wilderness Areas, and do not expose sampling crews to carbon monoxide, which is produced by the generator motor. In addition, the gasoline needed to power a generator is flammable and hazardous to the environment if spilled. However, generator-powered models often have higher power output with more duration, compared with battery-powered models.

Battery-powered backpack electrofishing models require facilities and equipment to recharge batteries, the sampling time is limited by the capacity of or number of available batteries, and traditional lead acid electrofishing batteries are heavy. Depending on the model, a backpack electrofishing unit, powered by a 24-V, 12-ampere-hour (Ah) conventional lead acid battery, weighs 14–18 kg, and the battery contributes 47–60% to the overall weight. Lithium ion batteries of comparable capacity and voltage are lighter in weight, require less maintenance, and have a higher recharge cycle capacity (number of charge–discharge cycles) compared with traditional lead acid batteries (Albright et al. 2012).

In this study, we described the modification and use of a lithium ion battery, which was used to power a backpack electrofishing unit, and compared these with a conventional lead acid battery. The goal of this modification was to reduce the weight of the electrofishing unit, and therefore reduce the risk of fatigue-related injuries to field crews, with minimal change in performance of the electrofishing unit.

METHODS

A 12.6-Ah, 25.9-V lithium ion battery and charger were purchased from BatterySpace.com. The battery weighed 2.00 kg and cost US$376 (Table 1). To charge the lithium ion battery we used a model CH-L2596N charger with a maximum output of 180 W and cost of $86. The lithium ion battery had a fuel gauge (battery discharge indicator), which allowed the user to assess the remaining charge level.

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TABLE 1. Physical characteristics and cost (US$) of a conventional lead acid battery and a lithium ion battery used to power a backpack electrofishing unit. The cost of the battery charger alone and combined battery and charger are also shown.

Characteristic	Lead acid battery	Lithium ion battery
Manufacturer	Smith-Root	Powerizer
Model	6682	PLB-8570170-7S-FG
Voltage (V)	24	25.9
Ampere-hour (Ah)	12	12.6
Dimensions (mm)	200 × 150 × 90	200 × 120 × 75
Weight (g)	8,437	1,996
Fuel gauge	None	Included
Battery cost	$384.00	$375.95
Parts for compatibility	None	$92.00
Charger model	UBC24	CH-L2596N
Charger cost	$360.00	$85.95
Total cost with parts and charger	$744.00	$553.90

The lithium ion battery was modified using a Smith-Root battery adapter (part 07459, cost $50) in order to connect it to a Smith-Root model 12 electrofishing unit. The modifications required removing the terminal ends of the battery adapter and connecting the wiring to the terminals of the lithium ion battery. A similar modification was made to the lithium ion battery charger using a Smith-Root equipment adapter (part 07458; cost $42). The Smith-Root model 12 electrofishing battery holder did not require modification because the lithium ion battery was similar in size and shape to the lead acid battery.

The characteristics and performance of the lithium ion battery, used to power a backpack electrofishing unit, were compared with those of a sealed lead acid battery of similar capacity. For comparison we used a Smith-Root 12-Ah, 24-V model lead acid battery that weighed 8.44 kg and cost $384 (Table 1). The lead acid battery had no method to assess charge level except during recharging. To charge the lead acid battery we used Smith-Root model UBC24 charger that had a maximum output of 60 W and cost $360.

We used two bench tests to compare the performance of similar capacity lithium ion and lead acid batteries used to power a backpack electrofishing unit. The bench tests were conducted indoors, where variables such as depth, substrate, conductivity, and temperature could be controlled across tests that could be replicated under identical conditions.

The first bench test used a Smith-Root BAT-01 battery analysis tool. This tool measured the amount of time (in seconds) required to discharge a battery to below 19.6 V at a continuous load of 5.76 Ω. During each test, the batteries were charged to capacity, and time to discharge (below 19.6 V) was measured. The battery analysis test was replicated six times for each battery type, and the results were compared using a *t*-test.

The second bench test used a Smith-Root model 12 backpack electrofishing unit operated at two different settings (300 V at 90 Hz and 500 V at 90 Hz). For each test, the batteries were charged to capacity. Tests were conducted using a traditional rat-tail cathode and a wand type anode with a 28-cm-diameter aluminum ring. Tests were done in a nonmetallic container containing 208 L of freshwater at a water temperature of 18°C. Space between the anode and cathode was fixed at 55 cm and the anode and cathode were submerged to a depth of 60 cm. Setting levels of the electrofishing unit were then set for the particular test, and the unit was set to run continuously by depressing the anode activation switch. Time until the battery stopped operating the electrofishing unit was measured using the seconds counter on the unit. This test was replicated three times for each battery type and power level, and results were compared using a *t*-test. Both the battery analysis and model 12 electrofishing unit testing were conducted under the same conditions (e.g., temperature, depth, distance between the anode and cathode, conductivity) with the same equipment, and only the specific battery was changed between tests.

