DIET, SPATIAL ORGANIZATION, AND HABITAT RELATIONSHIPS OF FISHERS IN SOUTH-CENTRAL BRITISH COLUMBIA

by

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Diet, Spatial Organization, and Habitat Relationships of Fishers
in South-Central British Columbia

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Abstract

Diet, spatial organization, and habitat relationships of fishers (*Martes pennanti*) were examined in British Columbia using fisher carcasses and a field study of transplanted and resident fishers. Nineteen species of food were found in 261 stomachs. The primary prey of fishers were snowshoe hares (*Lepus americanus*), red squirrels (*Tamiasciurus hudsonicus*), and southern red-backed voles (*Clethrionomys gapperi*). Female fishers consumed small prey more frequently and mustelids less frequently than did males. These difference in diets are likely related to the extreme sexual dimorphism of fishers.

Fifteen fishers (13 F, 2 M) were radio-collared and transplanted into the study area during 2 winters. Fishers wandered extensively while transient. Nine of 15 transplanted fishers established home ranges while in radio-contact, and 8 of them established home ranges by mid-April. Home range establishment appeared to be mediated by reproductive requirements.

Home ranges of fishers in the Sub-Boreal Spruce Biogeoclimatic Zone of British Columbia were smallest during winter and largest during summer. Home ranges of female fishers with kits were smaller than those of females without offspring. Fishers exhibited temporal avoidance rather than intrasexually exclusive home ranges.

Fishers selected habitats at the landscape, stand, patch, and habitat element scales. While transient, transplanted fishers avoided early seral stage forests, and selected for one type of young forest habitat. Fishers did not exhibit selectivity for the inclusion of any particular types of stands in their seasonal home ranges. However, within their home ranges, fishers used non-forested stands less frequently than available. Fishers also exhibited stand level selectivity for habitats grouped by volume of coarse woody debris, vegetation strata, and tree stocking densities. At the patch level, fishers were selective for volume of coarse woody debris, vegetation strata, and tree stocking densities. Fishers used large cottonwood trees for whelping. They used rust brooms or tree cavities in large trees and large coarse woody debris for resting.

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Introduction

The fisher (*Martes pennanti*) is a medium-sized mustelid that occurs throughout most of British Columbia, except on coastal islands and is uncommon in the southern portion of the province (Cowan and Guiget 1973). It is an important furbearing mammal in British Columbia, ranked third to fourth in average pelt value (Banci 1989). Because it occurs at relatively low densities and has low productivity, fishers are susceptible to overtrapping. Recent decreases in harvests, in conjunction with high trapping effort, indicate that serious population declines threaten fishers in British Columbia (V. Banci, B.C. Ministry of Environment, *pers. comm.*).

Effective management of fishers depends upon knowledge of several aspects of their biology. The composition and diversity of their diet constrain fishers' use of their environment and the habitats that they can use. The spatial organization and size of fisher home ranges affect the densities at which fisher populations can occur. Although knowledge of these factors is necessary, most problems in fisher management are related to a lack of understanding of habitat use and critical habitat requirements.

Little is known about the biology of fishers in coniferous forests of western North America. Although use of habitat by fishers has been studied in western United States (California, Schempf and White 1977, Buck *et al.* 1979; Idaho, Jones 1991; Montana, Roy 1990, Heinemeyer 1993; Oregon, Ingram 1973), most studies of fishers are from eastern North America (e.g. Kelly 1977, Powell 1977, Arthur 1987).

The fisher occupies many different forest types throughout its range. Although not considered as old growth dependent as martens (*Martes americana*) (Edwards and

Cowan 1957), fishers use mature to old growth forest seral stages (Grinnell *et al.* 1937, deVos 1952, Ingram 1973, Buck *et al.* 1979, Johnson 1984), especially for resting and natal dens. Ingram (1973) and Douglas and Strickland (1987) predicted that severe and extensive disturbances by logging or fire may seriously reduce habitat value for fishers. In much of British Columbia, critical fisher habitat may be altered because most logging occurs in mature to old-growth forests.

Because an ecological study of fishers has not been conducted in British Columbia, wildlife and habitat managers have been cautious about extrapolating results from other forest types. The goal of my study is to provide information on the diet, spatial organization, and habitat use of fishers to ensure that fisher management prescriptions for British Columbia are developed within an appropriate ecological context.

In Chapter 1, I describe the winter diet of fishers and identify their primary prey species. In Chapter 2, I examine patterns of home range establishment of fishers and determine their spatial organization. In Chapter 3, I examine habitat selectivity by fishers at landscape, stand, patch, and habitat element scales. In Chapter 4, I summarize my results and discuss their implications to the management of fishers and their habitat in British Columbia.

Study Area

Fisher carcasses were collected by the B.C. Ministry of Environment, Lands and Parks from traplines in the Sub-Boreal Spruce (SBS), Montane Spruce, Interior Douglas-fir, Interior Cedar-Hemlock, Sub-Boreal Pine-Spruce and Boreal Black and White Spruce biogeoclimatic zones. Because it was mandatory to submit carcasses of fishers trapped incidentally on traplines within the Cariboo Sub-region during the trapping seasons of 1990-1992, 57% of the carcasses from known locations were from the SBS zone within the Cariboo and Peace-Omineca regions.

The intensive study area is 1500 km^2 and centred 65 km northeast of Williams Lake, British Columbia. It lies entirely within the dry-warm subzone of the SBS zone. The SBS is a heavily-forested, coniferous, montane zone dominating the landscape of the central interior of British Columbia (Fig. 1) and generally occurs from valley bottoms up to 1300 m in elevation (Meidinger *et al.* 1991). The climate of the SBS is continental, and is characterized by severe, snowy winters and relatively warm, moist, and short summers. Mean annual temperatures in the SBS range from 1.7 to 5 C (Meidinger *et al.* 1991).

The study area is composed of 2 biogeoclimatic variants: SBS dry-warm1 and dry-warm2 (SBSdw1 and SBSdw2, respectively) (Fig. 2). These variants reflect differences of regional climate within the SBSdw subzone, and manifest themselves in variations in vegetation, soil, and ecosystem productivity (Pojar *et al.* 1991). The SBSdw2 is slightly drier and cooler than the SBSdw1 (Table 1), and thus the SBSdw1 has somewhat higher ecosystem productivity (B.C. Ministry of Forests 1987). Between 25-

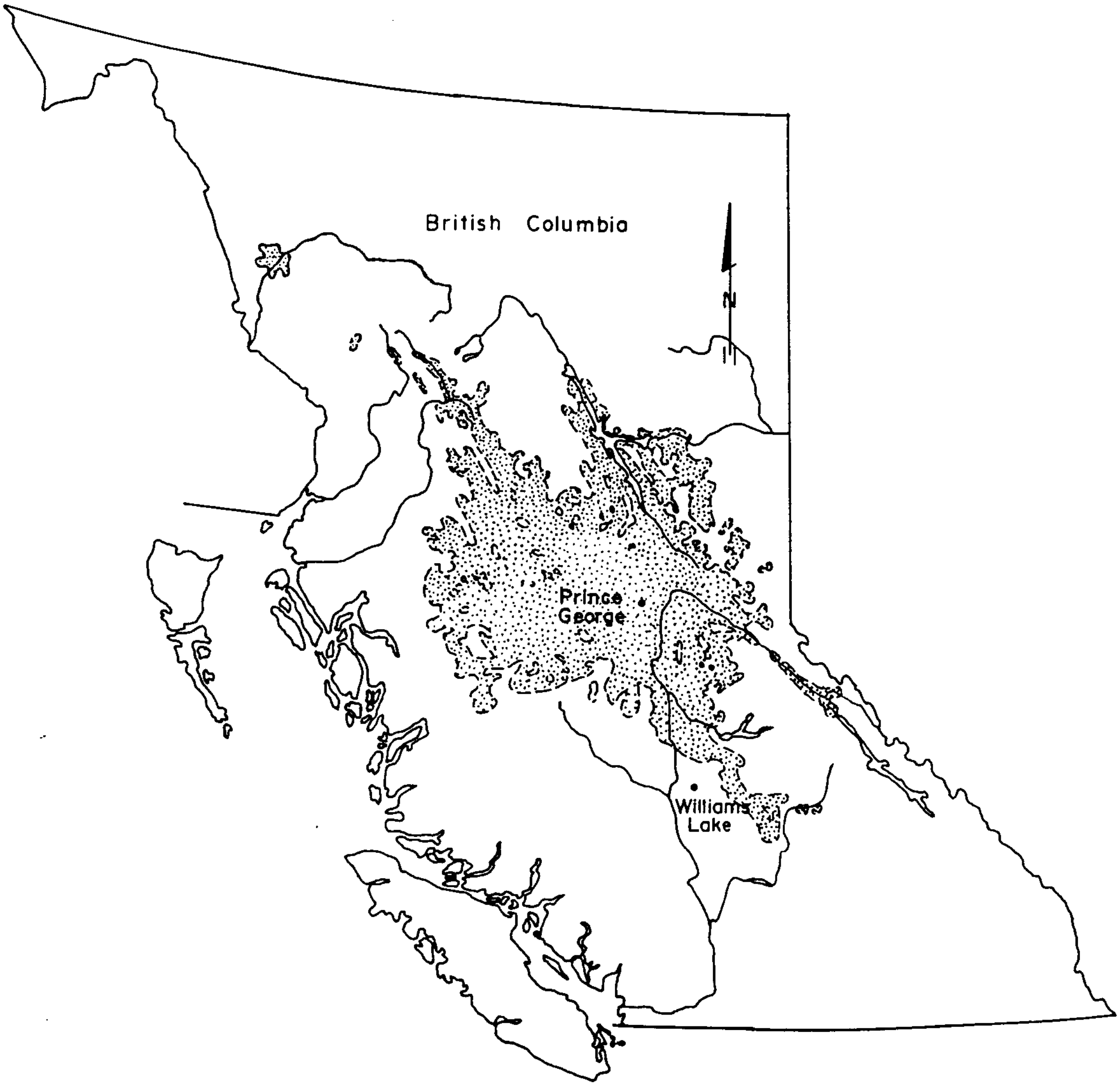


Fig. 1. Extent of the Sub-Boreal Spruce biogeoclimatic zone in British Columbia (adapted from Meidinger *et al.* 1991).

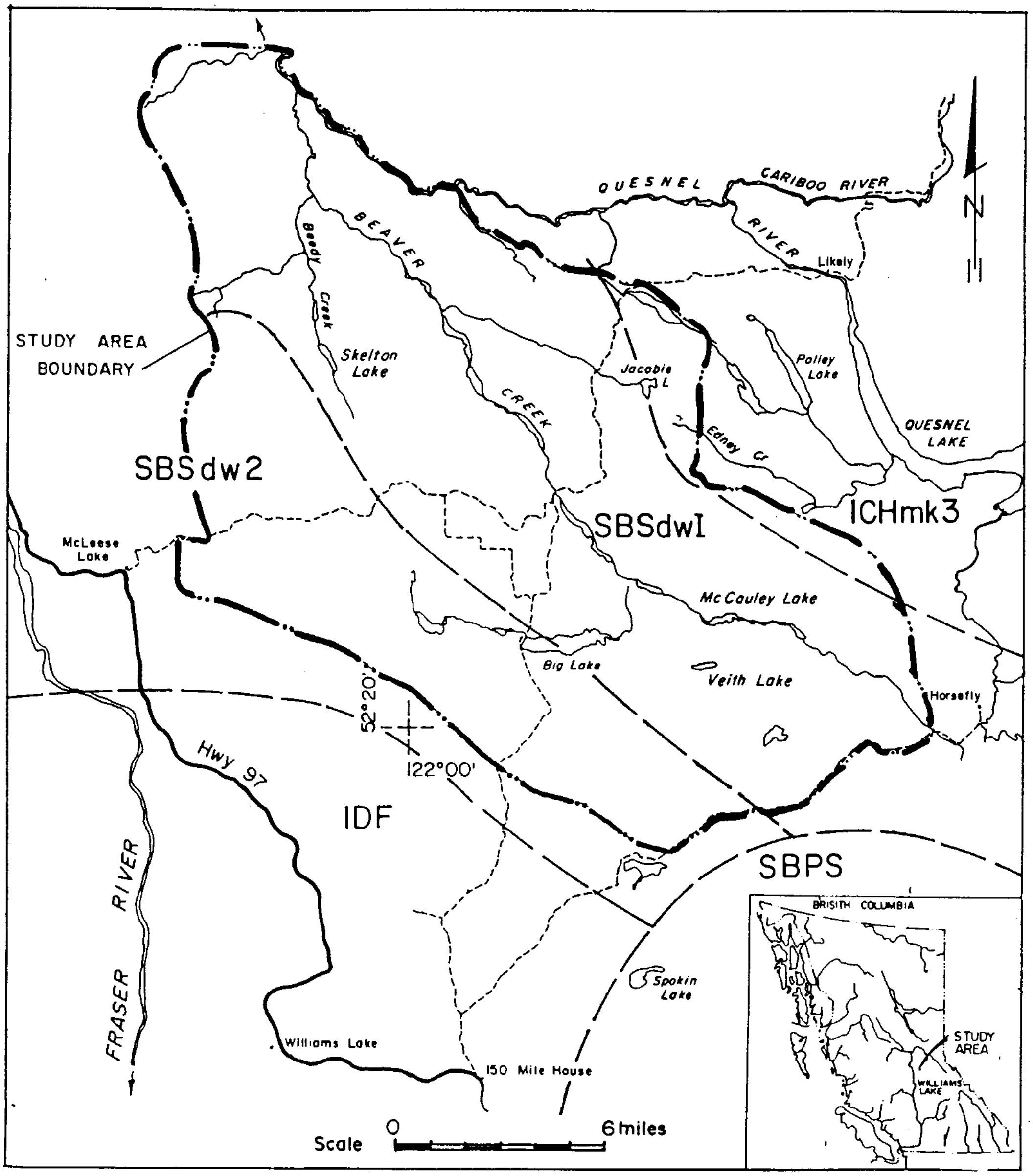


Fig. 2. Location of the study area and biogeoclimatic subzones and variants. The study area is composed entirely of SBSdw1 and SBSdw2 variants. The broken line is the study area boundary.

