

Articles

Factors Influencing the Postrelease Movements of Translocated Fishers: Implications for Translocation Success

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Abstract

Long distance, postrelease movements of translocated wildlife can be a key factor limiting translocation success. Yet, for many species, we have little or no understanding of factors that influence postrelease movements. Translocations have been important for recovering fisher *Pekania pennanti* populations across the southern portion of their North American range. However, little is known about the postrelease movements of translocated fishers and how these movements may be influenced by demographic or translocation-process factors. To restore fishers in Washington State, we moved 90 fishers from central British Columbia and released them at nine sites in the Olympic Fisher Recovery Area on the Olympic Peninsula of Washington from 2008 to 2010. We evaluated postrelease movements of 48 fishers to determine both the distance and duration of movements prior to home range establishment. Fishers moved extensively following their release. Multimodel selection indicated a high level of support for the hypothesis that postrelease movements differed by fisher sex and age; whereas, year of release had no apparent effect on movements, and release date had only a marginal influence on movements. Mean distance ($\pm 95\%$ CI) from a release site to a home range was greater for adult males (62.0 ± 19.6 km) than for juvenile males (31.4 ± 16.0 km), adult females (30.9 ± 21.1 km), and juvenile females (29.0 ± 13.5 km). Mean number of days from release until home range establishment was similar for the sexes; however, the variance in movement duration was greater for females. Twenty-six of 27 females established home ranges over an 11-mo period (December–October), while 19 of 21 males did so within a 4-mo period (April–July). Mean home range sizes differed between males (128.3 ± 21.1 km²) and females (63.5 ± 9.0 km²) and were among the largest reported for the species. A greater proportion of females (18 of 27; 67%) than males (8 of 21; 38%) established home ranges within or partially within the recovery area. Six females left a previously established home range during the breeding season, presumably to find breeding males. Given the large distances that fishers can move following release, translocation success could be furthered by releasing individuals at fewer sites in the interior of large reintroduction areas to facilitate greater exposure to a recovery area and greater opportunity to interact with conspecifics and potential mates.

Keywords: endangered; fisher; *Pekania pennanti*; postrelease movements; translocation

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Introduction

Long-distance, postrelease dispersal of released animals has been identified as a primary factor limiting successful population reestablishment following species translocations (Armstrong and Seddon 2008; Moehrenschrager and Lloyd 2016; Swaisgood and Ruiz-Miranda 2018; Berger-tal et al. 2020). The uncertainty that dispersal imposes on translocation success is based on the unpredictable behavior of stressed individuals being released into a foreign environment and forced to move about safely to find food and cover, potential mates, and a suitable home range (Armstrong and Seddon 2008; Parker et al. 2012). This exploration can increase an individual's risk to predation and other sources of mortality, and the level of risk is likely to increase with postrelease movements of greater distance or duration. Individuals that disperse beyond selected release or recovery areas will likely encounter landscapes with less high-quality habitat, fewer potential mates, or a greater number of predators and hazards (Miller et al. 1999; Stamps and Swaisgood 2007; Spinola et al. 2008; Le Gouar et al. 2012; Harrington et al. 2013). Consequently, long-distance dispersers may be less likely to contribute to translocation success (Van Heezik et al. 2009; Ryckman et al. 2010; Swaisgood and Ruiz-Miranda 2018; Berger-Tal et al. 2020).

In the contiguous United States (U.S.), translocations have played a key role in restoring populations of the fisher *Pekania pennanti*, a mid-sized carnivore of the family Mustelidae (weasels and allies). Historically, fishers occurred throughout the northern temperate and boreal forests of North America (Powell 1993; Lewis et al. 2012). Extremely high prices paid for fisher pelts in the late 1800s and early 1900s (up to ~\$350 U.S./pelt; Seton 1926; Bailey 1936; Grinnell et al. 1937; Dalquest 1948) caused the fisher to be overexploited and extirpated from much of the southern portion of its range in the northern United States and southern Canada (Strickland et al. 1982; Powell 1993), including all of Washington State, where it is listed as an endangered species (Hayes and Lewis 2006; Lewis et al. 2018). Since the mid-1900s, ≥ 35 fisher translocations have been reported within the fisher's historical range in North America, and ≥ 25 of these (~71%) resulted in the successful establishment of a population (Lewis et al. 2012).

Many factors may influence the movements of translocated individuals following release, including sex and age (Moehrenschrager and MacDonald 2003; Van Heezik et al. 2009; Ryckman et al. 2010; Nussear et al. 2012), the timing of releases (Proulx et al. 1994), number and location of release sites (Powell et al. 2012), the size and quality of the release or recovery areas (Linklater and

Swaisgood 2008; Le Gouar et al. 2012; Osborne and Seddon 2012), and the presence of conspecifics in a release area (Sjoasen 1997; Van Heezik et al. 2009; Mihoub et al. 2011). One or more of these factors could be correlated with reduced movements (in distance or duration), greater fidelity to a reintroduction area, or more rapid home range establishment. Managers could then use this information to shape translocation processes and founder populations to minimize post-release movements and presumably enhance the odds of successfully restoring populations (Linklater and Swaisgood 2008; Canessa et al. 2014; Batson et al. 2015; Moehrenschrager and Lloyd 2016).

Despite the abundance of fisher translocation programs (Lewis et al. 2012), only one published study reported information about the postrelease movements of radiocollared individuals (Proulx et al. 1994). Information about postrelease movements from previous fisher translocations is largely anecdotal and indicates that these movements varied greatly in distance, duration, and outcome (Weckwerth and Wright 1968; Roy 1991; Heinemeyer 1993; Proulx et al. 1994; Weir 1995; Fontana et al. 1999; Serfass et al. 2001). These previous studies were instrumental in helping us frame a priori models of factors potentially affecting postrelease movements of fishers in Washington.

To reestablish a self-sustaining population in Washington, partners from State, Provincial, Federal, and private organizations translocated 90 fishers from central British Columbia to Olympic National Park from 2008 to 2010 (Lewis et al. 2018). We evaluated factors that could influence postrelease movements and translocation success to inform future translocation efforts in the State. Our specific objectives were to 1) describe the distance and duration of fisher movements from release sites to established home ranges; 2) evaluate the effects of sex, age, release date, and release-year cohort on the timing of home range establishment, the distance fishers move from a release site to an established home range, and the duration of these movements; 3) estimate home range size and locations; and 4) characterize exploratory forays made by fishers outside established home ranges. Data used for our analyses are available on U.S. Geological Survey ScienceBase catalog (Happe et al. 2022) and in Supplemental Materials (Reference Data S1, S2).

Study Area

The study area (14,412 km² [5,564 mi²], centered at 47.76°N, -123.53°E) encompassed most of the Olympic Peninsula in western Washington, which is bordered by the Pacific Ocean to the west, the Strait of Juan de Fuca



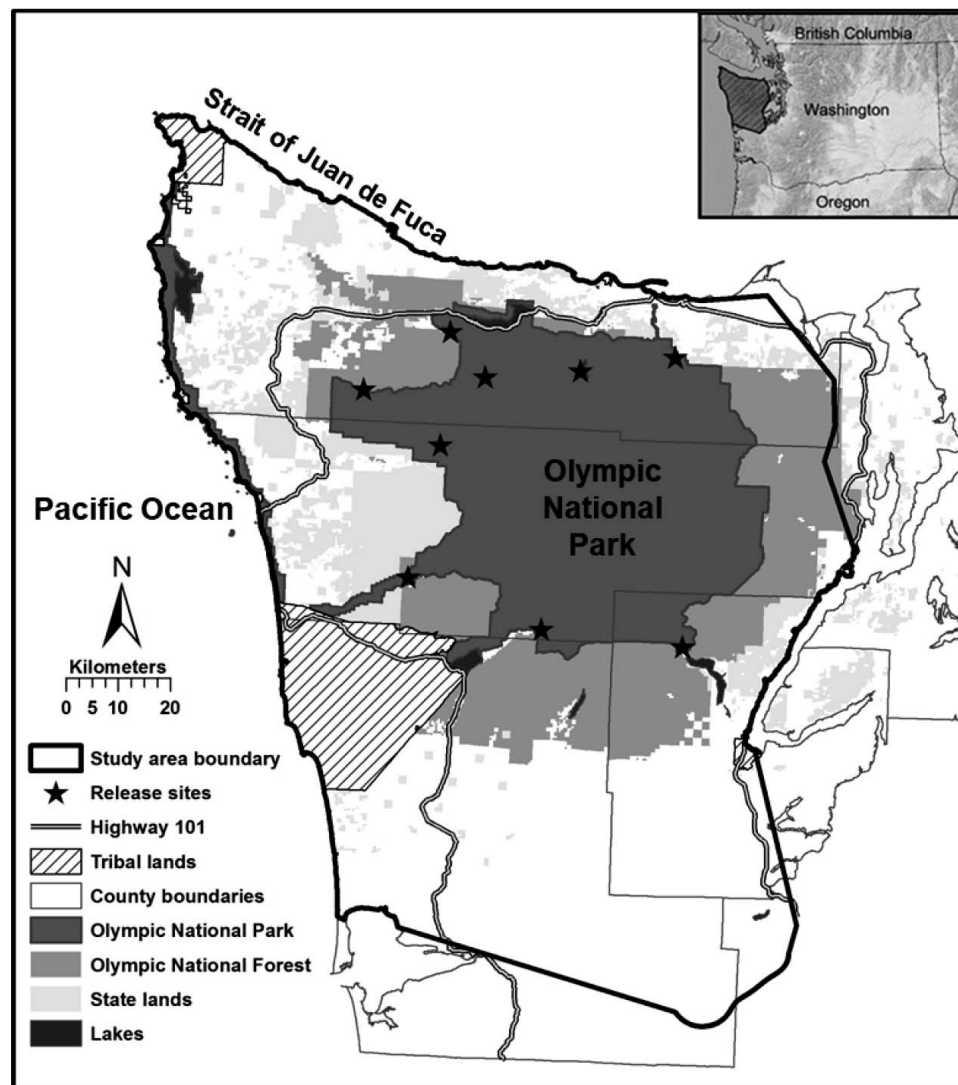


Figure 1. Study area and land ownerships on the Olympic Peninsula, Washington, where fishers *Pekania pennanti* were released and monitored from 2008 to 2011. Stars indicate general areas where fishers were released from 2008 to 2010.

to the north, and Puget Sound to the east (Figure 1). The center of the Peninsula is dominated by the Olympic Mountains, which rise from sea level to 2,415 m atop Mount Olympus. The central mountainous core of the Peninsula lies mostly within Olympic National Park and Olympic National Forest, where management favors wilderness preservation and retention of late-seral forest characteristics. Lower elevations are mosaics of Federal, State, Tribal, and private lands that are managed with greater emphasis on commercial timber production (apart from low-elevation parts of Olympic National Park; Figure 1). We identified the combined Olympic National Park and Olympic National Forest (6,275 km²) as the Olympic Fisher Recovery Area (OFRA) because, on account of its abundance of mid- and late-seral forest cover, we considered it to be the optimal area in Washington State for supporting a self-sustaining population of fishers (Lewis and Hayes 2004; Hayes and Lewis 2006).