RESULTS AND DISCUSSION

The lithium ion battery cost 2% less and its weight was 76% lighter than a sealed lead acid battery of similar capacity (Table 1). When we included the cost of the charger and modifications, the cost of the lithium ion system ($553.90) was approximately 26% less than that of the conventional lead acid battery system ($744.00).

During the battery analysis tool test the sealed lead acid battery discharge time averaged 10,327 s (2.9 h) and the lithium ion battery averaged 8,887 s (2.5 h) (Table 2). During the bench

TABLE 2. Mean operating time (s) for two battery types during performance testing used to power a backpack electrofishing unit (SD in parentheses).

	Mean operating time (s)				
Test	Lead acid battery	Lithium ion battery	Difference between the means	*t*-value	*P*-value
Battery analysis tool	10,327 (324)	8,887 (610)	1,440	5.28	0.0003
Electrofishing unit, 300 V at 90 Hz	19,141 (83)	17,408 (511)	1,733	5.77	0.0045
Electrofishing unit, 500 V at 90 Hz	8,233 (298)	8,038 (235)	195	0.078	0.4802

test of the electrofishing unit at 300 V and 90 Hz the sealed lead acid battery discharge time averaged 19,141 s (5.3 h) and the lithium ion battery averaged 17,408 s (4.8 h). In both the battery analysis tool test and the electrofishing unit bench test at 300 V and 90 Hz, the sealed lead acid battery had a significantly longer discharge time than the lithium ion battery (Table 2). In these tests, the lithium ion battery had 24–29 min less operating time (9–14% less) than the lead acid battery. When the electrofishing unit was tested at 500 V and 90 Hz, average operating time was similar for the lead acid and lithium ion batteries ($<$4 min difference). Differences in operating times between the lithium ion and lead acid batteries, at differing voltage settings, were due to differences in the discharge profiles between the battery types. The discharge profile of a lithium ion battery is relatively flat compared with the sloping profile of a lead acid battery, which results in similar discharge profiles at higher loads (Albright et al. 2012).

We field tested the lithium ion battery while collecting Chinook Salmon *Oncorhynchus tshawytscha* parr from headwater tributaries of the South Fork Salmon River in central Idaho during the summer of 2011. The primary goal of field testing was to determine whether the lithium ion battery during actual use in the field would provide sufficient power for a day of sampling. Water temperature ranged from 7.3°C to 13.4°C and conductivity ranged from 21.3 to 25.6 μS/cm during field testing. Procedures for fish collection during field testing used a single-pass technique (Meador et al. 2003) and were described by Achord et al. (1996, 2007). In our field test, a Smith-Root model 12 backpack electrofishing unit powered by the lithium ion battery provided between 21,506 and 25,681 s (6–7 h) of sampling time when operated at 400 V and 90 Hz. This amount of time is sufficient for most field sampling. The time required to discharge a battery depends on the resistance of the circuit and the voltage applied; lower resistance and higher voltage will discharge a battery quicker. Discharge times for other users may be different from the results reported here due to differences in circuit resistance and the voltage applied. Due to the high variability in sampling conditions (i.e., conductivity, temperature, depth, target species, stream discharge, experience of sampling crew, and electrofishing unit settings), which can influence resistance and the voltage applied, it was not possible in this evaluation to address the range of discharge times that others may experience. However, the fuel gauge on the lithium ion battery is a useful tool for sampling crews to monitor the remaining capacity of a battery while sampling in the field. We did not compare the performance of the lead acid and lithium ion batteries in the field because of the number of variables we could not control such as sampling depth, substrate, conductivity, temperature, distance between the anode and cathode, and crew experience, any of which could change the load on the battery and thus the operating time.

Electrofishing operations can be dangerous and require adequate planning and preparation to be conducted safely (PSC 2008). Stream sampling using a backpack electrofishing unit can expose the user to a variety of hazards. The most serious of these hazards are due to the performance of potentially strenuous activity while moving upstream, against the water current, and on substrate that is often slippery and uneven (Berry 1996). The additional weight of a backpack electrofishing unit may increase the risk of injury to field staff, particularly as fatigue associated with long periods of sampling effort develops. In our study, replacing a conventional 12-Ah lead acid battery with a 12.6-Ah lithium ion battery reduced the weight of a Smith-Root model 12 backpack electrofishing unit by 55% from 14.2 to 7.4 kg. The backpack electrofishing unit with a lithium ion battery was lighter and easier to carry; thus, it provided safer sampling conditions for field crews by reducing fatigue and the risk of fatigue-related injuries.

Since the completion of this study, Smith-Root began offering a lithium ion battery for their backpack electrofishing units. The Smith-Root lithium ion battery specifications are 24 V and 9.6 Ah, and as of August 2012, it sells for $995. The Smith-Root's lithium ion battery charger cost $360. Smith-Root estimates their lithium ion battery has a recharge cycle capacity of at least 2,000 times, which is more than for their lead acid batteries that have recharge cycle capacity of 250–300 times (www.Smith-Root.com/electrofishers/batteries).

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