Table 1. Climate of the SBSdw1 and SBSdw2 variants (B.C. Ministry of Forests 1987).

Variant	Mean annual precipitation (mm)	Mean annual temperature (C)	Mean May-September temperature (C)
SBSdw1	527	3.7	12.8
SBSdw2	493	3.4	11.9

50% of the precipitation in both variants occurs as snowfall (Meidinger *et al.* 1991). Most of the study area lies within the SBSdw1 variant; the SBSdw2 variant covers approximately 30% of the study area. Eastern portions of the SBSdw1 are transitional to the wetter, more productive Interior Cedar-Hemlock biogeoclimatic zone. The study area consists of gently rolling hills, with elevations ranging between 750 and 1250 m. Upper elevations on the western border of the study area are transitional to the moist-cool variant of the SBS, which occurs on hills above 1300 m (B.C. Ministry of Forests 1987). The study area is bounded on the south and southwest by the drier Sub-Boreal Pine-Spruce and Interior Douglas-fir zones, and on the east by the Interior Cedar-Hemlock zone (Fig. 2).

Forests are dominated by Douglas-fir (*Pseudotsuga menziesii*), lodgepole pine (*Pinus contorta*), and hybrid white spruce (*Picea engelmannii* x *glauca*), with minor deciduous components of trembling aspen (*Populus tremuloides*), paper birch (*Betula papyrifera*), and black cottonwood (*Populus balsamifera trichocarpa*). Common understory species are prickly rose (*Rosa acicularis*), falsebox (*Paxistima myrsinites*), thimbleberry (*Rubus parviflorus*), black twinberry (*Lonicera involucrata*), kinnikinnick (*Arctostaphylos uva-ursi*), and saskatoon (*Amelanchier alnifolia*). The SBSdw has a natural disturbance regime of frequent, large scale burns on a cycle of about 300 years, with most stands burning every 100 years (R. Coupé, B.C. Ministry of Forests, *pers. comm.*). Forest harvesting, using a variety of techniques, has occurred over the past 40 years, creating a mosaic of seral stages and stand types throughout the study area. Land clearing for cultivation and cattle grazing has occurred extensively along most valley bottoms.

Succession in the dry-warm subzone follows a typical pattern on mesic sites. Following disturbance by fire, herbs and shrubs initially invade the site, proceeded by an aspen - Douglas-fir pole-sapling stage in wetter sites, and lodgepole pine on well-drained sites. These plant associations remain into the young forest stage, after which Douglas-fir or hybrid spruce dominate the overstory of the mature and old growth seral stages. The amount and species composition of understory vegetation varies among stand types. Overstory canopy closure is typically between 40-80% for young forest to old growth seral stages.

Fishers have been present historically throughout the study area, and have been trapped since at least 1860 (S. Nicol, registered trapline owner, *pers. comm.*). The trapping season in this area is open from the beginning of November through to mid-February, but most of the trappers in the study area agreed to suspend trapping of martens and fishers, or use live traps in areas with resident fishers, during the course of the study. A small, low density, population of fishers likely inhabited the study area prior to the initiation of my study (Hebert 1989).

Chapter 1

Winter Diet of Fishers in British Columbia

Introduction

Within the family Mustelidae, some species are omnivorous (e.g. striped skunks, *Mephitis mephitis*), whereas others are carnivorous (e.g. fishers; wolverines, *Gulo gulo*). Although in some areas fishers specialize on porcupines (*Erethizon dorsatum*) and snowshoe hares (*Lepus americanus*) (Powell 1982), their diet can be quite broad. Other foods include deer (*Odocoileus* spp., primarily as carrion), squirrels (*Tamiasciurus* and *Glaucomys* spp.), microtines, shrews (*Sorex* spp.), birds (mostly passerine and galliform), martens, berries and other vegetation, and even fish and snakes (Coulter 1966, Clem 1977, Kelly 1977, Kuehn 1989, Giuliano *et al.* 1989, Martin 1994).

Fishers switch prey in response to availability (Powell and Brander 1977). This plasticity allows fishers to switch foods when populations of their primary prey decrease and thus compensate for changes in the availability of prey. During a snowshoe hare population decline, the occurrence of hares in the diet decreased (Leonard 1980, Kuehn 1989). In Minnesota, Kuehn (1989) reported that the consumption of small mammals was negatively correlated with the density of snowshoe hares, and noted that fat indices of fisher carcasses did not change with a decline in the snowshoe hare population. He concluded that fishers were not affected significantly by fluctuations in any one prey species because they were able to switch to more available prey at lows in the snowshoe hare cycle.

Many populations of furbearers oscillate with the prey species upon which they rely. Although harvests of fishers in Canada as a whole appear to peak on a 9.7 year cycle (Cowan 1938), Keith (1963) noted that there was no evidence of a fisher cycle in British Columbia, suggesting that British Columbia's fisher populations do not specialize on a single prey species. The diets of fishers in British Columbia should be more diverse than elsewhere in their range because fishers may not rely heavily upon snowshoe hares and use alternate prey when snowshoe hare populations decline.

Sexual dimorphism in mustelids has been hypothesized as a mechanism to partition resources and reduce dietary overlap between the sexes (Brown and Lasiewski 1972). Fishers are sexually dimorphic, with males about 70% larger than females. Although food niche separation is expected in fisher diets, researchers have detected little difference between diets of the two sexes (Coulter 1966, Clem 1977, Kuehn 1989). Male fishers consume more carrion and fruit than do females (Giuliano *et al.* 1989, Kuehn 1989), but dietary overlap is still high, leading Giuliano *et al.* (1989) to conclude that prey partitioning between the sexes is unlikely.

Knowledge of the composition of the fisher's winter diet is important for several reasons. Fishers are active throughout the winter and during that season experience an energy bottleneck, where energy costs are high and food availability is low compared to other seasons of the year (Powell 1982). During this time, fishers must rely on a limited resident prey base. The composition and breadth of the fisher's winter diet are important for understanding and predicting effects of habitat alteration on the feeding ecology, and therefore individual and population responses to timber harvesting. The relative catchability (Buskirk and Powell 1994) of potential prey during winter will influence diet composition and thus the habitats in which fishers are able to hunt successfully for prey. Composition and breadth of the diet are useful in determining how fishers may respond to changes in prey availability and explain some of the patterns of habitat use of males and females.

Unfortunately, most published information about the diets of fishers are from studies performed in eastern North America. Little is known about the diets of fishers in western coniferous forests (e.g. British Columbia), where prey diversity is likely different than that in eastern areas. Martin (1994) hypothesized that in western North America, fishers are more reliant on snowshoe hares for food, and so their diet diversity should be lower than that in eastern areas. My objective is to describe the winter food habits of fishers in central British Columbia. I will also examine the diets of different age and sex classes of fishers.

Methods

Trappers donated 331 fisher carcasses from throughout British Columbia between 1989 and 1993. All but one carcass were collected during the winter trapping season. Fisher carcasses were stored frozen at Simon Fraser University and B.C. Ministry of Environment, Lands and Parks facilities in Williams Lake, B.C. I thawed the carcasses for 12 h, after which morphometric measurements were taken. I removed each head and placed it in 70 C water for 45 min, and removed two premolar 4 teeth for cementum aging (Strickland *et al.* 1982, Arthur *et al.* 1992). I tied the stomachs at the cardiac and pyloric sphincters, removed them, sealed them in water-filled bags, and froze them for later examination.

I thawed the stomachs again and washed the contents to remove unidentifiable tissue and extraneous detrital matter. I then oven dried the remaining washed hairs, feathers, and bones for 48 h at 70 C. Macroscopic examination of the stomach contents was performed to aid in identification of prey items. I then spread the dried sample evenly on a 100 x 100 mm grid and selected guard hairs using random coordinates. For each of the first 70 stomachs that I examined, I selected 30 hairs for identification. I was able to identify all of the prey species in each of these stomachs by identifying the first 15 hairs; subsequently, only 15 hairs were selected for identification from the remaining stomachs.

I placed each randomly selected guard hair on a green acetate strip, which was mounted on a labelled microscope slide. A second slide was placed over the acetate and hairs, forming a "sandwich" which was pressed together by four clamps. I heated the hairs, acetate, and slides at 120 C for 20-25 min. Following heating, the cover slide was removed, I displaced each hair approximately 1 mm, and mounted a glass cover-slip permanently over the hairs and acetate.

I identified hairs following the methods of Moore *et al.* (1974) and Kennedy and Carbyn (1981), and feathers following Day (1966). I identified hairs to the lowest taxonomic level possible, and feathers to order. I identified hairs based upon macroscopic features, medullary patterns, and cuticular impressions. Hairs were compared to reference collections and the keys of Moore *et al.* (1974) and Kennedy and Carbyn (1981). Feathers were identified from the formation of the downy barbules found on the rami of the covert feathers. I recorded species of prey and number of food items for each stomach. I arranged prey species into food groups based upon categories of taxa or habitat specific groups (e.g. aquatic mammals), and analyzed them in relation to the sex and age of fishers.

Results

Of the 331 carcasses collected, only 261 had intact stomachs. I identified 19 different prey species in these 261 stomachs (Table 2). Non-digestible material was found in 226 stomachs while 35 stomachs were empty. I found a single food item in 70 stomachs; as many as seven species of food were recorded in one stomach ($\bar{x} = 2.17$ food items per stomach, SE = 0.10, $n = 261$). I recorded 566 food item occurrences in 226 stomachs. The Shannon diversity index (Shannon and Weaver 1949) of food items in the diet was 1.16.

Snowshoe hares were the single most common species of prey identified in the stomachs, occurring in 82 of 261 stomachs (31.4%). Red squirrels were used extensively as well (26.9%), followed by southern red-backed voles (18.5%), and porcupines (16.1%). Fisher hairs were present in 39 of 261 stomachs (14.9%). In 16 of these occurrences, fewer than 5 fisher hairs were found in the sample of 15 hairs. I assumed that these hairs were likely the result of grooming and excluded these occurrences of fisher hairs from further analyses. However, for the remaining 23 occurrences of fisher hairs in the stomachs, more than 5 fisher hairs were identified in the random sample of 15 hairs from the stomachs. Bones, claws and other non-digestible material from fishers were recorded in several of the stomachs that contained large quantities of fisher hair. I

Table 2. Prey species recorded in fisher stomachs collected between 1988-1993 in British Columbia. All but one stomach were collected between November and February. Fishers consumed snowshoe hares most frequently. $n = 261$ stomachs.

Prey species	Frequency (stomachs)	Percentage of stomachs
Soricidae	32	12.3
Leporidae		
Snowshoe hare	82	31.4
Sciuridae		
Northern flying squirrel (*Glaucomys sabrinus*)	15	5.8
Red squirrel (*Tamiasciurus hudsonicus*)	70	26.9
Castoridae		
Beaver	38	14.6
Cricetidae		
Deer mouse (*Peromyscus maniculatus*)	33	12.7
Bushy-tailed woodrat (*Neotoma cinerea*)	4	1.5
Arvicolidae		
Southern red-backed vole (*Clethrionomys gapperi*)	48	18.5
Microtus spp.	15	5.8
Muskrat	37	14.2
Erethizontidae		
Porcupine	42	16.1
Mustelidae		
Marten	23	8.8
Fisher	39	15.8
Short-tailed weasel (*Mustela erminea*)	2	0.9
Artiodactyla		
Deer	23	8.8
Moose (*Alces alces*)	39	15.8
Domestic cattle	4	1.5
Galliformes	19	7.3
Plants		
Vaccinium spp. berries †	1	0.3

† summer diet item

treated these occurrences as incidences of predation on fishers, and included them in my analyses.