The Olympic Peninsula has a temperate, maritime climate characterized by warm summers and cool winters (Peel et al. 2007). Annual precipitation ranges from 315 to 500 cm on the western slope of the Olympic Mountains; whereas annual precipitation is typically < 40 cm in the rain-shadow of the Olympic Mountains (the northeastern corner of the Olympic Peninsula; Gavin and Brubaker 2015). Eighty percent of annual precipitation on the Olympic Peninsula falls from October through March. Most winter precipitation falls as rain at elevations < 305 m (1,000 ft) and as snow above 760 m (2,500 ft).

The moist climate and broad range of elevations support a diversity of conifer-forest vegetation types across the Peninsula (Franklin and Dyrness 1988; Houston and Schreiner 1994; National Park Service 2005). Low- to mid-elevation forests are dominated by Sitka spruce *Picea sitchensis* (primarily in the western valleys and Pacific coastal area), whereas Douglas-fir *Pseudotsuga menziesii*, western hemlock *Tsuga hetero-*

phylla, western redcedar *Thuja plicata*, Pacific silver fir *Abies amabilis* zone, mountain hemlock *Tsuga mertensiana*, and subalpine fir *Abies lasiocarpa* assume greater dominance at mid- and higher elevations (Franklin and Dyrness 1988; Houston and Schreiner 1994). Forests in the Sitka spruce zone on the western Olympic Peninsula are often referred to as temperate rainforests, and are characterized by large-diameter trees, epiphytic plants, and dense understory vegetation (Franklin and Dyrness 1988). Hardwoods (red alder *Alnus rubra*, bigleaf maple *Acer macrophyllum*, and black cottonwood *Populus trichocarpa*) are common in riparian forests along major rivers (Houston and Schreiner 1994; National Park Service 2005).

In addition to translocated fishers, the Olympic Peninsula study area was occupied by a diverse community of mammalian carnivores. This community included black bears *Ursus americanus*, coyotes *Canis latrans*, mountain lions *Puma concolor*, bobcats *Lynx rufus*, river otters *Lontra canadensis*, Pacific martens *Martes caurina*, western spotted skunks *Spilogale gracilis*, long-tailed weasels *Mustela frenata*, and ermines *Mustela erminea* (Happe et al. 2020). Bobcats, mountain lions, and coyotes are known predators of fishers (Powell 1993; Lewis 2014; Wengert et al. 2014).

Methods

Radiocollaring and release

From January 2008 to February 2010, project partners captured 90 fishers (50 F, 40 M) in central British Columbia and temporarily held them in captivity for a health assessment and approval by a licensed veterinarian. We transported approved fishers to the Olympic Peninsula generally within 10–30 d following capture (with exception of five individuals that were held longer for additional veterinary care; Lewis 2014; Table 1). To facilitate postrelease monitoring, we equipped 82 (50 F, 32 M) fishers with a 40-g VHF radiocollar (model MI-2 with mortality sensor, Holohil Systems Ltd, Carp, Ontario, Canada; <http://www.holohil.com>). Of the remaining eight translocated fishers, we equipped five males (each weighing > 4.5 kg) with a 120-g Argos satellite collar (Kiwisat 202; Sirtrack Ltd., Havelock North, New Zealand; <http://www.sirtrack.com>) and equipped three males with a 41-g VHF transmitter (model IMP/310/L with mortality sensor; Telonics Inc., Mesa, AZ; <http://www.telonics.com>) surgically implanted in the abdominal cavity.

We transported fishers by truck from the captive facility in central British Columbia to Port Angeles, Washington, in 1 d. Upon arrival in Washington, we housed fishers overnight in their transport boxes and released them the following morning at predetermined release sites in the OFRA. From January 2008 to February 2010, we released 90 fishers at nine general areas within the Park to facilitate fisher occupancy of large landscapes dominated by late-seral conifer forest (Figure 1; Lewis 2014). Animal handling procedures met or exceeded guidelines of the American Society of Mammalogists for the use of wild mammals for research (Sikes and the

Table 1. Number of fishers *Pekania pennanti* released on the Olympic Peninsula, Washington, from 27 January 2008 to 20 February 2010, by release-year cohort, release dates, sex, and age class.

Release-year cohort	Fisher age	Females	Males	Totals
Release-year cohort 1 ^a	<1	3	1	4
	≥1	9	5	14
	All	12	6	18
Release-year cohort 2 ^b	<1	6	7	13
	≥1	14	4	18
	All	20	11	31
Release-year cohort 3 ^c	<1	7	12	19
	≥1	11	11 ^d	22
	All	18	23	41
Grand totals		50	40	90

^a Fishers in release-year cohort 1 were released on 27 Jan 2008 and 2 Mar 2008.

^b Fishers in release-year cohort 2 were released on 21 Dec 2008, 17 Jan 2009, and 23 Feb 2009.

^c Fishers in release-year cohort 3 were released on 24 Dec 2009, 21 Jan 2010, and 20 Feb 2010.

^d Five adult males were equipped with Argos collars that subsequently failed; only one of these males was included in our analysis.

Animal Care and Use Committee of the American Society of Mammalogists 2016) and were approved by the British Columbia Ministry of Environment (Permit WL07-40389).

Radiotelemetry

We monitored postrelease movements by radiotracking fishers from a fixed-wing aircraft, although we also occasionally located them from the ground when close to roads. We attempted to locate each fisher at least once per week; however, inclement weather prevented flights during some weeks, and the large size and rugged terrain of the study area, the short transmission distance of the radio collars, and the extensive movements of many fishers, made it impossible to locate each fisher every week. During each flight, we surveyed a portion of the study area by flying parallel flight-lines (approximately 5 km apart) over forested habitats. We located fishers by scanning the frequencies of radio collars until a signal was detected. After a transmitter signal was detected, the pilot isolated a fisher to a specific location, which we recorded as coordinates of the Universal Transverse Mercator grid system using a global positioning system. We gave each location an accuracy rating based on the flight biologist's judgment of signal strength, altitude of the aircraft, and time spent locating the fisher. We gave an accuracy rating of 1.5 to locations with an estimated error < 500 m, a rating of 2 for locations with an estimated error < 1 km, a rating of 3 for locations with an estimated error < 5 km, and a rating of 4 for locations with an estimated error > 5 km. We gave a rating of 1 to ground locations where the location was known (e.g., carcass found, visual observation, fisher occupying a known den), or considered to have an error ≤ 100 m.

We evaluated the accuracy of aerial locations by placing test collars at 31 known locations within the



study area that were representative of the range of topographic and vegetation conditions occupied by fishers. The locations of test collars were unknown to our pilots, so we obtained unbiased estimates of location errors by having pilots estimate test collar locations with the same intensity of search effort they used when locating a fisher. Test collar locations that were given an accuracy rating of 1.5 had a mean location error of 281 ± 47 m (SE), and locations given an accuracy rating of 2 had a mean location error of 420 ± 117 m. Thus, the accuracy of test-collar locations was generally greater than that indicated by the assigned accuracy rating.

For analyses of postrelease movements and home range estimation, we used only locations with accuracy ratings ≤ 2 . To avoid temporal autocorrelation, we used locations collected ≥ 24 h apart. We used no more than 1 telemetry location/wk derived from ground radio-tracking procedures to minimize any bias associated with a greater number of ground locations for fishers that occupied areas with greater vehicle access. We made an exception to this rule for male M011 because this male inhabited an area that was entirely accessible by vehicle and its movements were consistently monitored from the ground at routine intervals by the staff of the Makah Tribal Forestry Department.

Postrelease movements and home range establishment

After release, fishers generally explore their new environment prior to establishing a home range (Heinemeyer 1993; Proulx et al. 1994; Weir 1995). The nature of this exploration may vary considerably among individuals, but once a translocated fisher finds a suitable location, its movements become more localized and shorter in distance as it establishes a home range (Weir 1995). To identify a change in movement distances associated with home range establishment, we calculated the mean-squared distance (MSD) between consecutive locations for each fisher, following the methods of Weir (1995) and Weir et al. (2009). We calculated MSD by squaring the six individual distances between the first seven locations (e.g., distance from location 1 to 2, 2 to 3, ... 6 to 7) and then averaging those six distances. We repeated this calculation for all locations in each fisher's data set in increments of seven locations (i.e., distances between locations 1–7, 2–8, 3–9, etc.) until an MSD value was calculated for all groupings of six consecutive movement distances. To estimate the date when home range establishment began, we plotted MSD (y-axis) against date (x-axis) and examined these data to identify a date when MSD decreased noticeably and remained at a lower level; we used a minimum of 10 locations collected for ≥ 2 consecutive months to indicate home range establishment.

We estimated the distance from each fisher's release site to its newly established home range by measuring the distance from the release site to the geographic center of the first 10 home range locations (dependent variable:

Distance; Data S1, *Supplemental Material*). We characterized the duration of a postrelease movement as the number of days between each fisher's release date and the estimated date of home range establishment (i.e., date of the first home range location; dependent variable: Duration; Data S1, *Supplemental Material*). We established several a priori models of factors potentially influencing either distance or duration of postrelease movements. Based on previous studies of dispersal behavior of mammals (Greenwood 1980; Clobert et al. 2012) and the limited dispersal information for fishers (Leonard 1980; Arthur et al. 1993; York 1996; Aubry et al. 2004), we hypothesized that postrelease movements (either distance or duration) may differ between sexes and age-classes of fishers (independent variables: Sex and Age; including Sex $\times$ Age interaction). We classed all released fishers as juveniles (i.e., age < 1 y old at time of release) or adults (≥ 1 y old at time of release [yearlings were approaching their second birthday at time of release]). The initiation of the breeding season has biological importance for fisher movements and reproductive behavior (Douglas and Strickland 1987; Powell 1993; Facka et al. 2016); therefore, we also hypothesized that the number of days from a release date until the start of the breeding season (1 March; Powell 1993; independent variable: Release Date) may influence postrelease movements. Consequently, we evaluated both the number of days from a release date to home range establishment and the calendar dates of home range establishment. Lastly, the presence of conspecifics within a release area can influence the movements of subsequently released individuals; therefore, we evaluated the influence of cohort membership on the postrelease movements of individuals released in year 1, 2, or 3 (independent variable: Release-Year Cohort). We modeled potential linear effects of one- and two-variable models (as well as sex $\times$ age-class interaction) on Distance and Duration using PROC GENMOD in SAS (SAS Institute, Inc. 2009). We evaluated relative parsimony among models by ranking candidate models with Akaike's Information Criteria for small samples (AIC_c ; Burnham and Anderson 2002). We collectively examined the maximized log-likelihood and ΔAIC_c values and significance levels of individual model parameters to rule out uninformative model parameters (Burnham and Anderson 2002:131; Arnold 2010).