For stomachs with known trapping dates (N = 158), the occurrence of snowshoe hares increased from 6.6% in the 1989-90 trapping season (1 of 15 stomachs) to 41.4% in 1990-91 (12 of 29 stomachs), decreased to 37.0% in 1991-92 (20 of 54 stomachs), and declined further to 30.0% for the season of 1992-93 (18 of 60 stomachs). However, these changes over the four trapping seasons were not statistically significant ($\chi^2 = 6.05$, df = 3, $P < 0.25$).

Based upon similar niches and body sizes, I aggregated the 19 recorded prey species into 9 food groups: small mammals (mice, voles, and shrews), squirrels, galliform birds, snowshoe hares, porcupines, mustelids, ungulates (moose [*Alces alces*] and deer [*Odocoileus* spp.]), aquatic mammals (beavers [*Castor canadensis*] and muskrats [*Ondatra zibethicus*]), and berries. Using this aggregation, small mammals were the most frequently occurring food group in fisher stomachs (132 of 566 food group occurrences; 23.3%), followed by squirrels (15.0%), snowshoe hares (14.5%), aquatic mammals (13.3%), ungulates (12.9%), mustelids (9.5%), porcupines (7.4%), galliform birds (3.4%), and berries (0.2%).

I compared the diets among the different sex and age classes of fishers. There were no significant differences in number of items per stomach among juveniles (<1 yr), subadults (1 yr), and adults (≥2 yr) (Kruskal-Wallis test, $\chi^2 = 0.68$, df = 2, $P < 0.71$), or between sexes (normal approximation of Mann-Whitney test, $Z = -0.57$, $P < 0.57$). There were no significant differences in the occurrences of the 9 food groups among juvenile, subadult, and adult fishers ($\chi^2 = 9.83$, df = 14, $P < 0.77$).

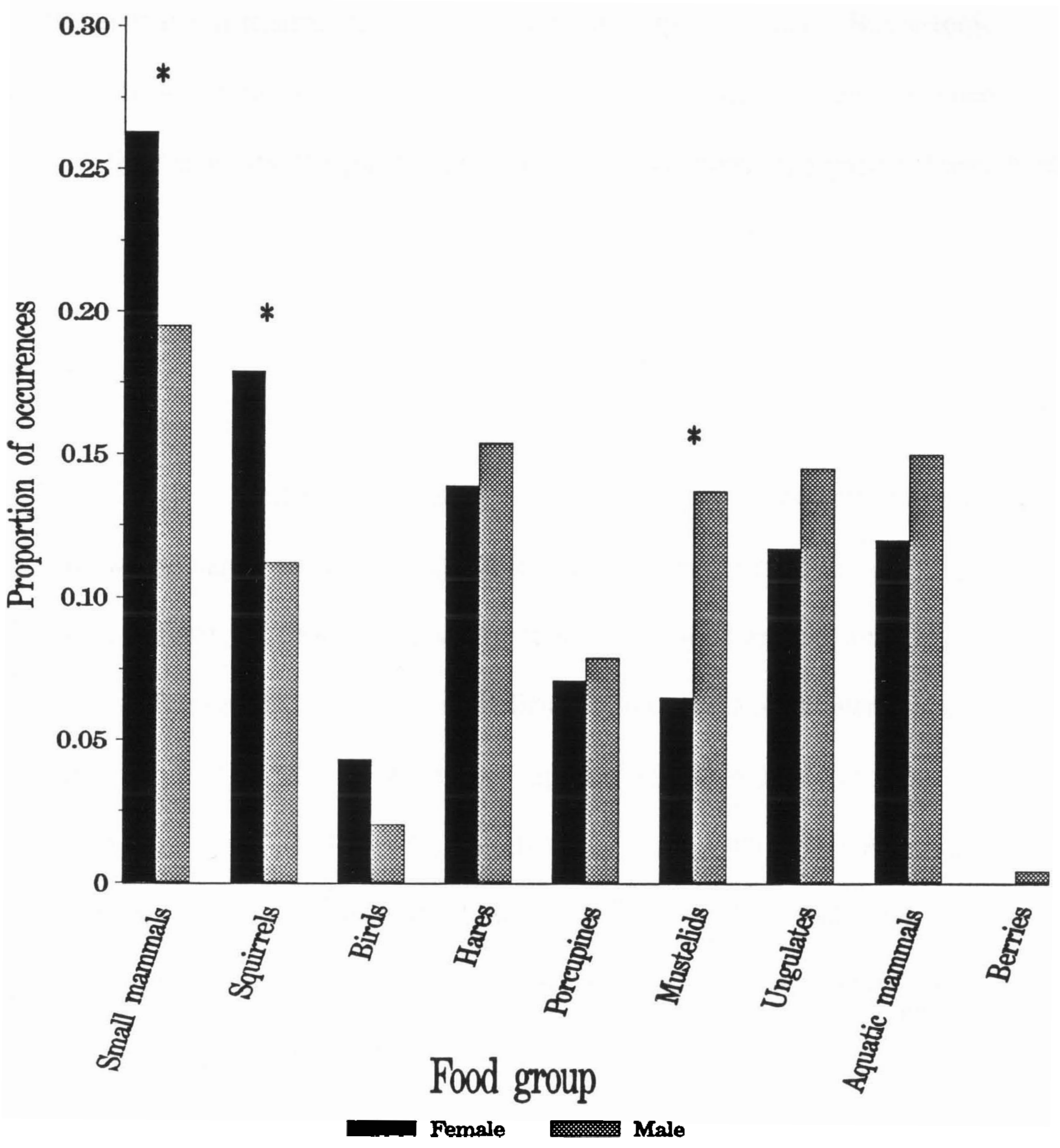


Fig. 3. Winter diets of female and male fishers in British Columbia, 1988-1993. Female fishers consumed small mammals and squirrels more frequently and mustelids less frequently than did male fishers ($\chi^2 = 19.77$, df = 8, $P < 0.01$). * indicates significant difference between sexes (Bonferroni-adjusted Z-tests, $P \leq 0.05$). $n = 566$ food group occurrences.

However, the occurrences of food groups in fisher stomachs were significantly different between the sexes ($\chi^2 = 19.77$, df = 8, $P < 0.01$) (Fig. 3). Female fishers exploited the small mammal and squirrel food groups more often than did males (Bonferroni-adjusted *Z*-tests; small mammals, $P < 0.05$; squirrels, $P < 0.02$). Males included mustelids in their diet more frequently than did females (Bonferroni-adjusted *Z*-test; $P < 0.01$).

Discussion

The analysis of stomach contents revealed the diversity of prey consumed by fishers. Snowshoe hares, small mammals, and squirrels were used extensively, and comprised the majority of food group occurrences. Other food groups, such as porcupines, galliform birds, ungulates, mustelids, berries, and aquatic mammals, occurred less frequently. Many authors have reported similar richness in fisher diets (Coulter 1966, Clem 1977, Kelly 1977, Powell 1982, Banci 1989). However, the stomach contents examined in my study show that fishers in British Columbia consume a wider diversity of food species than do fishers in other areas (Martin 1994). Most studies report fewer species per stomach than I observed.

In central British Columbia, snowshoe hares are the most frequently used species of prey. Throughout many areas of the fisher's range, snowshoe hares are probably the primary food resource exploited by fishers (Kuehn 1989). In most analyses of fisher food habits, snowshoe hares are a prevalent diet component, occurring in usually at least 20% of samples (Powell 1982).

Fishers in central British Columbia did not exhibit any detectable differences in the consumption of snowshoe hares across years. Fisher carcasses in my study were collected from the trapping seasons of 1989 to 1993, coinciding with the peak and crash of the snowshoe hare cycle in central British Columbia (T. Sullivan, University of British Columbia, *pers. comm.*). The occurrence of snowshoe hares in the fisher stomachs collected during this time indicate that although fishers consumed hares more frequently during the peak years (1990-1992) compared to the crash year (1993), the difference between years was not statistically significant.

Martin (1994) noted that diet diversity indices decreased with increasing occurrence of snowshoe hares in fisher diets. Although the diets of fishers in my study had a very high occurrence of snowshoe hares, they were the most diverse fisher diets recorded, contrary to Martin's (1994) hypothesis. The high diet diversity may be the result of collecting fishers from central British Columbia, where fishers are exposed to regional differences in prey abundances and diversity, and not related to the proportion of snowshoe hares in the diet.

Although snowshoe hares occurred frequently in fisher stomachs, squirrels, mice, voles, and shrews also comprised a major component of prey occurrences. Many authors have concluded that fishers likely search for larger prey such as snowshoe hares and porcupines (Powell and Brander 1977, Powell 1979a, Kuehn 1989), but will take smaller prey opportunistically (Thompson and Colgan 1990). My study supports this hypothesis because, even during periods of high snowshoe hare abundance, small prey such as mice, shrews, and squirrels, still form a substantial component of fishers' diets.

Although the majority of analyses concur that porcupines are often an important part of the fishers' diet (deVos 1952, Powell 1981, Kelly 1977, Arthur 1987), in British Columbia, porcupines do not appear to be used heavily by fishers. High availability of other prey items, and the increased handling time to kill porcupines, may decrease the use of porcupines by fishers, although one porcupine may provide food for a fisher for up to 1 month (Powell 1981). It is likely that porcupine remains were over-represented in the stomachs that I examined because of the relatively long duration that quills stay in the stomach, compared to other prey remains (Banci 1987).

Relative occurrences of mustelid species in the stomachs of fishers in my study differ from those of many published reports of fishers' diets. Several authors have reported that fishers eat weasels and martens (e.g. deVos 1952, Coulter 1966, Raine 1987, Jones 1991), but not with the frequency observed in my study. My results also show that fishers occasionally ate other fishers. Of the 10 stomachs that contained fisher hairs, claws and bones, 7 were from fishers trapped in quick-kill Conibear 120 or 220 sets. Thus, ingestion of fisher hair was not incidental to fighting leghold traps, as suggested by Coulter (1966). Some martens and fishers occurring in the fisher's diet are likely scavenged from trapper's sets (*pers. obs.*), but others may have been preyed upon (Seton 1926, deVos 1952, Raine 1987).

Several studies have recorded beavers and muskrats in fishers diets, and attributed the occurrences to scavenging of trap bait (Clem 1977, Kelly 1977, Kuehn 1989), but others have suggested that fishers hunt them (Raine 1981) or feed on them as carrion (Leonard 1980). Trap bait was determined by Kelly (1977) to be a source of food for fishers in New Hampshire. The low number of beaver and muskrat hairs occurring in stomachs containing these prey species suggests that fishers in my study may have been eating skinned muskrat and beaver carcasses used as trap bait.

Many studies have concluded that ungulate carrion plays an important role in fisher diets (deVos 1952, Coulter 1966, Kelly 1977, Powell 1982, Kuehn 1989). Kelly (1977) hypothesized that prior to European settlement, carrion scavenged from large carnivore kills formed an important component of the fisher's diet in eastern North America. Fishers in British Columbia appear to use ungulates frequently; ungulate hair occurred in 22.7% of the stomachs. This is similar to the results of diet analyses in Maine (24.4%, Coulter 1966), Ontario (44%, deVos 1952), and New Hampshire (27.5%, Kelly 1977). However, contrary to eastern studies, fishers in British Columbia tended to consume moose more often than deer. Determining the frequency of use of ungulate carrion in fisher stomachs using the random hair selection procedure may underestimate their actual contribution to the diet. Because ungulates have a low surface to volume ratio, animals feeding on ungulate carcasses could ingest little or no hair. Thus, ungulates may be under-represented in the diet sample.

The occurrence of ungulate remains in the diet of fishers have always been attributed to feeding on carrion (Coulter 1966, Kelly 1977, Powell 1982). However, during one intensive monitoring period in my intensive study (Chapter 2-3), a radio-collared female fisher was observed attacking an adult female mule deer (*Odocoileus hemionus*). At 1500 on 14 April 1992, a female fisher that had whelped recently was being monitored closely to determine maternal den attentiveness and movement patterns. She had left her den 4 hours previously, moved about 1200 m, and was returning back towards the den. I do not know whether the fisher was trailing the deer, but she attacked the deer while it rested in a dense thicket of saplings within an old-growth Douglas-fir stand, located 50 m from the observer. The fisher attacked the deer on its left shoulder, and ripped off a piece of skin and flesh measuring 10 x 20 cm. After the initial attack, the deer fled the fisher, limping. The fisher followed attentively, and pursued the deer in the direction of the fisher's maternal den. During a later inspection of the area, I failed find a deer carcass, so I do not know if the fisher eventually killed the deer, or simply wounded it.

Fishers are one of the most sexually dimorphic members of the family Mustelidae (Moors 1980). The fishers in my study had a degree of dimorphism of 1.64 ($\bar{x}_{\mathrm{Male}}$ body mass : $\bar{x}_{\mathrm{Female}}$ body mass), which is above the ratio of 1.6 used by Ralls (1977) to define extreme dimorphism. The causes of this dimorphism in the Mustelidae have been considered by many authors (Brown and Lasiewski 1974; Moors 1977, 1980; Erlinge 1979; Powell 1982; Holmes and Powell 1994). One of their explanations is that diet overlap between sexes is minimized by sexual dimorphism (Brown and Lasiewski 1974).