Home range size and exploratory forays

We estimated home range sizes for fishers with ≥ 20 locations collected over ≥ 6 consecutive months following the estimated date of home range establishment (Data S2, *Supplemental Material*). To allow comparisons among fisher populations, we used two common methods to estimate the configuration and size of fisher home ranges (Lofroth et al. 2010). We used the fixed-kernel method with smoothing parameters selected by least-squares cross-validation (Worton 1989) to estimate 95% (home range) and 50% (core area) utilization distribution contours. We also estimated home



Table 2. Outcome of postrelease movements of 90 radiocollared fishers *Pekania pennanti* released from 27 January 2008 to 20 February 2010 on the Olympic Peninsula, Washington, by release-year cohort and sex.

Outcome	Females, n (%)				Males, n (%)			
	Cohort 1 (n = 12)	Cohort 2 (n = 20)	Cohort 3 (n = 18)	All (n = 50)	Cohort 1 (n = 6)	Cohort 2 (n = 11)	Cohort 3 (n = 23)	All (n = 40)
Home range established ^a	10 (83)	7 (35)	10 (56)	27 (54)	5 (83)	6 (55)	10 (43)	21 (53)
Insufficient data to indicate establishment ^b	2 (17)	13 (65)	8 (44)	23 (46)	1 (17)	5 (45)	13 (57)	19 (47)

^a Home range establishment was identified for 48 fishers (27 F, 21 M) that occupied a localized area based on > 10 locations collected over > 2 consecutive mo.

^b Data were insufficient because 1) contact was intermittent or lost, 2) a mortality occurred (remains were recovered), or 3) a mortality signal was detected but the fisher's status as alive or dead could not be determined. We conducted extensive aerial searches regularly to locate missing fishers (lost signals), so we attributed most of these losses to transmitter failure as opposed to emigration from the peninsular study area.

ranges using the 100% minimum convex polygon method. We used Home Range Tools for Arc GIS (Rodgers et al. 2007) to delineate home ranges and Program Animal Space Use (Horne and Garton 2009) to calculate smoothing parameters.

When estimating home ranges, we identified exploratory forays outside established home ranges and removed telemetry locations associated with those forays. We defined exploratory forays as movements associated with telemetry locations > 2 interquartile ranges from the median x or y location coordinates of all locations obtained during the period of home range occupancy, where those locations existed as isolated kernels (containing ≤ 2 locations) separate from the primary home range distribution (i.e., 95% fixed kernel utilization distribution). These forays occurred outside home range boundaries, so we eliminated all locations associated with exploratory forays and re-estimated home ranges and core areas from the remaining locations. We also measured the distances from outlier points to the perimeter of the home range to evaluate the seasonal patterns and magnitude of exploratory forays among radio-collared fishers.

Results

Postrelease movements and home range establishment

Among the 90 fishers released from 2008 to 2010, 48 (27 F, 21 M) met our criteria for home range establish-

ment (Table 2). Movement distances to home ranges, the number of days to home range establishment, and the timing of home range establishment, varied substantially among individuals (Figures 2–4). Fishers established home ranges at distances ranging from 2.6 to 108.0 km from their release sites and the number of days from release to home range establishment ranged from 2 to 383 d after release (Figures 2 and 3; Table 3). The best-supported model of factors associated with distance to a home range included effects of sex, age, and sex × age interaction (Table 4). This top model garnered 62% of the total model weight. The beta coefficient for sex × age interaction was highly significant ($\beta = -28,694$, SE = 12,417, $P = 0.02$), indicating that postrelease dispersal distances of adult males were approximately 28.7 km longer on average than the those of females or juvenile males (Table 3). Although there was moderate model support for individual effects of sex and age (without interaction), age effects clearly influenced movements of males. As a result of these age- and sex-related differences in postrelease movements, a greater proportion of females (18 of 27; 67%) than males (8 of 21; 38%) established home ranges nearer to their release sites and within or partially within the Olympic Recovery Area ($z = 1.97$, $P = 0.04$; Figure 2).

We found weak support for a slight negative effect of release date on postrelease movements of fishers. Models containing release date garnered 10% of the total model weights. The β coefficient for release date in the univariate model was -244 ± 150 (SE, $t = 1.65$, $P = 0.10$), indicating a small but marginally significant

Table 3. Mean distance from the release site to the center of a home range and mean number of days from the release date to the home range establishment date for 48 translocated fishers *Pekania pennanti* (27 F, 21 M) that established a home range on the Olympic Peninsula, Washington, 2008–2011.

Sex and age	Distance (km) from release site to home range center			Days from release to home range establishment		
	Mean	95% CI ^a	Range	Mean	95% CI ^a	Range
Females (n)						
<1 y old (11)	29.8	15.5–42.5	3.1–60.4	140.3	84–197	6–270
≥1 y old (16)	30.9	21.1–40.6	4.1–66.4	143.1	92–193	2–383
All (27)	30.1	22.7–37.5	3.1–66.4	142.9	107–178	2–383
Males (n)						
<1 y old (12)	31.4	15.3–47.4	2.6–92.5	138.9	112–166	8–195
≥1 y old (9)	62.0	42.4–81.6	30.9–108.0	135.7	89–182	43–272
All (21)	44.5	31.2–57.8	2.6–108.0	137.9	115–161	8–272

^a 95% confidence interval.



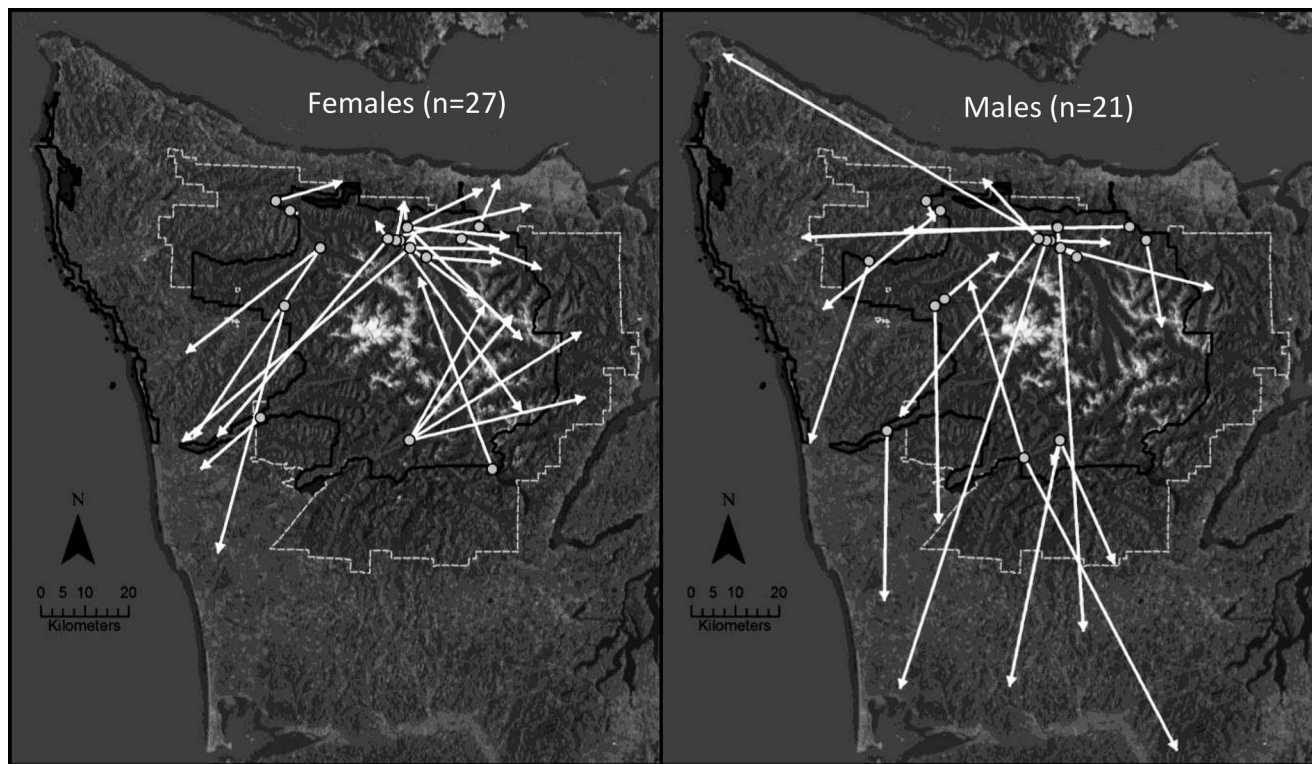


Figure 2. Vectors illustrating straight-line distances from fisher *Pekania pennanti* release sites to the center of corresponding home ranges of 27 females and 21 males that established home ranges on the Olympic Peninsula, Washington, 2008–2011. Olympic National Park (black boundary) and Olympic National Forest (dashed white line outside the park) comprise the Olympic Fisher Recovery Area.

negative effect on movement distances for fishers released closer to the onset of the breeding season (1 March). There was essentially no model support for the effect of release-year cohort on postrelease movement distances of translocated fishers.

We found negligible support for the effects of any model variables on the duration of postrelease movements of fishers prior to home range establishment (Table 5). The null model, indicating no covariate effects, was the highest-supported model, garnering 40% of the total model weight. Univariate models containing potential effects of release date, sex, and age were moderately supported based on AIC_c values near 2, but log-likelihood values of these models were essentially equal, indicating model fit was not improved by the addition of these variables (Burnham and Anderson 2002; Arnold 2010).