Because fishers are sexually dimorphic, many authors have expected dietary differences between the sexes, but not found them (Coulter 1966, Clem 1977, Leonard 1980, Powell 1982, Giuliano *et al.* 1989). In my study, male and female fishers exploited food resources differentially, as predicted by Moors (1980). Because females are smaller, they should be more efficient foraging for small animals than males. As well, because of their smaller size, females should be less able to exploit larger prey. The larger size of males allows them to exploit a broader prey base, but they are less efficient preying on smaller animals (Powell 1982). Female fishers in British Columbia consumed the smallest prey items (mice, voles, shrews, and squirrels) more frequently than did males, whereas males consumed more mustelids than did females. Some of these differences could be due to differences in home ranges and movements. Males defend larger home ranges than females (Powell 1982, Douglas and Strickland 1987), and hence males are more likely to encounter and scavenge prey items such as carrion and trap bait.

Because of differences in the diets between male and female fishers, females should search for prey in areas with abundant small mammals and snowshoe hares, whereas males are apt to forage in habitats with greater abundances of mid-sized prey. I expect differences to occur in habitats used by the different sexes. I expect that fishers will forage in habitats that provide food and cover for snowshoe hares, squirrels, mice, voles, and shrews. These may be structurally complex habitats, comprised of large volumes of coarse woody debris, and dense layers of low and high shrub.

Chapter 2

Home Range Establishment and Spatial Organization of Fishers in South-central British Columbia

Introduction

Fishers are solitary carnivores, and other than mothers raising their young, they interact with conspecifics usually only during mating and territorial defence (Powell 1982). Fishers are aggressive and conspecific interactions often lead to fights and are occasionally fatal. The asociality of fishers is also exhibited in their spatial organization. Fishers exhibit intrasexually exclusive home ranges, a common spacing pattern among the Mustelidae (Powell 1979b), in which territories of members of the same sex may overlap (Kelly 1977), but this is extremely rare (Arthur 1987).

Differential selection pressures between the sexes have resulted in different space use strategies for each sex, and subsequently, the spatial organization of the population. Moors (1980) hypothesized that male mustelids are larger than females so that they can cover large areas more quickly, and therefore encounter more females as potential mates, whereas the smaller size of females optimizes prey capture during rearing of the young (Powell 1982). To sequester sufficient resources and meet the greater energy demands of increased size, males have larger home ranges than females. This difference in home range sizes influences dispersal because males will likely have to travel farther to locate an area which provides access to potential mates and is not occupied by another male. Females, on the other hand, establish home ranges based upon habitat quality and when they disperse, they only have to travel as far as the next suitable habitat that is not occupied by another female.

The ecological challenges faced by transplanted animals, when they are released into a low density population, are similar, in many aspects, to those encountered by juveniles during natal dispersal. The transplanted animal is confronted with an unfamiliar environment and must search for a suitable area in which to establish a home range. During this search, transient individuals will have to contend with residents that will defend their territories aggressively (Krebs 1971), and they will have to find enough food to meet their energy requirements. The transplanted animal will also have to search broadly across the landscape to locate an adequate array of habitats in which to establish a home range.

There are also several differences between natal dispersal and transplantation. For instance, the transplantation of different age classes of fishers will likely influence the patterns of home range establishment. Adult fishers that have dispersed previously and established home ranges as juveniles before being captured and transplanted will have had experience with unfamiliar habitats and conspecifics. These adult fishers may know which habitats to avoid, and thus find suitable habitats more quickly. They also should know which social cues indicate presence of resident fishers and thus avoid potential conflicts with conspecifics.

Transplantation has been used to manage many mustelid species, including fishers. At least 10 states and provinces have transplanted fishers to either repopulate areas where they have been extirpated, or to reinforce diminishing populations (Banci 1989). The majority of these programs involved acquiring fishers from other jurisdictions with abundant fishers and simply releasing the animals in areas of historic fisher occurrence.

Information from the early programs is limited because transplanted fishers were not generally radio-tagged and little or no monitoring was conducted. In most of these releases, however, managers felt that fisher populations were successfully reestablished, and in the case of Wisconsin, that they rapidly recolonized suitable habitats (Petersen *et al.* 1977).

Recently, Alberta and Montana have monitored several releases of radio-collared fishers. Roy (1991) and Heinemeyer (1993) followed the fate of 56 radio-collared fishers transplanted from Wisconsin to the Cabinet Mountains of Montana, and Proulx *et al.* (1994) reintroduced 17 radio-collared fishers into the parklands of central Alberta. Both transplantation programs used "soft-release" techniques (Davis 1983) to allow the fishers to acclimate to their new surroundings prior to release.

The objective of "soft-release" transplantation is to induce the animal which is released to establish its home range in the immediate vicinity of the transplant site. Movement away from the transplant site may be caused by the lack of incentives for the animal to remain in its release area. Davis (1983) recommended using a "soft-release" procedure when transplanting martens. Soft-release techniques provide stimuli which entice the transplanted animal to remain in the vicinity of the release. A readily-available food source is provided by the researcher, familiar scents from the animal's faeces and urine are distributed in the release area, and in most cases, the animal is released into suitable habitat (as defined by the researcher). Conversely, the "hard-release" method usually supplies suitable habitat as the sole incentive for an animal to stay in its release area.

In my study, I examined patterns of home range establishment and spatial organization of fishers in the dry-warm subzone of the Sub-Boreal Spruce biogeoclimatic zone (SBSdw) of British Columbia by transplanting fishers from the Chilcotin River drainage and monitoring their subsequent movements. Transplantation may allow researchers to examine dispersal movements, and reveal which factors are important in mediating home range establishment. After the fishers have established territories, the resultant spatial organization will provide information on space use patterns and spatial relationships. My objectives in this chapter are: to determine the patterns of home range establishment; to describe the spatial organization of fishers; and to examine effects of season and reproductive status on space use.

Methods

Immobilization and release procedures

Trappers live-trapped fishers during the early winters of 1990-91 and 1991-92. All of the fishers were caught in 30 x 30 x 100 cm box livetrap sets on traplines in the Chilcotin River drainage, approximately 300 km west of Williams Lake, B.C. The trappers transported each fisher in a covered boxtrap from their capture sites to the B.C. Ministry of Environment facilities in Williams Lake. Upon arrival, I monitored the fishers for several hours to assess their physical condition.

I anaethesized each fisher for 45-90 min using a 10:1 ketamine hydrochloride:xylazine hydrochloride mixture administered at 22 mg/kg body weight, injected intramuscularly. When required, I injected the fishers with an additional 15 mg/kg of ketamine to maintain anaesthesia.

During the immobilization process, I weighed, sexed, and measured each fisher. I removed a premolar 1 tooth from healthy fishers for cementum annuli analysis (Strickland *et al.* 1982), whereas I classed fishers that had worn teeth or lingual erosions as adult or juvenile by palpitating the sagittal crest (Powell 1982). I fitted fishers with mortality-sensing, whip antennae radiocollars transmitting signals in the 150 MHz range (Lotek Engineering model SMRC-5, 16 month duration, or Telonics model MOD 205, 12 month duration). In addition to transplanted fishers, residents were live-trapped within the study area, immobilized, and fitted with radiocollars.

Following immobilization, fishers were kept at an isolated private residence near 150 Mile House, B.C. prior to being transported to their release sites. I housed each fisher in large 1.5 x 2.0 x 0.5 m holding pens, with removable 1.0 x 0.5 x 0.5 m nest boxes. During this time, I fed the fishers skinned muskrats and meat scraps and gave them water *ad libitum*. I confined each fisher to the nest box prior to transport, and then transported the fisher by truck and snowmobile to its release site. At the release site, I reconstructed the yard portion of their cages, and joined the nest box to the cage. I covered the top above the yard portion of the cage with conifer boughs to provide shelter and avoid snow accumulation in the cage.

I released each fisher at a different location in the study area and "soft-released" (Davis 1983) all but one fisher. I confined each fisher to their cages at the release sites for 5-6 days to acclimate them to their new surroundings. I visited the fishers daily to inspect their physical condition, provide water and food, and collect their scats. On the day before release, I spread animal carcasses and the majority of the fisher's scats throughout the surrounding 1 ha of forest. On the release day, I opened the cage door quietly to ensure that the fisher was disturbed as little as possible.

I relocated fishers using standard ground and aerial telemetry procedures (White and Garrot 1990). I located fishers from the air using a Cessna 172 aircraft, with two bi-directional H-antennae mounted on the wing struts. I recorded directional bearings of fishers using three-element, collapsible Yagi antennae at permanent ground stations. I estimated ground relocations using Locate II software (Nams 1991), which uses the maximum likelihood estimator to calculate transmitter locations and error polygons (Nams and Boutin 1991).

I assessed telemetry error using two methods. Blind transmitter location trials were performed by placing a transmitter in the forest and allowing a second researcher to relocate the transmitter from the air. Accuracy from the air was within 30 m, producing an error polygon smaller than 1 ha. I determined telemetry error from the ground from 95% error polygons estimated using the maximum likelihood estimator.

Immediately following release, I relocated each fisher twice per week from the air, and when possible, located daily from the ground. Unfortunately, logistical constraints limited the desired sampling regime such that intervals between relocations of recently released fishers ranged from 1 to 7 days. Following home range establishment, I located each fisher with a functioning radiocollar at least twice per week. I considered successive locations independent if separated by at least 16 h; this interval allowed the fishers to potentially access any point within their home range (*sensu* Lair 1987).

Determination of home range establishment and size

I considered home ranges to be established when transplanted fishers began to exhibit site fidelity. I quantified site fidelity using the mean squared distance (MSD) (Calhoun and Casby 1958) of a set of 6 successive locations. MSD is calculated as the average of the squared distances of a set of x,y points from their arithmetic centre. This measure is identical to the r^2 of Swihart and Slade (1985). The mean square distance is roughly analogous to the sum of squares in univariate statistics that is used as a measure of dispersion of points about an estimated mean. In 2 dimensions, the mean squared distance measures the dispersion of the values (i.e. locations) from a central point. As the locations become more widely dispersed, the squares of the distances from each location to the central point become greater. Thus, an animal that is exhibiting little or no site fidelity will have a larger MSD than if it were exhibiting site fidelity. As a fisher establishes a home range, it will begin to exhibit site fidelity, and the MSD of successive sets of locations will decrease.

I quantified site fidelity by examining the MSD of successive sets of locations for each fisher. I generated sets of locations by using 6 successive locations. The next set was created by dropping the first location from the previous set, and adding on the next successive location. Each set therefore has 5 locations in common with the previous set. I compared successive sets until there were no longer substantial differences in the value of the MSD between consecutive sets. Unfortunately, I was unable to derive a statistical test to demarcate the change point of the data, so I determined the home range establishment dates by subjectively assessing the MSD versus time relationship for each fisher (Fig. 4). I defined site fidelity as beginning the point after which the variability of the MSD versus time plot decreased and stabilized. I defined the date of home range establishment as the first date of the set of locations that revealed the initiation of site fidelity.

To ensure the validity of this method for determining home range establishment, I used several other measures to assess site fidelity. I plotted distance from release site to the centre of successive sets of locations over time. I also compared the distances between arithmetic centres of successive sets until the variability between distances stabilized (Fig. 4). I defined home ranges as being established as the point after which all subsequent locations were contained within the minimum convex polygon used by the fisher from May-December (*sensu* Arthur *et al.* 1993). I analyzed movement patterns prior to home range establishment by calculating the minimum total distance moved between successive locations and the minimum convex polygon (Hayne 1949) of all locations before home range establishment.

I estimated home ranges using the adaptive kernel technique, with *h* selected by cross validation and the smoothing parameter chosen by the least squares method (Worton 1989, Seaman and Powell 1991). The adaptive kernel technique is a nonparametric method for estimating an animal's utilization distribution using a probabilistic model (Worton 1989). I determined the boundary of each home range from the 90% isopleth of the utilization distribution (90% UD). I defined core areas as those that covered 50% of the utilization distribution for each fisher. I calculated seasonal home ranges for winter (15 November - 31 March), summer (1 April - 14 September), and autumn (15 September - 14 November). Because female fishers' movements are affected by the presence of kits, which lasts from early April until late July (Leonard 1980), I did not consider spring as a separate season from summer. I estimated home ranges from a minimum of 20 independent locations. I also estimated home ranges using the 95% minimum convex polygon (Ackerman *et al.* 1990) from all locations collected after home range establishment.