Despite no discernable difference in the mean duration of postrelease movements among sex and age classes of fishers, the variance in movement duration was greater for females than for males ($F = 3.02$, $P = 0.007$). Twenty-six of 27 females established home ranges over an 11-mo period (from December to October) in their first year, while 19 of 21 males established home ranges within a 4-mo period (April to July; Figure 4). Males had a clear peak of home range establishment in June, whereas the distribution of

establishment dates of females was bimodal with lesser peaks in April and August (Figure 4).

Home range size and distribution

We estimated home range sizes for 29 (19 F, 10 M) of the 90 fishers released from 2008 to 2010 (Table 6; Figure 5). Female home ranges were estimated with an average of 40.1 ± 3.6 (SE) telemetry locations (range: 20–70) obtained over an average of 508 ± 45 d (range: 197–912), whereas the home ranges of males had an average of 30.1 ± 3.3 locations (range: 23–57) obtained over an average of 476 ± 55 d (range: 226–838). Mean home range sizes were larger for males than for females based on both the 95% utilization distribution contours (128.3 km^2 vs. 63.5 km^2 , respectively; t -test for unequal variances = -2.82 , $df = 12$, $P = 0.015$) and the 100% minimum convex polygon method (79.6 km^2 vs. 50.8 km^2 , respectively; t -test for unequal variances = -2.55 , $df = 26$, $P = 0.017$; Table 6; Figure 5).

The disproportionately greater number of females than males that established home ranges within the OFRA was greater still when considering only the 29 fishers for which we had sufficient location data to estimate home range size (Figure 5): 15 of 19 females (79%) as compared with 3 of 10 males (30%; $z = 2.77$, $P = 0.005$). There was limited overlap of estimated home ranges of males and females as indicated by only 3 of

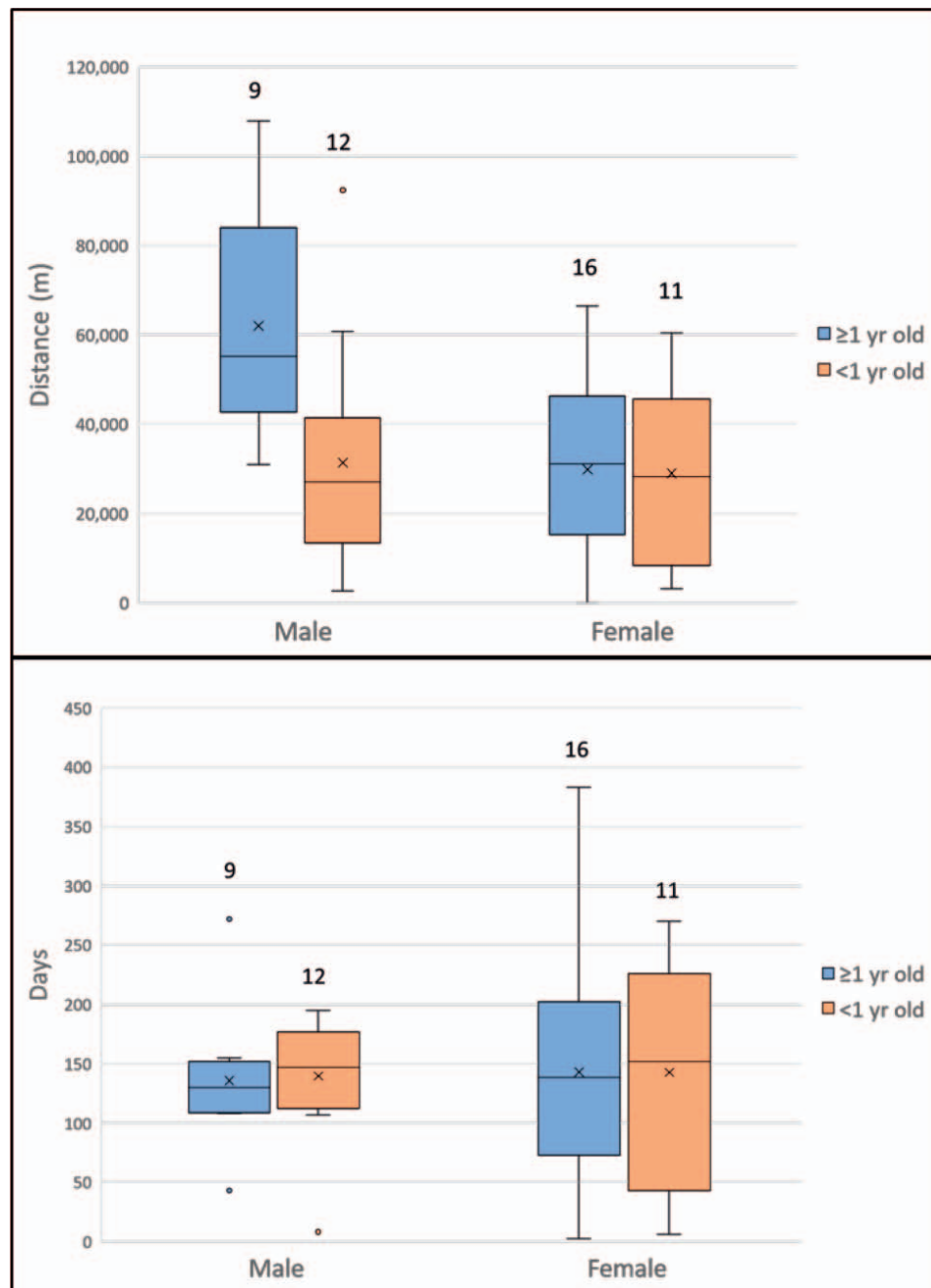


Figure 3. Distributions of distances (m) and duration (days) of postrelease movements of translocated fishers *Pekania pennanti* in Olympic National Park, Washington, 2008–2011. Each box shows the 25th–75th percentiles of the data with the median (horizontal line) and means (x) shown within. Whiskers display the range of remaining values with the exception of outlier points (shown as dots), which were > 1.5 inner quartile ranges from nearest observation in the distribution. Sample sizes for each group are shown above each box.

10 male home ranges overlapping by $> 5\%$ with home ranges of 5 of the 19 females. The extent of home range overlap we observed may have been underestimated because of the possible presence and home range establishment of fishers with failed transmitters. Female home ranges overlapped spatially in 3 locations in the study area; male home ranges did not overlap (Figure 5).

Exploratory forays

Both male and female fishers made exploratory forays beyond the boundaries of their home ranges, and several did this on > 1 occasion (Table S1, *Supplemental Material*). We obtained 10 locations for males > 10 km from their home ranges, and 14 such locations for females (Figure 6). Examination of these locations indicated eight forays made by six females (ages 2–6

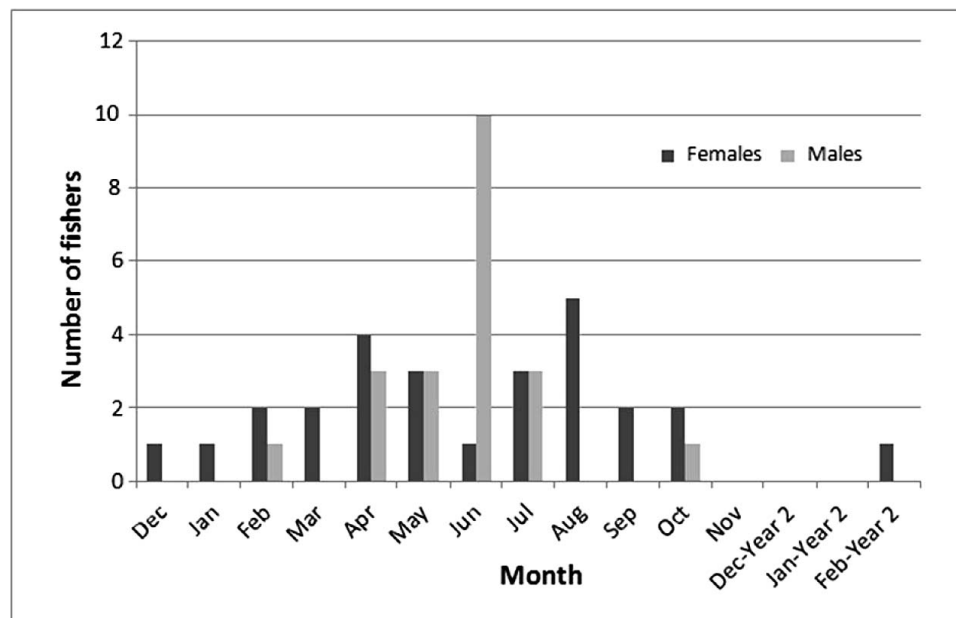


Figure 4. The month of establishment for 27 female and 21 male fishers *Pekania pennanti* that established home ranges on the Olympic Peninsula, Washington, 2008–2011. Dates of home range establishment were constrained by release dates; fishers were released from 21 December to 2 March.

y) and five forays made by four males (ages 2–4 y; Table S1, *Supplemental Material*). Fishers were located > 10 km beyond their home range boundaries only during the breeding season (1 March to 30 June; Figure 6). Male forays were concentrated during the breeding season, whereas females also made shorter forays (< 10 km) outside the breeding season (Figure 6). The

duration of these forays ranged from 26 to 130 d for males and from 12 to 100 d for females (Table S1, *Supplemental Material*). In addition to breeding season forays, we observed three females shift core-use-areas within established home ranges, with two of these spatial shifts initiated during the breeding season. We also observed three fishers (2 F, 1 M) abandon

Table 4. Model selection results for covariates potentially affecting distance between release sites and established home ranges of fishers *Pekania pennanti* released on Washington's Olympic Peninsula, 2008–2010. Model covariates included sex (male vs. female), age (< 1 vs. ≥ 1 y old), release date (number of days fishers were released before the onset of breeding season [1 March]), and release-year cohort (1 = 2008, 2 = 2009, 3 = 2010). Model selection results for each a priori model include the number of estimable parameters (K), Akaike's Information Criterion for small samples (AIC_c), AIC_c differences (ΔAIC_c), -2 log-likelihood values, and Akaike weights (ω_i ; Burnham and Anderson 2002).