Results

I transplanted 15 fishers over 2 winters. Five females were released in the winter of 1990-91, and 10 fishers (8 F, 2 M) were released in early 1992. I spaced the 1990-91 releases more or less evenly from 22 November 1990 to 19 February 1991. I released fishers in 1992 from 16 January to 4 March, with 6 fishers being released on 11 February. I transplanted 6 juveniles (5 F, 1 M), 3 one-year olds (all females), and 6 adults (5 F, 1 M) into the study area. As well, 7 resident fishers were live-trapped and radio-collared within the study area. Two resident females were juveniles at first capture; the others were adults (4 F, 1 M). I located fishers with functioning radiocollars from 15 December 1990 to 30 May 1993.

Transplanted fishers moved a mean of 10.6 km within 24 h after release, and there were no significant differences between sexes (Wilcoxon 2-Sample Test, $S = 4.0$, $Z = -0.47$, $P < 0.64$) or year of release (Wilcoxon 2-Sample Test, $S = 12.0$, $Z = -1.12$, $P < 0.22$). Logistic constraints affected the number of relocations during the first week following release; I could estimate the distance moved during the first week following release for only 8 of 15 fishers. These fishers moved a mean of 19.3 km from their respective release sites by the end of the first week. They moved farther during the second winter of releases than the first (1991, $\bar{x} = 9.8$ km, $n = 3$; 1992, $\bar{x} = 25.0$ km, $n = 5$; one-tailed Wilcoxon 2-Sample Test, S = 8.0, $Z = -1.49$, $P < 0.07$).

Radiotransmitter failure limited the number of relocations obtained for each fisher. Twenty-nine radiocollars were fitted on 22 fishers. Radiocollars lasted between 5 and 296 days, with a mean duration of 133 days (SE = 13.6, $n = 29$). Lotek collars lasted an average of 142 days (SE = 15.1, $n = 12$), while Telonics collars emitted signals for an average of 126 days (SE = 20.9, $n = 17$).

Subjective assessment of the MSD and home range centre versus time plots (Figs. 4 - 6) illustrate that 9 of the 15 transplanted fishers established home ranges while in radio-contact. Two of the transplanted fishers' radiocollars ceased transmitting signals within 8 days after release. Two fishers slipped their collars before they had established home ranges (6 and 55 days following release). One fisher (F766, Fig. 4e) appeared to exhibit site fidelity, but its radiocollar failed before enough locations could be gathered to verify home range establishment. Nine of the 10 transplanted fishers for which locational data were sufficient established home ranges between 9 and 196 days after release ($\bar{x} =$ 53.3 days, SE = 14.8).

None of the transplanted fishers which I could monitor died while transient. One transplanted female died in the winter, 2 years following home range establishment, and one other transplanted female was killed by a male fisher during the mating season after occupying a home range for 2.5 years and whelping twice. Two transplanted fishers were killed in trappers' sets, one after establishing his home range, and the other after I lost radio-contact with her before home range establishment. One resident fisher died in

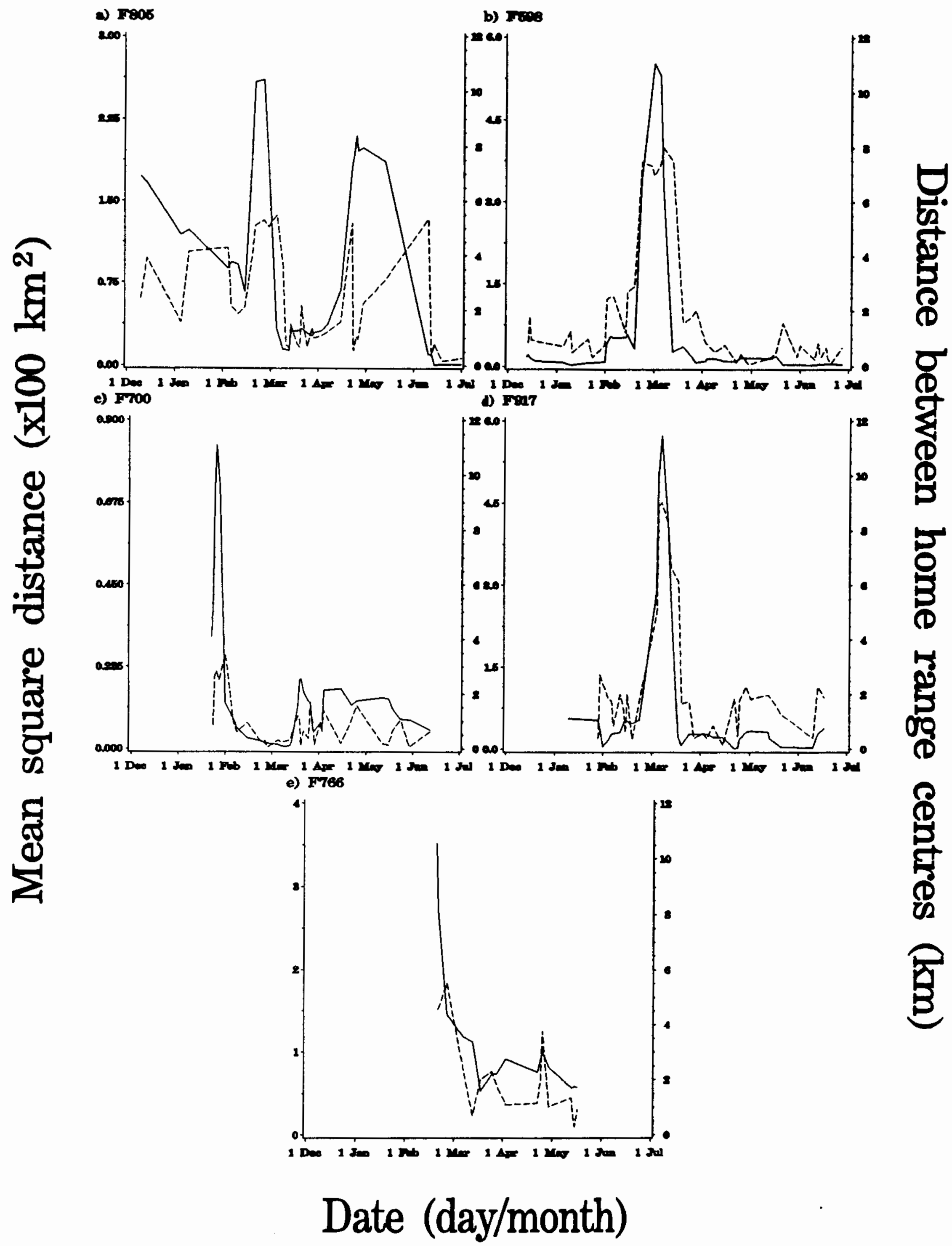


Fig. 4. Mean square distances and distance between arithmetic centres of successive sets of 6 locations for fishers transplanted 1990-1991. Solid lines are mean square distances. Dotted lines are distance between consecutive home range centres.

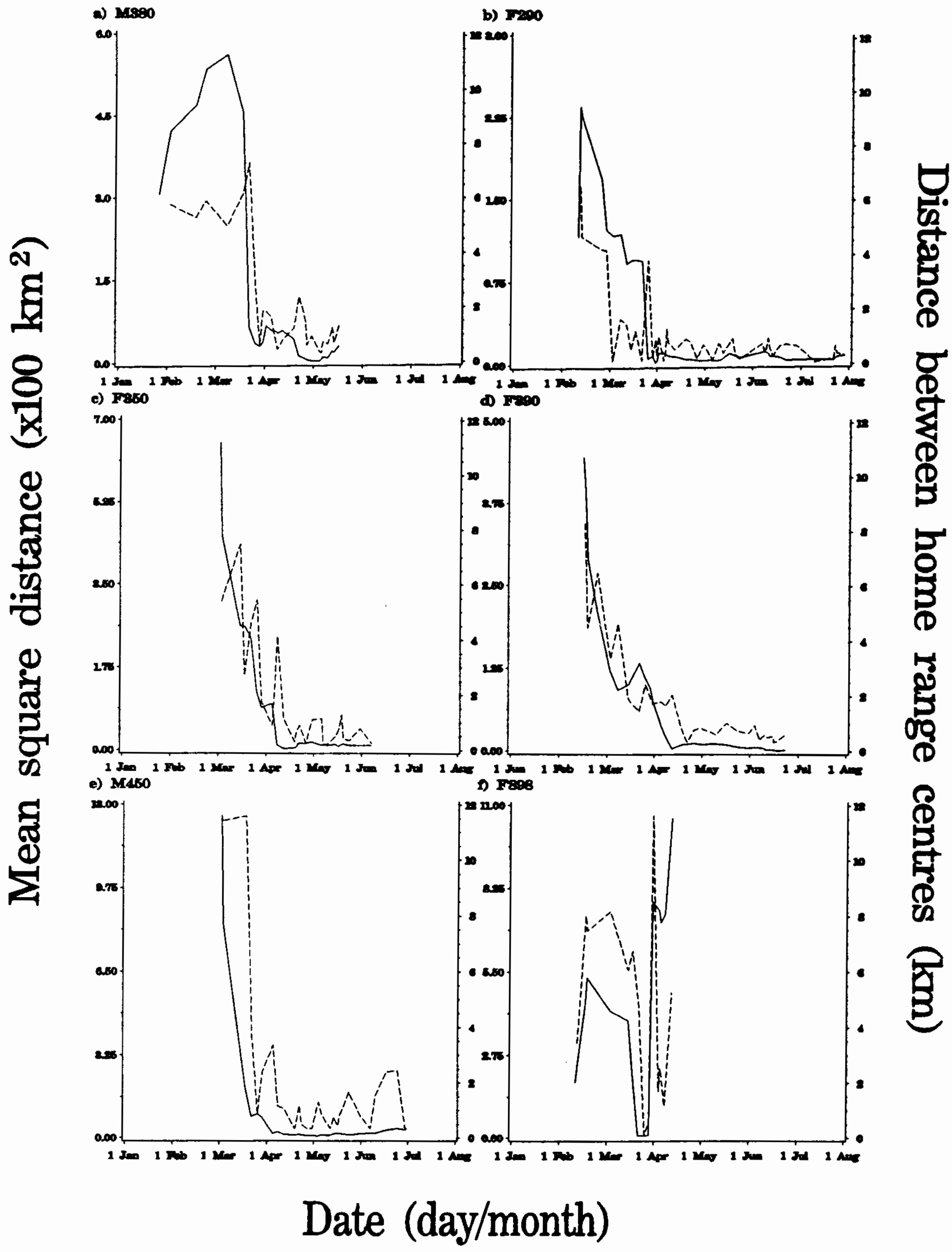


Fig. 5. Mean square distances and distance between arithmetic centres of successive sets of 6 locations of fishers transplanted 1992. Solid lines are mean square distances. Dotted lines are distances between consecutive home range centres.

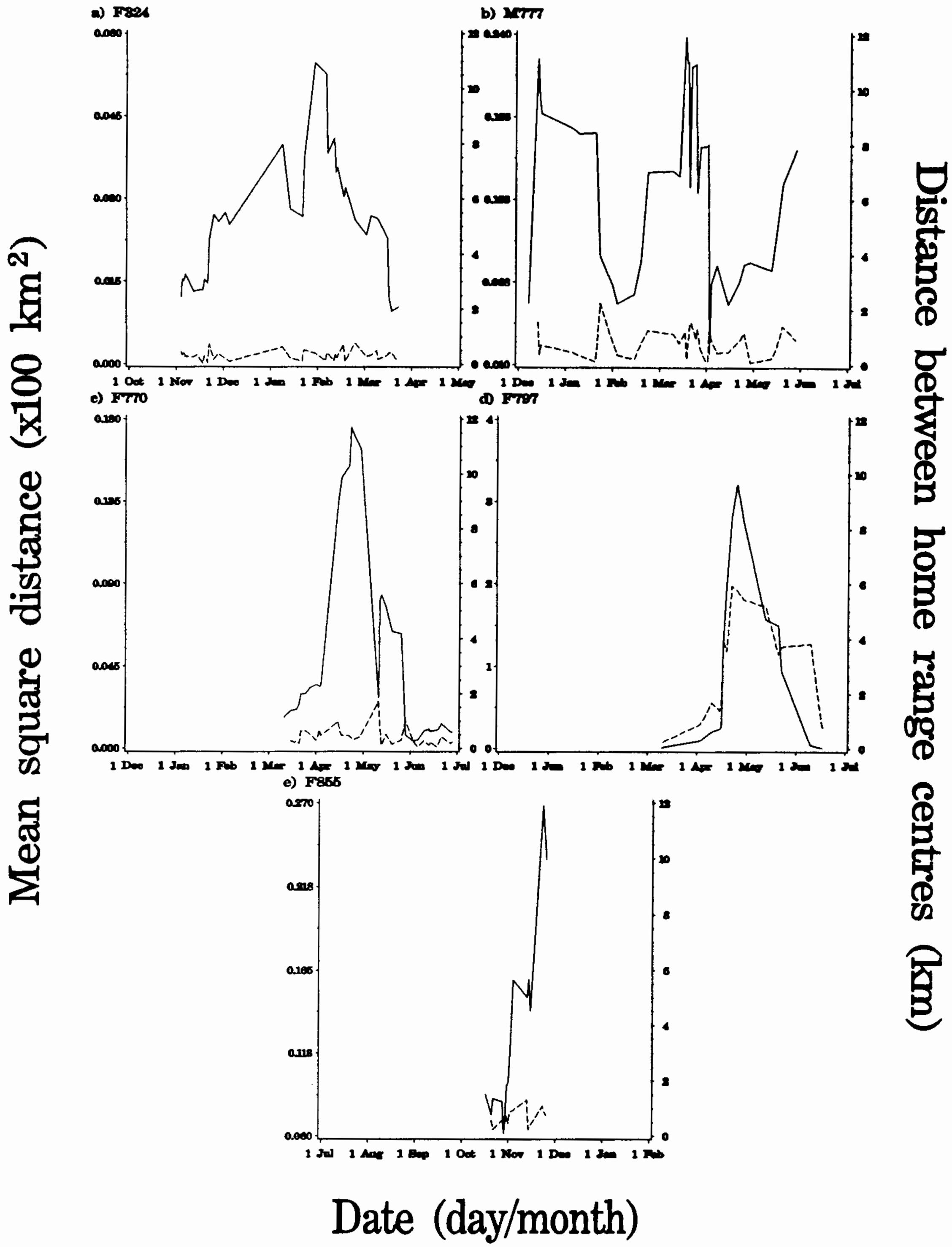


Fig. 6. Mean square distances and distances between arithmetic centres of successive sets of 6 locations of resident fishers live-trapped 1990-1991. Solid lines are mean square distances. Dotted lines are distances between consecutive home range centres.

a slash-pile near a mine tailings dump during a period of extreme cold (-46 C).