Model	K	AIC_c	ΔAIC_c	-2 log-likelihood	ω_i
Sex + Age + Sex × Age	5	1,103.31	0.00	1,091.88	0.62
Sex + Age	4	1,105.88	2.56	1,096.95	0.17
Sex + Release date	4	1,107.93	4.62	1,099.00	0.06
Sex	3	1,108.26	4.95	1,101.71	0.05
Age	3	1,109.66	6.34	1,103.11	0.03
Release date	3	1,109.97	6.66	1,103.43	0.02
Null	2	1,110.28	6.97	1,106.02	0.02
Age + Release date	4	1,110.78	7.47	1,101.85	0.01
Sex + Cohort	5	1,110.96	7.65	1,099.53	0.01
Cohort	4	1,113.72	10.40	1,104.79	0.00
Age + Cohort	5	1,113.94	10.63	1,102.52	0.00

Table 5. Model selection results for factors potentially affecting the number of days elapsed between release dates and home range establishment for fishers *Pekania pennanti* released on Washington's Olympic Peninsula, 2008–2010. Model covariates included sex (male vs. female), age (< 1 vs. ≥ 1 y old), release date (number of days fishers were released before the onset of breeding season [1 March]), and release-year cohort (1 = 2008, 2 = 2009, 3 = 2010). Model selection results for each a priori model include the number of estimable parameters (K), Akaike's Information Criterion for small samples (AIC_c), AIC_c differences (ΔAIC_c), -2 log-likelihood values, and Akaike weights (ω_i ; Burnham and Anderson 2002).

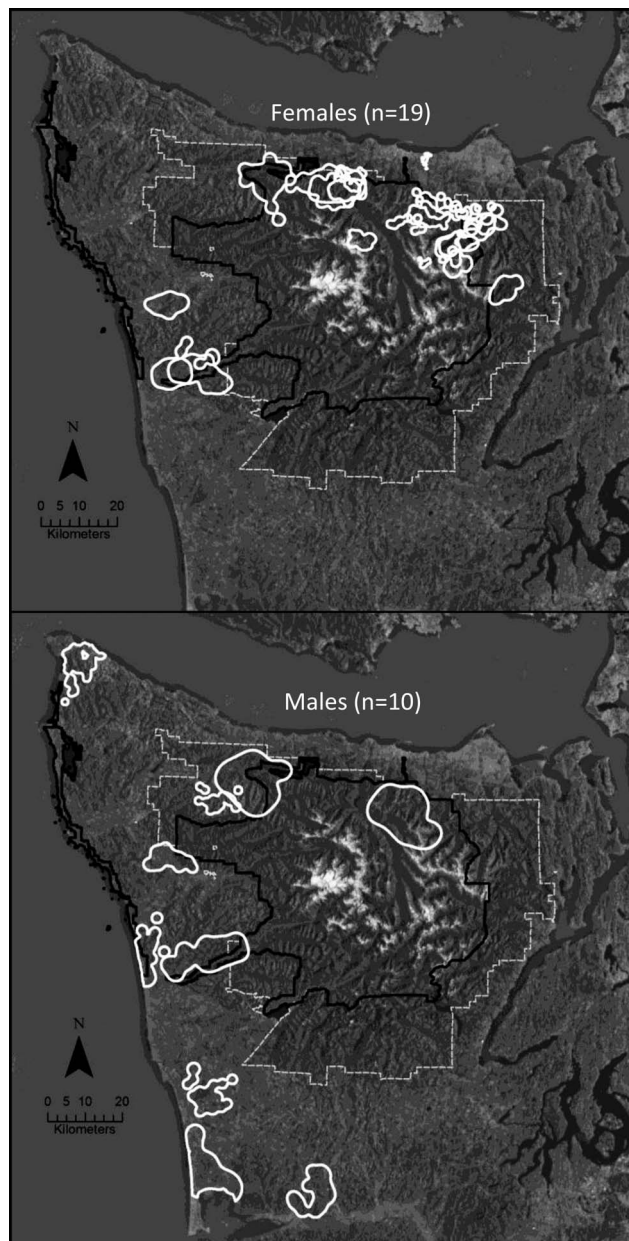
Model	K	AIC_c	ΔAIC_c	-2 log-likelihood	ω_i
Null	2	558.26	0.00	553.99	0.40
Release date	3	560.40	2.14	553.85	0.14
Sex	3	560.49	2.23	553.94	0.13
Age	3	560.54	2.28	553.99	0.13
Cohort	4	562.63	4.37	553.70	0.04
Sex + Release date	4	562.74	4.48	553.81	0.04
Age + Release date	4	562.77	4.51	553.84	0.04
Sex + Age	4	562.87	4.61	553.94	0.04
Sex + Cohort	5	565.04	6.78	553.62	0.01
Age + Cohort	5	565.11	6.85	553.68	0.01
Sex + Age + Sex × Age	5	565.36	7.10	553.93	0.01

Table 6. Estimates of home range and core area sizes (km²) for fishers *Pekania pennanti* released on the Olympic Peninsula, Washington, 2008–2010; sizes were estimated for fishers with ≥ 20 home range locations obtained over ≥ 6 consecutive months.

Estimator	Females (n = 19)			Males (n = 10)		
	Mean	95% CI	Range	Mean	95% CI	Range
100% MCP ^a	50.8	33.9–67.6	3.2–126.6	79.6	65.2–93.9	38.5–188.1
95% UD ^b	63.5	45.8–81.1	2.9–136.7	128.3	86.8–169.7	49.9–238.7
50% UD ^b (core area)	15.3	10.8–19.7	0.6–39.1	32.8	22.1–43.4	12.1–63.8

^a MCP = Minimum convex polygon estimate of home range.

^b UD = Utilization distribution estimate of a home range (95%) or core area (50%) using a fixed-kernel estimating procedure.

**Figure 5.** Estimated home ranges (95% fixed-kernel utilization distributions) for female and male fishers *Pekania pennanti* on the Olympic Peninsula, Washington, 2008–2011. Olympic National Park (black boundary) and Olympic National Park (dashed white boundary outside the park) comprise the Olympic Recovery Area.

established home ranges during the breeding season and establish new home ranges > 20 km away after the breeding season.

Discussion

We released 90 fishers mostly along the periphery of a large (6,275 km²) recovery area (the OFRA) because it comprised the largest block of continuous fisher habitat and because of the limited road access to its central interior. The OFRA was dominated by unmanaged mid- and late-seral forests, which have been considered high-quality habitat for fishers (Lewis and Hayes 2004; Raley et al. 2012; Lewis et al. 2016). We estimated that this area would support > 50 fishers because of its size and habitat composition (Lewis and Hayes 2004); however, we could not predict how individuals would move once released in the OFRA or if enough would remain in the recovery area to initiate a population. The movement distances and durations we observed varied broadly for individual fishers, resulting in many fishers dispersing beyond the boundary of the recovery area. Despite these broad movements, our follow-up monitoring of released fishers on the Olympic Peninsula study area from 2013 to 2016 indicated persistence and a widespread distribution of the founding individuals and their progeny for ≥ 6 y following the last releases (Happe et al. 2020). Hence, the movement patterns we observed contributed to successful population establishment, at least over the short term (Happe et al. 2020).

Our strategy of releasing the 90 founders across nine release areas over 3 y was based on two main objectives: 1) reducing the incidence of injuries or mortalities that could result from antagonistic interactions when releasing many, likely stressed, individuals simultaneously at a single release site; and 2) establishing fishers broadly across the recovery area to facilitate widespread occupancy and population growth. Based on the number of exploratory forays made by females during the breeding season, however, we suspect that broadly distributing fishers may have hindered their ability to quickly find potential mates. We hypothesize that the prevalence of extraterritorial movements of females we observed during the breeding season may have been associated with a scarcity of breeding males. Moreover, the wide spacing of release sites may have reduced the frequency of intraspecific interactions among released individuals and extended the exploratory movement phase as individuals sought mates, other conspecifics,



Variability in both postrelease movement distances and durations highlights the extent to which individual behaviors may also influence restoration outcomes. In addition to sex-specific differences in habitat affinities of fishers, postrelease movements of fishers may also reflect individual differences in innate characteristics such as boldness, responses to stress, and responses to being released in a foreign environment (Dickens et al. 2010; Moehrenschrager and Lloyd 2016). Stamps and Swaisgood (2007) hypothesized that individuals from a source population in one area of a species' range may not readily identify important habitat qualities in another part of its range. Poor recognition of habitat quality could prompt released-individuals to search extensively for familiar-looking habitats and place them at greater

Postrelease dispersal distances of translocated fishers in Washington were typically greater than juvenile dispersal distances reported in resident native populations. Rather, postrelease dispersal distances in the OFRA were comparable to the longest postnatal dispersal distances previously reported. Arthur et al. (1993)

Table 7. Home range size estimates for fishers *Pekania pennanti* in western North America, based on studies conducted from 1983 to 2021.

			Home range size (km ²)	
Study	Location	Method ^a	Males (n)	Females (n)
MCP estimates				
Weir et al. 2009	Central British Columbia	100% MCP	144.2 (3)	52.6 (11)
This study	Olympic Peninsula, Washington	100% MCP	79.6 (10)	50.8 (19)
Yaeger 2005	Northwestern California	100% MCP	38.3 (9)	23.5 (7)
Zielinski et al. 2004	Northwestern California	100% MCP	58.1 (2)	15.0 (7)
Buck et al. 1983	Northwestern California	100% MCP	19.8 (5)	4.2 (4)
Mazzoni 2002	Southern Sierra Nevada	100% MCP	21.9 (4)	11.9 (7)
Zielinski et al. 2004	Southern Sierra Nevada	100% MCP	30.0 (4)	5.3 (8)
Badry et al. 1997	Central Alberta	95% MCP	24.3 (2)	14.9 (5)
Aubry and Raley 2006	Southern Cascades, Oregon	95% MCP	62.0 (4)	25.0 (7)
Other estimates				
Davis 2009	Central British Columbia	95% FK	166.4 (1)	30.6 (9)
Weir et al. 2009	Central British Columbia	95% FK	161.3 (3)	37.9 (11)
This study	Olympic Peninsula, Washington	95% FK	128.3 (10)	63.5 (19)
Heinemeyer 1993	Northwestern Montana	90% AK	85.2 (2)	27.5 (7)
Jones 1991	North-central Idaho	90% HM	78.6 (6)	40.5 (4)

^a Methods included: Minimum Convex Polygon (MCP); Fixed Kernel (FK); Adaptive Kernel (AK); and Harmonic Mean (HM).

evaluated the dispersal of 13 juvenile fishers in a resident population in Maine and found that dispersal distances ranged from 4.5 to 19.5 km and did not differ between males and females. In a resident population in Massachusetts, York (1996) reported greater dispersal distances for males (10–60 km; $\bar{x} = 25$; $n = 10$) and females (12–107 km; $\bar{x} = 37$; $n = 19$), which did not differ statistically by sex. Dispersal distances > 50 km were also reported for individual fishers in Manitoba (Leonard 1980) and Oregon (Aubry et al. 2004).