The transplanted fishers established home ranges between 1 February and 10 June 1991, and between 5 and 12 April in 1992 (Fig. 7). The establishment of home ranges did not occur uniformly throughout the year (Rayleigh's test, $z = 5.13$, $n = 9$, $P < 0.005$). The mean date of home range establishment across all years was 1 April (95% CL; 1 March - 30 April).

Most of the transplanted fishers established home ranges at least 15 km from their respective release sites (Fig. 8). The mean distance from release site to home range centre was 24.7 km in 1991, and 41.3 km in 1992, however, these differences were not statistically significant (*t*-test, $t = -1.39$, df = 7, $P < 0.21$). Distances moved per day by each transplanted fisher were longer before than after home range establishment (paired sample *t*-test, $t = 5.67$, df = 9, $P < 0.01$).

The transplanted fishers wandered extensively prior to establishing a home range. While transient, 4 fishers wandered through areas of more than 700 km^2 and most of the fishers travelled at least 100 km in total distance before establishing a home range (Table 3). The fishers were able to move long distances between relocations; one male fisher moved 53.2 km in less than 68 h. During the transient phase, fishers crossed the Quesnel River on several occasions, and many of its smaller tributaries as well.

Annual 90% UD home ranges were calculated for 6 fishers (5 F, 1 M) (Table 4). The mean annual home range for females was 26.4 km^2 (SE = 9.2), and the 90% UD home range for the male was 46.5 km^2. The core areas of these home ranges were a mean of 4.4 km^2 (SE = 1.2) for females, and the male core area was 8.7 km^2. Overlap was extensive between the 90% UD home ranges of adjacent females, and between the

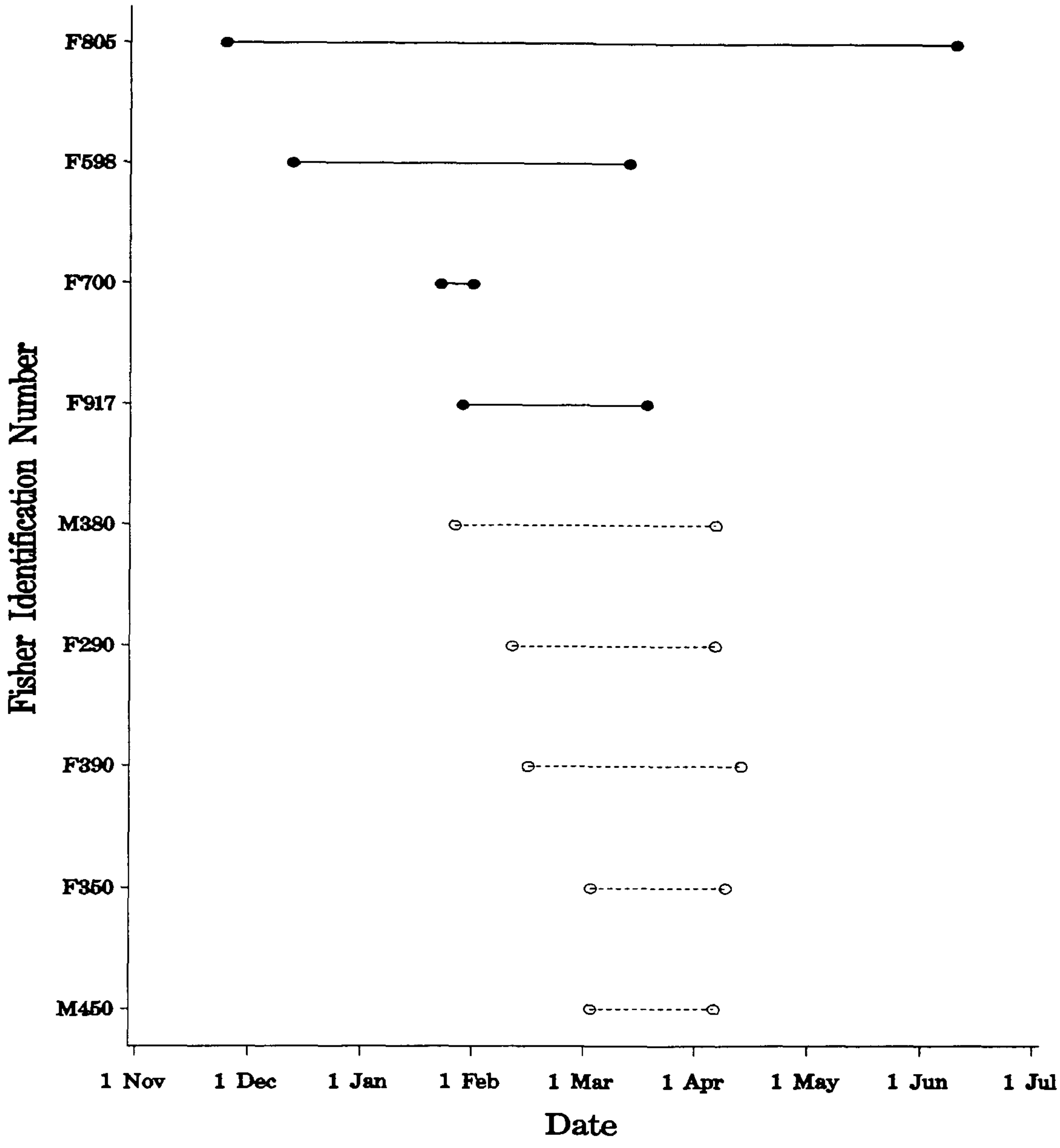


Fig. 7. Release and home range establishment dates of transplanted fishers which successfully established home ranges before radiocollar failure. Most fishers established home ranges by the start of the breeding season (10 April). Solid lines are 1990-91 releases. Dotted lines are 1992 releases.

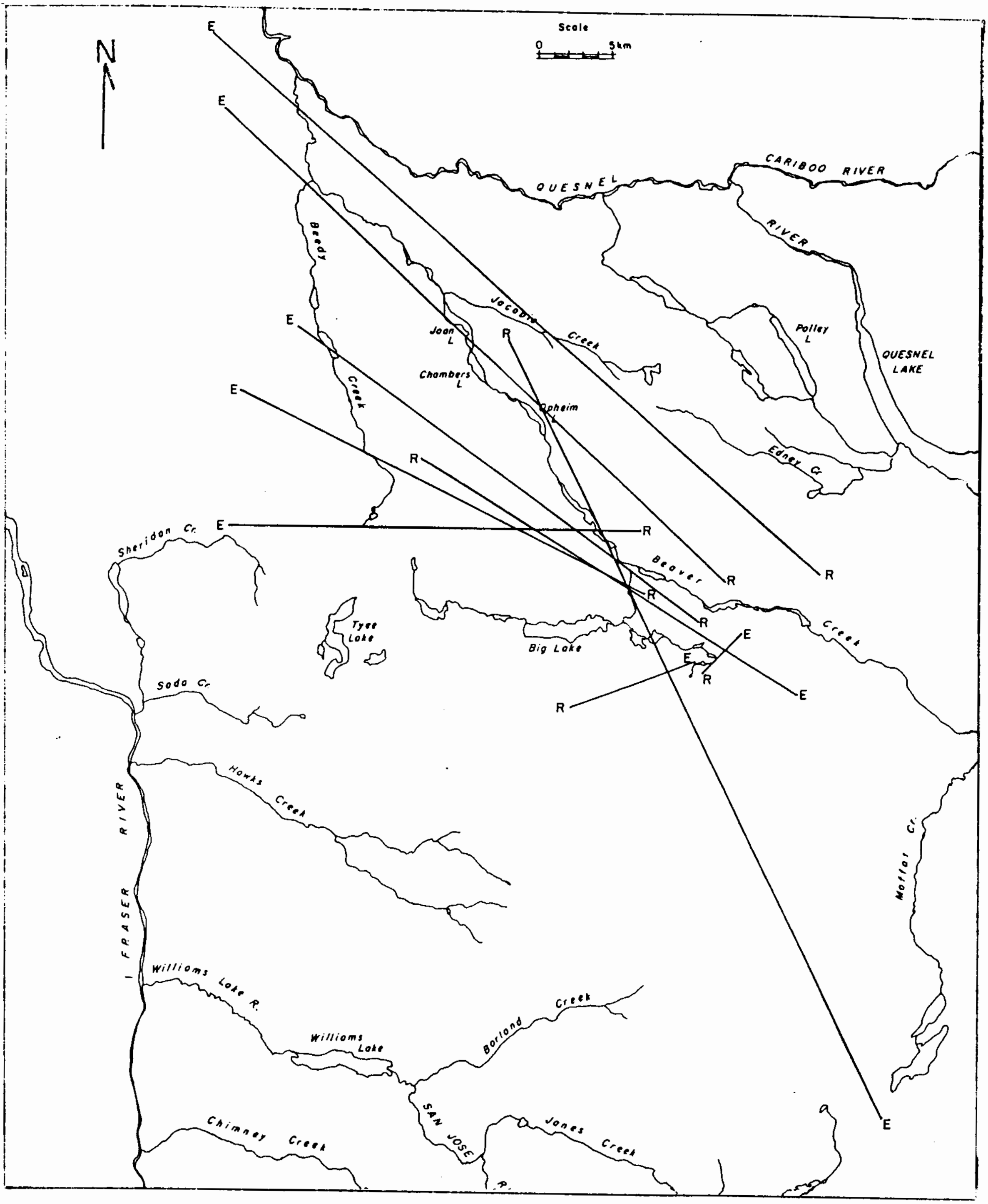


Fig. 8. Release sites (R) and centres of established home ranges (E) of fishers transplanted 1990-1992. Most fishers wandered extensively following release and established home ranges at least 15 km from their respective release sites.

Table 3. Pre- and post-home range establishment movements of fishers transplanted into the SBSdw subzone 1990-1992. MCP - minimum convex polygon home size (Ackerman *et al.* 1990). Total n = 613 relocations of 9 fishers.

	Pre-home range establishment			Post-home range establishment	
ID	*n*	Minimum total distance moved (km)	100% MCP (km^2)	*n*	95% MCP (km^2)
F290	16	132.4	301.7	57	39.1
F350	8	136.0	743.7	23	30.3
F390	14	172.3	733.8	21	17.0
F598	22	87.2	169.2	42	26.3
F700	5	12.5	50.2	210	52.5
F805	34	276.3	990.3	58	17.2
F917	17	93.8	108.6	23	45.0
M380	11	1055.5	188.9	20	82.3
M450	6	1038.1	987.0	26	46.5

male and females (Fig. 9). Substantial overlap occurred in the core areas of the annual home ranges for these fishers as well.

Summer home ranges were estimated for 8 females and 3 males (Table 4). The mean 90% UD home range for females was 33.0 km^2 (SE = 10.7), and 122.1 km^2 for males (SE = 66.5). Summer core areas were 7.6 km^2 for females (SE = 2.9) and 17.8 km^2 (SE = 8.0) for males. The least amount of seasonal home range overlap occurred during summer. During summer in both 1991 and 1992, little overlap occurred between the 90% UD for females (Fig. 10, 11a), and only once did the core areas of adjacent females overlap. The 90% and 50% UD of 2 males overlapped adjacent females' ranges during summer.

Although none of the transplanted female fishers whelped offspring in the spring following release, 3 females whelped 4 times during the study. The mean 90% UD home range size during the summer for these females was 6.8 km^2 (SE = 1.1), and the core areas were much smaller ($\bar{x}$ = 2.2 km^2, SE = 0.7) . Summer home ranges for females that did not whelp offspring ($\bar{x}$ = 44.7, SE = 10.8, n = 6) were larger than for females with kits.

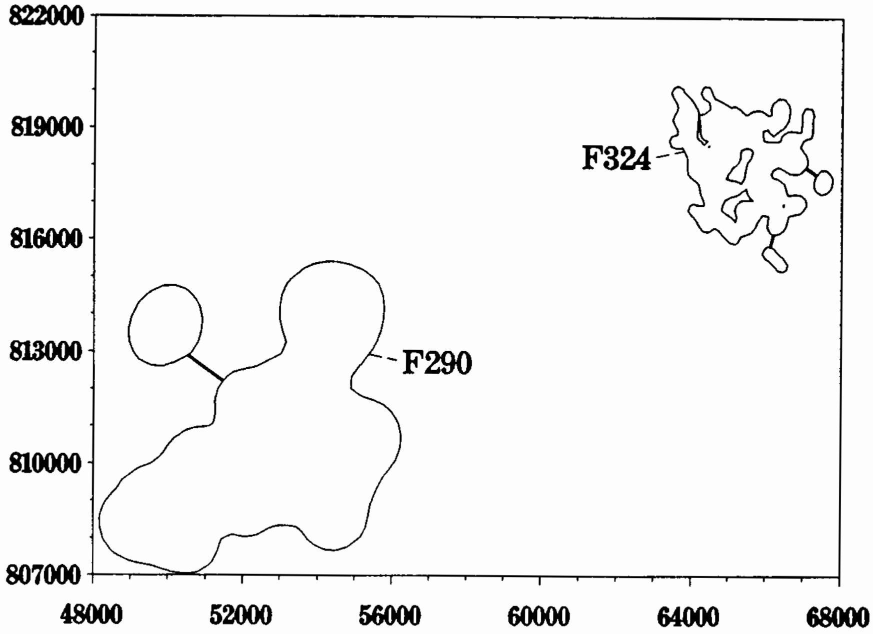
Autumn home ranges could be estimated for only 3 females (Table 4). The mean area of the 90% UD was 32.3 km^2 (SE = 18.3) and the core area was 6.8 km^2 (SE = 4.6). None of the home ranges were calculated from the same area and year, so the amount of overlap could not be estimated.

Winter home ranges were calculated for 7 fishers (6 F, 1 M) (Table 4). The mean 90% UD home range for females was 25.0 km^2 (SE = 2.6), and 73.9 km^2 for the one male. Winter core areas were 5.4 km^2 for females (SE = 1.5) and 11.8 km^2 for the

Table 4. Annual and seasonal home range (90% utilization distribution - 90% UD) and core areas of resident fishers in the SBSdw, 1990-1993. Home ranges were smallest during winter, and largest during summer. - indicates insufficient data.

	Female Area (km²) Mean	 ±SE	 *n*	Male Area (km²) Mean	 ±SE	 *n*
Annual						
90% UD	26.4	9.2	5	46.5	-	1
core area	4.4	1.2	5	8.7	-	1
Summer						
90% UD	33.0	10.7	8	122.1	66.5	3
core area	7.6	2.9	8	17.8	8.0	3
Autumn						
90% UD	32.3	18.3	3	-	-	-
core area	6.8	4.6	3	-	-	-
Winter						
90% UD	25.0	2.6	6	73.9	-	1
core area	5.4	1.5	6	11.8	-	1

a) Beedy Creek



b) Veith Lake

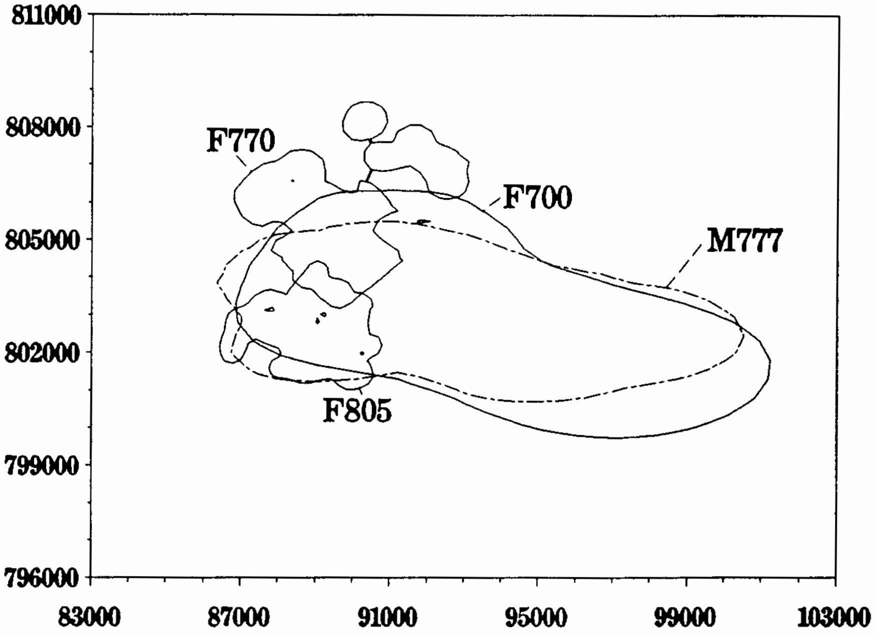


Fig. 9. Annual 90% UD home ranges for fishers in a) Beedy Creek and b) Veith Lake areas. Overlap was extensive among the females and male in the Veith Lake area. Each axis tick mark equals 1 km. Solid lines are female home ranges. Dashed lines are male home ranges.

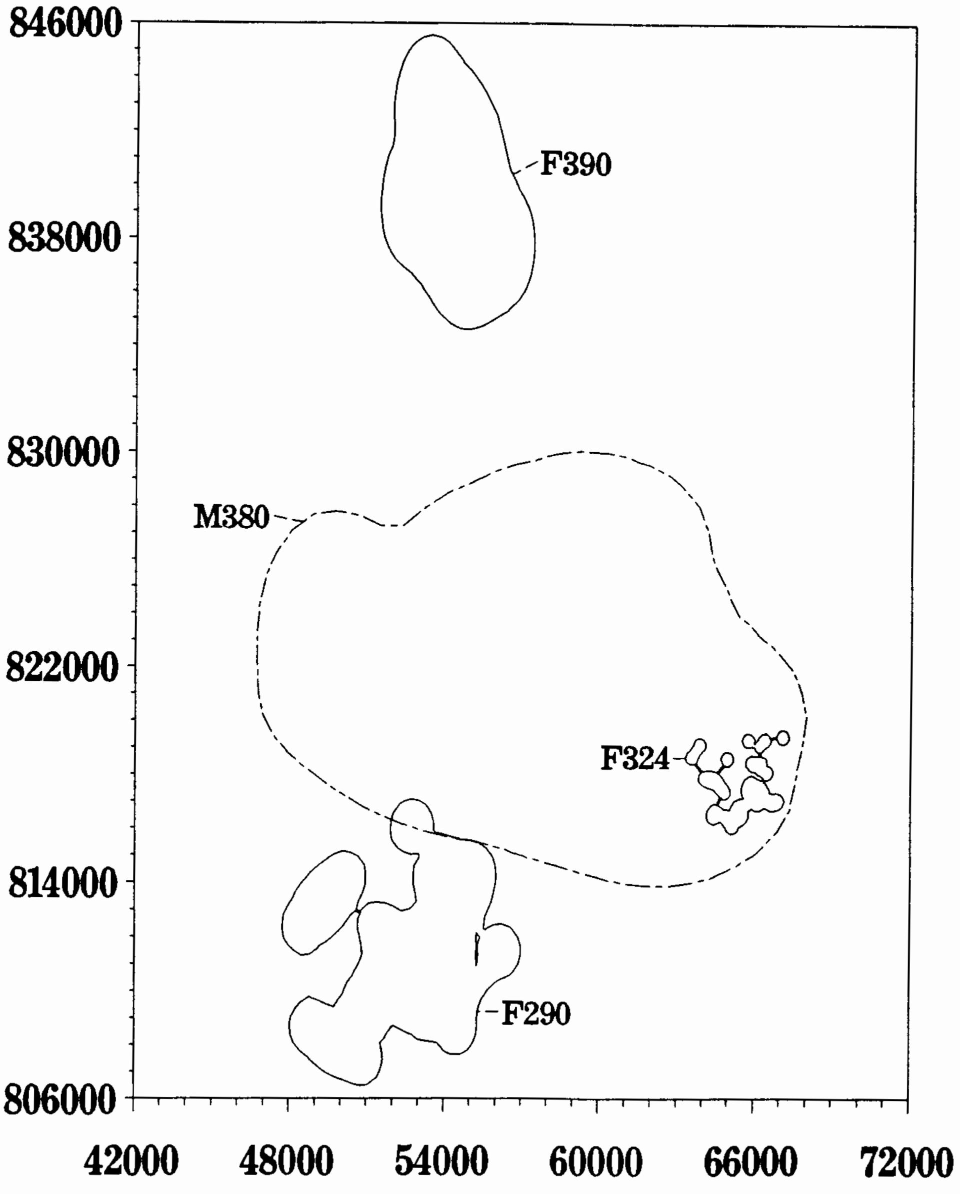
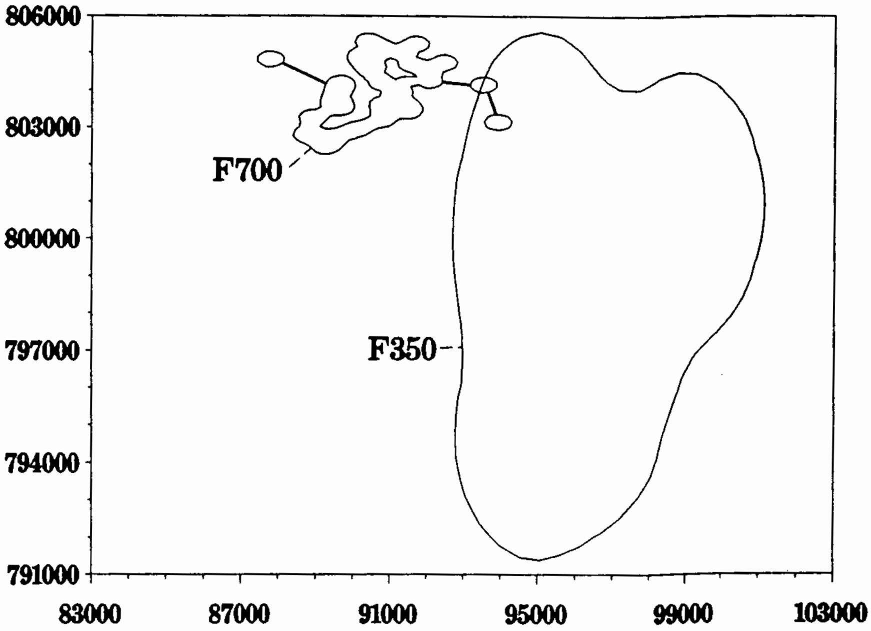


Fig. 10. Orientation and overlap of 90% UD home ranges for fishers during summer 1992 in the Beedy Creek area. Each axis tick mark equals 1 km. Solid lines are female home ranges. Dashed lines are male home ranges.

a) Summer 1992



b) Winter 1992

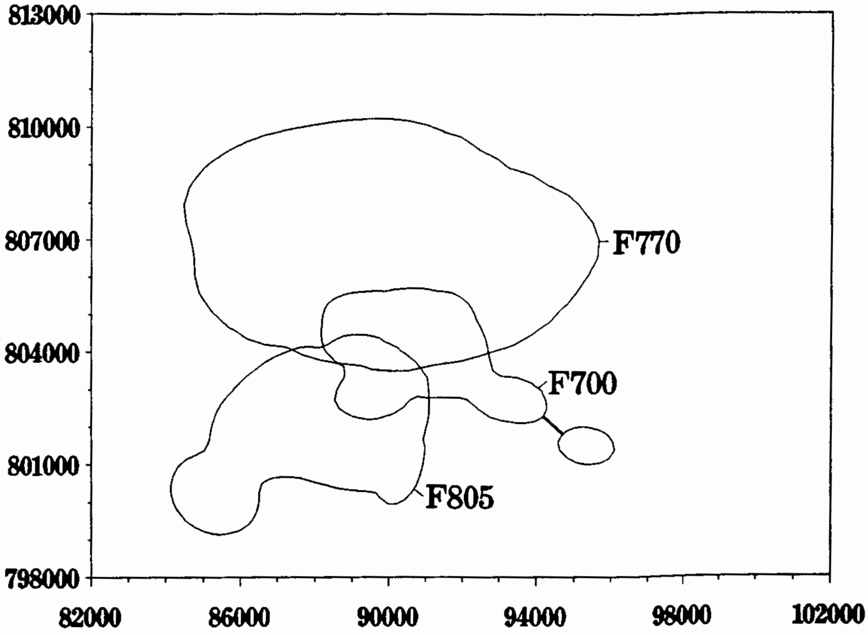


Fig. 11. Orientation and overlap of 90% UD home ranges for fishers during a) summer and b) winter 1992 in the Veith Lake area. Each axis tick mark equals 1 km. Solid lines are female home ranges.

male.