The mean duration of postrelease movements of fishers did not differ appreciably among sex- and age-classes, although the duration of movements of females was highly variable compared with males. Similarly, duration of movements was not demonstrably related to other process variables such as duration of captivity or release dates relative to the onset of breeding. The apparent lack of pattern amidst high variability in movement durations suggests the potential for other unmeasured factors (e.g., prey abundance or availability, reproductive status, habitat selection behavior) to influence movements and home range establishment, particularly for females. We did not determine the reproductive status of all females that established home ranges, but the effects of reproductive status on postrelease movements may have been an important unmeasured variable and warrants additional study. The narrow range of home range establishments by males near the end of breeding (in June) suggests that the timing of the breeding season had a more uniform influence on males than females.

The initial home ranges of fishers translocated from central British Columbia to the OFRA (this study) were among the largest reported for the species in western North America (Table 7). Habitat selection by translocated individuals is likely to be influenced by the natal environment (Stamps and Swaisgood 2007); therefore, translocated individuals may be inefficient at exploiting foreign environments and this inefficiency may require

translocated individuals to use relatively large home ranges to meet their energetic needs (Weilenmann et al. 2010; Russell et al. 2010). However, this inefficiency (and a corresponding home range size) may diminish as individuals gain familiarity with a new environment (Moehrenschrager and Macdonald 2003; Nussear et al. 2012) and would be less likely to affect offspring born in the recovery area. Additional research will help us understand how natal environments and postrelease movements of founder individuals relate to home range establishment and habitat selection by subsequent generations of fishers inside and outside the OFRA. It will also enable us to further evaluate the suitability of the landscapes within and outside the OFRA for supporting a restored fisher population on the Olympic Peninsula (Happe et al. 2020).

Management and Research Implications

Poor survival and long-distance dispersal of released individuals can have substantial effects on translocation success, so Armstrong and Seddon (2008) proposed several research questions to provide information for increasing the likelihood of success. These questions included “How are postrelease survival and dispersal affected by pre- and postrelease management?” Fishers may be less likely to leave a recovery area if they are released within the central interior of large landscapes (e.g., $\geq 1,000$ km²) that are dominated by optimal habitats. We also see benefit in releasing fishers at a small number of release sites (2–3) that are not widely dispersed (e.g., within 1–2 male-home-range diameters from each other) to facilitate conspecific interactions (i.e., mate acquisition, responding to positive cues [e.g., scent, scat] that indicate habitat quality). This approach may be especially useful when few individuals have been released (e.g., the first year of a project; translocations with small founder populations; Le Gouar et al. 2012).



Consolidating release sites could also reduce the number of risky breeding-season forays made by females.

The movements made by released females (and males) varied considerably by individual, release area, or the release year. Based on these findings, we have a better understanding of the proportion of the female population that could disperse beyond the bounds of a release area. An estimate of the loss of founder individuals to dispersal would be valuable information when planning the acquisition of an optimal founder population.

These implementation considerations were used in planning, conducting, and adaptively managing an ongoing fisher translocation in the Cascade Fisher Recovery Area in Washington (2008 to present; Lewis 2013, Lewis et al. 2020), where 81 fishers were released at 3 centrally located sites within the southern portion of the recovery area. These approaches may also have useful applications for planning proposed translocations of fishers in Oregon (Hiller 2015) or Montana (Coltrane and Inman 2021), for translocations being considered for wolverines in Colorado and California (Young et al. 2012; Wolverine Translocation Techniques Working Group 2013; McKelvey et al. 2014), or for translocations of other wide-ranging carnivores. Given the importance of postrelease movements and survival of released individuals for translocation success, an expansion of research and monitoring efforts to track factors affecting the relationships between postrelease movements and survival could provide key support for fisher recovery programs and those for other endangered carnivore populations. We also recognize several other fruitful avenues for future studies of translocated carnivores pertaining to relationships between postrelease movements of fishers, innate personality characteristics of founders, conspecific attraction, and habitat selection between natal and recovery areas.

Supplemental Material

Please note: *The Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Data S1. Movement distance and duration data for 48 fishers *Pekania pennanti* that established home ranges following release in Olympic National Park, Washington, 2008–2010. Data include covariates evaluated as influences of postrelease movement distance and duration, which include the sex, age, release date, and release-year cohort membership of each fisher.

Available: <https://doi.org/10.3996/JFWM-21-023.S1> (15 KB XLSX)

Data S2. Home range estimate data and associated attribute data for 29 fishers *Pekania pennanti* (19 F, 10 M) released in Olympic National Park, Washington, 2008–2010. Home range estimate data (i.e., area in km²) include fixed-kernel estimates for 95% (home range) and 50% (core area) contours, and 100% minimum convex polygon estimates of home ranges. Associated fisher attribute

data include the following variables: sex, release-year cohort membership, age at home range establishment, duration and timing of home range occupancy.

Available: <https://doi.org/10.3996/JFWM-21-023.S2> (44 KB XLS)

Table S1. Breeding season forays > 10 km from a home range boundary for 10 of 29 fishers *Pekania pennanti* with estimated home ranges on the Olympic Peninsula, Washington, 2008–2011. The breeding season for fishers is 1 March to 30 June.

Available: <https://doi.org/10.3996/JFWM-21-023.S3> (26 KB DOCX)

Reference S1. Aubry KB, Raley CM. 2006. Ecological characteristics of fishers (*Martes pennanti*) in the southern Oregon Cascade Range, update: July 2006. Olympia, Washington: U.S. Forest Service, Pacific Northwest Research Station.

Available: <https://doi.org/10.3996/JFWM-21-023.S4> (1.028 MB PDF)

Reference S2. Buck S, Mullis C, Mossman A. 1983. Final Report: Corral Bottom–Hayfork Bally fisher study. Arcata, California: Humboldt State University.

Available: <https://doi.org/10.3996/JFWM-21-023.S5> (3.585 MB PDF)

Reference S3. Davis LR. 2009. Denning ecology and habitat use by fisher (*Martes pennanti*) in pine dominated ecosystems of the Chilcotin Plateau. Master's thesis. Burnaby, British Columbia: Simon Fraser University.

Available: <https://doi.org/10.3996/JFWM-21-023.S6> (555 KB PDF)

Reference S4. Fontana AJ, Teske IE, Pritchard K, Evans M. 1999. East Kootenay fisher reintroduction program, 1996. Cranbrook: British Columbia Ministry of Environment, Lands, and Parks.

Available: <https://doi.org/10.3996/JFWM-21-023.S7> (2.157 MB PDF)

Reference S5. Heinemeyer KS. 1993. Temporal dynamics in the movements, habitat use, activity, and spacing of reintroduced fishers in northwestern Montana. Master's thesis. Missoula: University of Montana.

Available: <https://doi.org/10.3996/JFWM-21-023.S8> (7.486 MB PDF)

Reference S6. Hiller TL. 2015. Feasibility assessment for the reintroduction of fishers in western Oregon, USA. Portland, Oregon: U.S. Fish and Wildlife Service.

Available: <https://doi.org/10.3996/JFWM-21-023.S9> (3.335 MB PDF)

Reference S7. Jones JL. 1991. Habitat use of fisher in northcentral Idaho. Master's thesis. Moscow: University of Idaho.

Available: <https://doi.org/10.3996/JFWM-21-023.S10> (11.273 MB PDF)



Reference S8. Leonard RD. 1980. The winter activity and movements, winter diet and breeding biology of the fisher (*Martes pennanti*) in southeastern Manitoba. Master's thesis. Winnipeg: University of Manitoba.

Available: <https://doi.org/10.3996/JFWM-21-023.S11> (7.509 MB PDF)

Reference S9. Lewis JC, Ransom JI, Chestnut T, Werntz DO, Black S, Postigo JL, Moehrenschrager A. 2020. Cascades fisher reintroduction project: progress report for April 2019 to June 2020. Natural Resource Report NPS/PWR/NRR—2020/2211. Fort Collins, Colorado: National Park Service.

Available: <https://doi.org/10.3996/JFWM-21-023.S12> (5.033 MB PDF) and <http://www.npshistory.com/publications/mora/nrr-2020-2211.pdf>

Reference S10. Mazzoni AK. 2002. Habitat use by fishers (*Martes pennanti*) in the southern Sierra Nevada, California. Master's thesis. Fresno: California State University.

Available: <https://doi.org/10.3996/JFWM-21-023.S13> (1.465 MB PDF)

Reference S11. National Park Service. 2005. Fire management plan and environmental assessment. Port Angeles, Washington: Olympic National Park.

Available: <https://doi.org/10.3996/JFWM-21-023.S14> (1.404 MB PDF)

Reference S12. Roy KD. 1991. Ecology of reintroduced fishers in the Cabinet Mountains of northwest Montana. Master's thesis. Missoula: University of Montana.

Available: <https://doi.org/10.3996/JFWM-21-023.S15> (4.261 MB PDF)

Reference S13. Serfass TL, Brooks RP, Tzilkowski WM. 2001. Fisher reintroduction in Pennsylvania: final report of the Pennsylvania fisher reintroduction project. Frostburg, Maryland: Frostburg State University.

Available: <https://doi.org/10.3996/JFWM-21-023.S16> (7.380 MB PDF)

Reference S14. USDA Forest Service, and USDI Bureau of Land Management. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Portland, Oregon: U.S. Department of Agriculture Forest Service and U.S. Department of the Interior Bureau of Land Management.

Available: <https://doi.org/10.3996/JFWM-21-023.S17> (650 KB PDF)

Reference S15. Weir RD. 1995. Diet, spatial organization, and habitat relationships of fishers in south-central British Columbia. Master's thesis. Burnaby, British Columbia: Simon Fraser University.

Available: <https://doi.org/10.3996/JFWM-21-023.S18> (8.041 MB PDF)

Reference S16. Yaeger JS. 2005. Habitat at fisher resting sites in the Klamath Province of northern California. Master's thesis. Arcata, California: Humboldt State University.

Available: <https://doi.org/10.3996/JFWM-21-023.S19> (625 KB PDF)

Reference S17. York EC. 1996. Fisher population dynamics in north-central Massachusetts. Master's thesis. Amherst: University of Massachusetts.

Available: <https://doi.org/10.3996/JFWM-21-023.S20> (4.055 MB PDF)

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References

- Armstrong DP, Seddon PJ. 2008. Directions in reintroduction biology. *Trends in Ecology & Evolution* 23:20–25.
- Aronsson M, Persson J. 2018. Female breeding dispersal in wolverines, a solitary carnivore with high territorial fidelity. *European Journal of Wildlife Research* 64(1):489. Available: <https://doi.org/10.1007/s10344-018-1164-3>
- Arnold TW. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. *Journal of Wildlife Management* 74:1175–1178.
- Arthur SM, Paragi TF, Krohn WB. 1993. Dispersal of juvenile fishers in Maine. *Journal of Wildlife Management* 57:868–874.
- Aubry KB, Raley CM. 2006. Ecological characteristics of fishers (*Martes pennanti*) in the southern Oregon Cascade Range, update: July 2006. Olympia, Washington: U.S. Forest Service, Pacific Northwest Research Station (see *Supplemental Material*, Reference S1).
- Aubry KB, Wisely SM, Raley CM, Buskirk SW. 2004. Zoogeography, spacing patterns, and dispersal in fishers: insights gained from combining field and genetic data. Pages 187–206 in Harrison DJ, Fuller AK, Proulx G, editors. *Martens and fishers (Martes) in human-altered environments: an international perspective*. New York: Springer.
- Badry MJ, Proulx G, Woodard PM. 1997. Home-range and habitat use by fishers translated to the aspen parkland of Alberta. Pages 233–251 in Proulx G, Bryant HN, Woodard PM, editors. *Martes: taxonomy, ecology, techniques, and management*. Edmonton: Provincial Museum of Alberta.
- Bailey VO. 1936. The mammals and life zones of Oregon. *North American Fauna*, No. 55. Washington, D.C.: U.S. Department of Agriculture, Bureau of Biological Survey.
- Batson WG, Gordon IJ, Fletcher DB, Manning AD. 2015. Translocation tactics: a framework to support the IUCN Guidelines for wildlife translocations and improve the quality of applied methods. *Journal of Applied Ecology* 52:1598–1607.
- Berger-Tal O, Blumstein DT, Swaisgood RR. 2020. Conservation translocations: a review of common difficulties and promising directions. *Animal Conservation* 23:121–131.
- British Columbia Ministry of Forests, Mines and Lands. 2010. The state of British Columbia's forests, 3rd edition. Victoria, British Columbia: Forest Practices and Investment Branch. Available: https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/reporting/envreportbc/archived-reports/sof_2010.pdf. (December 2021).
- Buck S, Mullis C, Mossman A. 1983. Final Report: Corral Bottom–Hayfork Bally fisher study. Arcata, California: Humboldt State University (see *Supplemental Material*, Reference S2).
- Burnham KP, Anderson DR. 2002. Model selection and inference: a practical information-theoretic approach. New York: Springer-Verlag.
- Canessa S, Hunter D, McFadden M, Marantelli G, McCarthy MA. 2014. Optimal release strategies for cost-effective reintroductions. *Journal of Applied Ecology*. Available: <https://doi.org/10.1111/1365-2664.12253>
- Clobert J, Baguette M, Benton TG, Bullock JM. 2012. Dispersal ecology and evolution. Oxford, UK: Oxford University Press.
- Coltrane J, Inman R. 2021. Fisher occupancy twenty-five years after translocation in the Rocky Mountains of Montana. *Northwestern Naturalist* 102:43–54.
- Cowan I McT, Guiguet CJ. 1965. The mammals of British Columbia. *British Columbia Provincial Museum Handbook* 11:1–414.
- Dalquest WW. 1948. *Mammals of Washington*. Lawrence: University of Kansas Publications.
- Davis LR. 2009. Denning ecology and habitat use by fisher (*Martes pennanti*) in pine dominated ecosystems of the Chilcotin Plateau. Master's thesis. Burnaby, British Columbia: Simon Fraser University (see *Supplemental Material*, Reference S3).
- Dickens MJ, Delehanty DJ, Romero LM. 2010. Stress: an inevitable component of animal translocation. *Biological Conservation* 143:1329–1341.
- Douglas CW, Strickland MA. 1987. Fisher. Pages 511–529 in Novak MJ, Baker JA, Obbard ME, Malloch B, editors. *Wild furbearer management and conservation in North America*. Toronto: Ontario Ministry of Natural Resources.
- Facka AN, Lewis JC, Happe PJ, Jenkins KJ, Callas R, Powell RA. 2016. Timing of translocation influences birth rate and population dynamics in a forest carnivore. *Ecosphere* 7(1):e01223.10.1002/ecs2.1223
- Fontana AJ, Teske IE, Pritchard K, Evans M. 1999. East Kootenay fisher reintroduction program, 1996. Cranbrook: British Columbia Ministry of Environment, Lands, and Parks (see *Supplemental Material*, Reference S4).
- Franklin JF, Dyrness CT. 1988. *Natural vegetation of Oregon and Washington*. Corvallis: Oregon State University Press.
- Gavin DG, Brubaker LB. 2015. Late Pleistocene and Holocene environmental change on the Olympic Peninsula, Washington. *Ecological Studies* 222. Cham, Switzerland: Springer International Publishing.
- Greenwood PJ. 1980. Mating systems, philopatry and dispersal in birds and mammals. *Animal Behaviour* 28:1140–1162. Available: [https://doi.org/10.1016/S0003-3472\(80\)80103-5](https://doi.org/10.1016/S0003-3472(80)80103-5)



- Grinnell J, Dixon JS, Linsdale JM. 1937. Fur-bearing mammals of California. Berkeley: University of California Press.
- Happe PJ, Jenkins KJ, McCaffery RM, Lewis JC, Pilgrim KL, Schwartz MK. 2020. Occupancy patterns in a reintroduced fisher population during reestablishment. *Journal of Wildlife Management* 84:344–358. Available: <https://doi.org/10.1002/jwmg.21788>
- Happe PJ, Lewis JC, Jenkins KJ. 2022. Post-release point locations and survival history of fishers translocated from British Columbia to Olympic National Park, Washington, 2008–2010: U.S. Geological Survey Data Release. Available: <https://doi.org/10.5066/P9W1P2E0>.
- Harrington LA, Moehrenschrager A, Gelling M, Atkinson RPD, Hughes J, Macdonald DW. 2013. Conflicting and complementary ethics of animal welfare considerations in reintroductions. *Conservation Biology* 27:486–500.
- Hayes GE, Lewis JC. 2006. Washington State recovery plan for the fisher. Olympia: Washington Department of Fish and Wildlife. Available: <https://wdfw.wa.gov/publications/00228> (December 2021).
- Heinemeyer KS. 1993. Temporal dynamics in the movements, habitat use, activity, and spacing of reintroduced fishers in northwestern Montana. Master's thesis. Missoula: University of Montana (see *Supplemental Material*, Reference S5).
- Hiller TL. 2015. Feasibility assessment for the reintroduction of fishers in western Oregon, USA. Portland, Oregon: U.S. Fish and Wildlife Service (see *Supplemental Material*, Reference S6).
- Horne JS, Garton EO. 2009. Animal space use 1.3. Available: (http://www.cnr.uidaho.edu/population_ecology/animal_space_use) (December 2021).
- Houston DB, Schreiner EG. 1994. The Olympic Mountains and environs. Pages 14–26 in Houston, DB, Schreiner EG, Morehead BB, editors. *Mountain goats in Olympic National Park: biology and management of an introduced species*. Scientific Monograph NPS/NRO-LYM/NRSM-94/25. Port Angeles, Washington: U.S. Department of the Interior, National Park Service. Available: https://www.nps.gov/parkhistory/online_books/science/25/ (December 2021).
- Jones JL. 1991. Habitat use of fisher in northcentral Idaho. Master's thesis. Moscow: University of Idaho (see *Supplemental Material*, Reference S7).
- Le Gouar P, Mihoub JB, Sarrazin F. 2012. Dispersal and habitat selection: behavioural and spatial constraints for animal translocations. Pages 139–164 in Ewen JG, Armstrong DP, Parker KA, Seddon PJ, editors. *Reintroduction biology: integrating science and management*. Oxford, UK: Wiley-Blackwell.
- Leonard RD. 1980. The winter activity and movements, winter diet and breeding biology of the fisher (*Martes pennanti*) in southeastern Manitoba. Master's thesis. Winnipeg: University of Manitoba (see *Supplemental Material*, Reference S8).
- Lewis JC. 2013. Implementation plan for reintroducing fishers to the Cascade Mountain Range in Washington. Olympia: Washington Department of Fish and Wildlife. Available: <https://wdfw.wa.gov/publications/01556> (December 2021).
- Lewis JC. 2014. Post-release movements, survival and resource selection of fishers (*Pekania pennanti*) translocated to the Olympic Peninsula of Washington. Doctoral dissertation. Seattle: University of Washington. Available: <https://wdfw.wa.gov/publications/01655> (December 2021).
- Lewis JC, Hayes GE. 2004. Feasibility assessment for reintroducing fishers to Washington. Washington Department of Fish and Wildlife, Olympia, USA. Available: <https://wdfw.wa.gov/publications/00231> (December 2021).
- Lewis JC, Jenkins KJ, Happe PJ, Manson DJ, McCalmon M. 2016. Landscape-scale habitat selection by fishers translocated to the Olympic Peninsula of Washington. *Forest Ecology and Management* 369:170–183.
- Lewis JC, Happe PJ, Jenkins KJ, Werntz DO, Chestnut T, Ransom JI. 2018. Reintroducing fishers (*Pekania pennanti*) to forest ecosystems in Washington State, USA. Pages 198–203 in Soorae PS, editor. *Global reintroduction perspectives: 2018. Case-studies from around the globe*. Gland, Switzerland: International Union for Conservation of Nature/Species Survival Commission Reintroduction Specialist Group. Available: <https://www.researchgate.net/publication/323202814> (December 2021).
- Lewis JC, Powell RA, Zielinski WJ. 2012. Carnivore translocations and conservation: insights from population models and field data for fishers (*Martes pennanti*). *PLoS ONE* 7:e32726. Available: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0032726> (December 2021).
- Lewis JC, Ransom JI, Chestnut T, Werntz DO, Black S, Postigo JL, Moehrenschrager A. 2020. Cascades fisher reintroduction project: progress report for April 2019 to June 2020. Natural Resource Report NPS/PWR/NRR—2020/2211. Fort Collins, Colorado: National Park Service (see *Supplemental Material*, Reference S9).
- Linklater WL, Swaisgood RR. 2008. Reserve size, conspecific density, and translocation success for black rhinoceros. *Journal of Wildlife Management* 72:1059–1068.
- Lofroth EC, Raley CM, Higley JM, Truex RL, Yaeger JS, Lewis JC, Happe PJ, Finley LL, Naney RH, Hale LJ, Krause AL, Livingston SA, Myers AM, Brown RN. 2010. Conservation of fishers (*Martes pennanti*) in south-central British Columbia, western Washington, western Oregon, and California—volume I: conservation assessment. Denver, Colorado: U.S. Department of the Interior, Bureau of Land Management.
- Mazzoni AK. 2002. Habitat use by fishers (*Martes pennanti*) in the southern Sierra Nevada, California. Master's thesis. Fresno: California State University (see *Supplemental Material*, Reference S10).



- McKelvey KS, Aubry KB, Anderson NJ, Clevenger AP, Copeland JP, Heinemeyer KS, Inman RM, Squires JR, Waller JS, Pilgrim KL, Schwartz MK. 2014. Recovery of wolverines in the western United States: recent extirpation and recolonization or range retraction and expansion? *Journal of Wildlife Management* 78:325–334.
- Mihoub JB, Robert A, LeGouar P, Sarrazin F. 2011. Post-release dispersal in animal translocations: social attraction and the “vacuum effect”. *PLoS ONE* 6:e27453.
- Miller B, Ralls K, Reading RP, Scott JM, Estes J. 1999. Biological and technical considerations of carnivore translocation: a review. *Animal Conservation* 2:59–68.
- Moehrenschrager A, Lloyd NA. 2016. Release considerations and techniques to improve conservation translocation success. Pages 245–280 in Jachowski DS, Millspaugh JJ, Angermeier PL, Stotow R, editors. *Reintroduction of fish and wildlife populations*. Oakland: University of California Press.
- Moehrenschrager A, Macdonald DW. 2003. Movement and survival parameters of translocated and resident swift foxes *Vulpes velox*. *Animal Conservation* 6:199–206.
- National Park Service. 2005. Fire management plan and environmental assessment. Port Angeles, Washington: Olympic National Park (see *Supplemental Material*, Reference S11).
- Nussear KE, Tracy CR, Medica PA, Wilson DS, Marlow RW, Corn PS. 2012. Translocation as a conservation tool for Agassiz’s desert tortoises: survivorship, reproduction, and movements. *Journal of Wildlife Management* 76:1341–1353.
- Osborne PE, Seddon PJ. 2012. Selecting suitable habitats for reintroductions: variation, change and the role of species distribution modelling. Pages 73–104 in Ewen JG, Armstrong DP, Parker KA, Seddon PJ, editors. *Reintroduction biology: integrating science and management*. Oxford, UK: Wiley-Blackwell Publishing Ltd.
- Parker KA, Dickens MJ, Clarke RH, Lovegrove TG. 2012. The theory and practice of catching, holding, moving and releasing animals. Pages 105–137 in Ewen JG, Armstrong DP, Parker KA, Seddon PJ, editors. *Reintroduction biology: integrating science and management*. Oxford, UK: Wiley-Blackwell Publishing Ltd.
- Peel MC, Finlayson BL, McMahon TA. 2007. Updated world map of the Köppen–Geiger climate classification. *Hydrology and Earth Systems Sciences* 11:1633–1644.
- Pojar J, Meidinger D. 1991. British Columbia: the environmental setting. Pages 39–67 in Meidinger D, Pojar J, editors. *Ecosystems of British Columbia*, Special Report Series. Volume 6. Victoria, British Columbia: Research Branch, Ministry of Forests.
- Powell RA. 1993. The fisher: life history, ecology, and behavior. Second edition. Minneapolis: University of Minnesota Press.
- Powell RA, Lewis JC, Slough BG, Brainerd SM, Jordan NR, Abramov AV, Monakov V, Zollner PA, Murakami T. 2012. Evaluating translocations of martens, sables, and fishers: testing model predictions with field data. Pages 93–137 in Aubry KB, Zielinski WJ, Raphael MG, Proulx G, Buskirk SW, editors. *Biology and conservation of martens, sables, and fishers: a new synthesis*. Ithaca, New York: Cornell University Press.
- Proulx G, Kolenosky J, Badry M, Drescher MK, Seidel K, Cole PJ. 1994. Post-release movements of translocated fishers. Pages 197–203 in Buskirk SW, Harestad A, Raphael MG, Powell RA, editors. *Martens, sables, and fishers: biology and conservation*. Ithaca, New York: Cornell University Press.
- Raley CM, Lofroth EC, Truex RL, Yaeger JS, Higley JM. 2012. Habitat ecology of fishers in western North America: a new synthesis. Pages 231–254 in Aubry KB, Zielinski WJ, Raphael MG, Proulx G, Buskirk SW, editors. *Biology and conservation of martens, sables, and fishers: a new synthesis*. Ithaca, New York: Cornell University Press.
- Rodgers AR, Carr AP, Beyer HL, Smith L, Kie JG. 2007. HRT: Home Range Tools for ArcGIS. Version 1.1. Thunder Bay: Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research.
- Roy KD. 1991. Ecology of reintroduced fishers in the Cabinet Mountains of northwest Montana. Master’s thesis. Missoula: University of Montana (see *Supplemental Material*, Reference S12).
- Russell JC, McMorland AJC, MacKay JWB. 2010. Exploratory behavior of colonizing rats in a novel environment. *Animal Behaviour* 79:159–164.
- Ryckman MJ, Rosatte RC, McIntosh T, Hamr J, Jenkins D. 2010. Post release dispersal of reintroduced elk (*Cervus elaphus*) in Ontario, Canada. *Restoration Ecology* 18(2):173–180.
- SAS Institute, Inc. 2009. SAS/STAT user’s guide. Release 9.2. Cary, North Carolina: SAS Institute, Inc.
- Serfass TL, Brooks RP, Tzilkowski WM. 2001. Fisher reintroduction in Pennsylvania: final report of the Pennsylvania fisher reintroduction project. Frostburg, Maryland: Frostburg State University (see *Supplemental Material*, Reference S13).
- Seton ET. 1926. Lives of game animals. Volume 2. New York: Doubleday, Doran & Co.
- Sikes RS, and the Animal Care and Use Committee of the American Society of Mammalogists. 2016. Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. *Journal of Mammalogy* 97:663–688.
- Sjoasen T. 1997. Movements and establishment of reintroduced European otters *Lutra lutra*. *Journal of Applied Ecology* 34:1070–1080.
- Spinola RM, Serfass TL, Brooks RP. 2008. Survival and post-release movements of river otters translocated to western New York. *Northeastern Naturalist* 15:13–24.



- Stamps JA, Swaisgood RR. 2007. Someplace like home: experience, selection, and conservation biology. *Applied Animal Behaviour Science* 102:392–409.
- Strickland MA, Douglas CW, Novak M, Hunzinger NP. 1982. Fisher (*Martes pennanti*). Pages 586–598 in Chapman JA, Feldhamer GA, editors. *Wild mammals of North America: biology, management, and economics*. Baltimore, Maryland: Johns Hopkins University Press.
- Swaisgood RR, Ruiz-Miranda C. 2018. Moving animals in the right direction: making conservation translocation an effective tool. Pages 141–156 in Koprowski JL, Krausman PR, editors. *International wildlife: contemporary challenges in a changing world*. Baltimore, Maryland: The Wildlife Society.
- USDA Forest Service, and USDI Bureau of Land Management. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Portland, Oregon: U.S. Department of Agriculture Forest Service and U.S. Department of the Interior Bureau of Land Management (see *Supplemental Material*, Reference S14).
- Van Heezik Y, Maloney RF, Seddon PJ. 2009. Movements of translocated captive-bred and released critically endangered kākī (black stilts) *Himantopus novaezelandiae* and the values of long-term post-release monitoring. *Oryx* 43:639–647.
- Weckwerth RP, Wright PL. 1968. Results of transplanting fishers in Montana. *Journal of Wildlife Management* 32:977–980.
- Weilenmann M, Gusset M, Mills DR, Gabanapelo T, Schiess-Meier M. 2010. Is translocation of stock-raiding leopards into a protected area with resident conspecifics an effective management tool? *Wildlife Research* 37:702–707.
- Weir RD. 1995. Diet, spatial organization, and habitat relationships of fishers in south-central British Columbia. Master's thesis. Burnaby, British Columbia: Simon Fraser University (see *Supplemental Material*, Reference S15).
- Weir RD, Harestad AS, Corbould FB. 2009. Home ranges and spatial organization of fishers in central British Columbia. *Canadian Field-Naturalist* 123:126–132.
- Wengert GM, Gabriel MW, Mathews SM, Higley JM, Sweitzer RA, Thompson CM, Purcell KL, Barrett RH, Woods LW, Green RE, Keller SM, Gaffney PM, Jones M, and Sacks BN. 2014. Using DNA to describe and quantify interspecific killing of fishers in California. *Journal of Wildlife Management* 78:603–611.
- Wolverine Translocation Techniques Working Group. 2013. Restoration of wolverines: considerations for translocation and post-release monitoring. Available: http://jarvprojektet.weebly.com/uploads/1/3/9/2/13929225/2013_aberrestoration_of_wolverines_considerations_for_translocation_and_postrelease_monitoring.pdf (December 2021).
- Worton BJ. 1989. Optimal smoothing parameters for multivariate fixed and adaptive kernel methods. *Journal of Statistical Computation and Simulation* 32:45–57.
- Yaeger JS. 2005. Habitat at fisher resting sites in the Klamath Province of northern California. Master's thesis. Arcata, California: Humboldt State University (see *Supplemental Material*, Reference S16).
- York EC. 1996. Fisher population dynamics in north-central Massachusetts. Master's thesis. Amherst: University of Massachusetts (see *Supplemental Material*, Reference S17).
- Young JK, Hudgens B, Garcelon DK. 2012. Estimates of energy and prey requirements of wolverine. *Northwest Science* 86:221–229.
- Zielinski WJ, Truex RL, Schmidt GA, Schlexer FV, Schmidt KN, Barrett RH. 2004. Home range characteristics of fishers in California. *Journal of Mammalogy* 85:649–657.