Extensive overlap occurred between adjacent female fishers during winter; all females overlapped their 90% UD home range with other females (Fig. 11b), and overlap of the core areas occurred among all three females during winter of 1992. The male home range in winter 1991 almost completely encompassed one female's home range.

Discussion

Post-release movements

The majority of transplanted fishers wandered extensively following release, but they established home ranges within the study area. Initial movements away from their release site were large scale (>6 km), and large rivers and elevation changes of 700 m were not movement barriers, contrary to that predicted by Coulter (1966).

My study suggests that the soft-release procedures did not provide enough incentives for the transplanted fishers to remain in the vicinity of the release sites. Unlike the fishers released by Roy (1991) and Heinemeyer (1993) in Montana, all of the fishers in my study moved at least 1.6 km away from the release site within 1 day of release, and none were detected visiting the release cages again.

The long movements away from the release site may be influenced by the long duration of captivity which could alter initial post-release behaviour of fishers. In 1991, fishers were housed from 5 to 36 days, while in 1992, they were kept in captivity from 15 to 53 days. Heinemeyer (1993) observed that while in captivity, the fishers that Roy (1991) released exhibited behavioural changes and gained weight. These fishers were housed for at least 40 days, and were very susceptible to predation upon release (Roy 1991). Proulx *et al.* (1994) kept 14 fishers in captivity for 18-24 months, and released 3 fishers which were born in captivity. Initial movements of the fishers released in March in their study were very similar to those of the fishers that I released.

Although fishers did not remain at their release sites in my study, adding more "stay at release site" incentives may enhance the success of the soft-release procedure. Proulx *et al.* (1994) observed that movements of fishers released in June were much shorter than those of fishers released in March. The animals released in June established permanent home ranges in the immediate vicinity of their respective release sites. The difference in movements were attributed to tree and shrub canopy development, abundant food resources, and the lack of large-scale breeding movements (Proulx *et al.* 1994).

Although some of the fishers were released into apparently suitable habitat (e.g. F805 established a home range that included F700's release site), the application of the soft-release technique was not successful in my study, perhaps because of the lack of incentives to remain close to the release site and the duration of captivity. Releasing fishers with kits may be one way of ensuring that the transplanted animals remain near the release site. However, this would require housing the females for long periods of time and may create stress on the fishers. Fishers do not reproduce well in captivity (Powell 1982), and the stress associated with release may result in abandonment of the kits (Douglas and Strickland 1987). Either increasing the incentives for remaining close to the release cage (e.g. kits), reducing the amount of restlessness by housing them for shorter periods, or making captivity less stressful on fishers may improve the success of soft-release transplants.

The presence of resident fishers may have affected the movement patterns of the transient fishers. By the end of the first week following release, fishers transplanted in 1992 had moved farther away from their respective release sites than did fishers transplanted the previous winter. Because fishers have intrasexually exclusive home ranges, resident fishers would likely "exclude" transients from using areas of their home range, even individuals of the same age class. Erlinge (1977) found that resident stoats (*Mustela erminea*) were dominant to introduced members of the same sex and age class. With a higher population density during the second year of releases, the fishers released in 1992 would likely have had to travel farther to avoid conspecifics of the same sex. Scent marking may be used by fishers to define their home ranges (Powell 1982), so encounters between fishers need not have been direct. Because of these factors, fishers released during the second year may have had to travel more broadly to acquire sufficient resources and survive.

One of the major differences between my study and other studies is the extremely low mortality rate of my transplanted animals. Roy (1991) lost 14 of 32 fishers (43.8%) to either predation or fur trapping, and in the same study area Heinemeyer (1993) reported a mortality rate of at least 56% (14 of 25 radio-collared transplants). Proulx *et al.* (1994) reported that of four transplanted fishers that died, 3 died from intraspecific fights and the fourth was killed by a vehicle. In my study, only one fisher (1 of 15; 7%) died before I could verify that it had established a home range.

The source of transplanted animals may also affect the success of the transplant programme. Both Roy (1991) and Heinemeyer (1993) transplanted fishers from Wisconsin, where fishers have few natural predators, to Montana, where the predator community is more diverse. Roy (1991) attributed the high mortality rate of transplanted fishers to the inexperience of the animals in the new ecosystem. Proulx *et al.* (1994) released fishers from the boreal forests of Manitoba and Ontario into the deciduous-dominated parkland of central Alberta. The fishers transplanted in my study, however, were collected from the Sub-Boreal Pine-Spruce biogeoclimatic zone west of Williams Lake, B.C. This zone has forest types and a predator-prey community similar to those in the dry-warm Sub-Boreal Spruce (Steen and Demarchi 1991, Meidinger *et al.* 1991), so the impact of being released into a new area was likely lessened.

Home range establishment

Transplantation forces an animal to begin searching immediately in an unfamiliar environment for the resources it needs to survive. Given this potentially challenging situation, transplanted fishers can use one of three strategies to meet their needs. Powell (1979b) proposed that mustelids' space use patterns can be either transiency, temporary residency, or permanent residency.

The space use pattern which a transplanted animal selects, and its duration, will likely be influenced by the distribution of resources that the animal requires (i.e. food, mates, denning habitat, security cover) and the density of conspecifics. A transplanted fisher should remain transient if it does not locate an array of unoccupied habitats in which resources occur at an economically beneficial density and distribution. When an economically defendable array of habitats is located that is not occupied by a member of the same sex, the fisher should then establish a home range. This parsimonious model may be complicated further because factors other than habitat quality and occupancy likely influence a fisher's decision on when and where to establish its home range.

Heinemeyer (1993) hypothesized that home range establishment of transplanted fishers may be socially induced. In the first half of a 4 year transplantation programme, Roy (1991) observed home range establishment of only 2 of 32 radio-collared fishers soft-released into the Cabinet Mountains of Montana. Heinemeyer (1993) transplanted 24 radio-collared fishers into the same region in 1990 and 1991, of which 7 established home ranges. Heinemeyer (1993) attributed the increased success of the second half of the transplantation programme to the occurrence of resident fishers inducing settling of the transplants.

The rate of home range establishment among transplanted fishers in my study may have been enhanced by a low density among the resident fisher population. Prior to the 1990-91 transplants, 3 fishers were released into the study area in 1989, and 2 resident fishers were radio-collared. As well, during the first winter of releases (1990-91), fisher tracks were noted in at least 4 portions of the study area. At least 6 fishers were trapped commercially along the western boundary of the study area from 1990 to 1993. I therefore assume that the population in the 1500 km^2 study area was at least 9 fishers when my study was initiated in 1990. This existing population may have facilitated successful home range establishment of the transplanted fishers.

Many mustelid transplant programmes have involved releasing large numbers of animals to re-establishment the population. Slough (1994) believed that there was a positive correlation between the number of marten transplanted and the success of re-establishing marten populations. Roy (1991), Heinemeyer (1993), and Proulx *et al.*

(1994) released additional fishers without radiocollars as part of their transplant programmes. In their studies, the simultaneous release of up to 25 fishers may have affected the behaviour of the transplanted fishers. Unlike other studies of transplanted fishers, my study did not involve releasing large numbers of fishers. Frequent interaction with conspecifics (transient or resident) could elevate the fishers' movement rates, and induce the fishers to move away from the study areas.

Powell (1994a) hypothesized that male and female *Martes* space themselves to gain access to different resources: females need access to food, whereas males need access to females. This predisposition may explain the timing of home range establishment by the transplanted fishers in my study. Eight of 9 transplanted fishers for which home range establishment could be verified did so by 12 April. In British Columbia, fishers breed between 6 and 27 April (Hall 1942). Female fishers maintain their home ranges while the males roam about searching for females' territories (Coulter 1966, Powell 1982, Arthur 1987). Females likely communicate reproductive status to males through urine and scent marking along boundaries of their home ranges (Johnson 1984).

To maximize the likelihood of successful reproduction, it is in the females' reproductive interest to establish a home range before the breeding season. Because males locate reproductively receptive females through their scent marks, a female should exhibit site fidelity for at least the duration of the breeding season. By having a marked home range, a female is more likely to be located by a male when she is sexually receptive. Transient females, however, will be more difficult for males to locate, even if their scent marks indicate sexual receptiveness.

Of the 7 transplanted females that established home ranges, only one did not have a permanent home range by the start of the breeding season. However, this female (F805) exhibited a period of temporary residency from about 6 March to 15 April (Fig. 4a), which roughly corresponds to the breeding season. She then abandoned this temporary home range and wandered for 2 months. By 15 June, she returned to the area of her temporary residency and established a permanent home range.

Although I monitored only 2 males, they may have established home ranges to maximize the inclusion of females within their home ranges. Powell (1994a) hypothesized that males orient their home ranges to maximize breeding opportunities. Transplanted male fishers should establish their home ranges after the females begin to exhibit site fidelity so that they can find the area with the best breeding opportunities. One of the 2 males that were transplanted in my study established a home range that bordered or overlapped home ranges of at least 4 females. The other male moved south to an area where there were no radio-collared females. However, this area has had at least 4 female fishers harvested from it in the during 1990-1993, indicating that other females were likely present during my study.

Spatial organization

The 90% UD annual home ranges of the fishers examined in my study were similar to those observed in Heinemeyer's (1993) study of transplanted fishers, the only other study of fishers to date that has used the adaptive kernel technique (as recommended by Powell [1993]) to estimate home range size. The females' home ranges were on average almost half the area of the one male's range, a size ratio that is consistent with the estimates of Heinemeyer (1993), Powell (1982), and Arthur (1987).

The overlap of home ranges among fishers in my study appeared to be seasonal; home range overlap was minimal during summer, while home ranges of adjacent females overlapped during winter. Although fishers are reported generally to have intrasexually exclusive home ranges elsewhere (Kelly 1977, Powell 1982, Arthur *et al.* 1989), the female fishers in my study and others (Heinemeyer 1993) had home ranges that overlapped extensively. Arthur *et al.* (1989) reported that some home range overlap occurs within sexes, and Kelly (1977) hypothesized that the overlap in annual home ranges by fishers of the same sex in New Hampshire was the result of shifting space use patterns of the home ranges over a year.

Although spatial overlap was common in my study, temporal overlap was very rare. In areas where home range overlap occurred, the fishers were seldom within 1 km of each other at the same time, concurring with other studies that report that fishers rarely occur together (Coulter 1966, Arthur *et al.* 1989). Female fishers in my study did not exhibit intrasexually exclusive home ranges, but rather avoided each other, and spent the majority of their time in exclusive parts of their home range. Overlap occurred on the boundaries of their home ranges and other fishers of the same sex were rarely recorded deep within another's home range.

The lack of exclusive home ranges among the females may be the result of several factors. Transplanted fishers may take time to organize themselves and adequately define and scent-mark their territories. Heinemeyer (1993) reported an apparent lack of exclusive home ranges within sexes of transplanted fishers, which she attributed to a high density of resources decreasing the net benefits of territoriality. She further speculated that the typical mustelid spacing pattern was developing as individuals became more certain of conspecifics' residency status. In my study, however, there was still considerable overlap after 2 years of permanent residency by 3 female fishers, indicating that residency status was not a factor that substantially affected fishers' space use patterns.

I hypothesize that home range overlap is a consequence of fishers' exploratory movements outside of their home ranges. These exploratory movements may be made by more socially dominant members of the population. Most of the overlap that I observed between female fishers was the result of one female's (F700) brief excursions into the other females' home ranges. These movements lasted less than 24 h, and occurred when the residents were in another part of their home ranges. F700 may have been more socially dominant because she was the first transplanted fisher to establish a home range in that area. Exploratory movements may allow fishers to assess occupancy of adjacent habitats, reproductive status of conspecifics, and relative social status.

Home range size

Several factors may have influenced the size of the 90% UD home ranges in my study. The home range size during the season immediately following home range establishment was the largest in all cases in which fishers were monitored for more than one season. As a fisher becomes more familiar with the habitats within and near its home range, it may be able to optimize the use of its space, and home range size will decrease. This same process may occur as fishers mature because juvenile home ranges are larger than those of older age classes (Kelly 1977). Fisher home ranges have been reported to be smaller in winter than at other times of the year due to decreased mobility caused by soft snow (Leonard 1980, Raine 1981) or pregnancy (Kelly 1977), but others have reported that fishers moved extensively during winter (Coulter 1966, Arthur 1987).

Reproduction also affected the home range size of females. Female fishers with kits centre their movements about a maternal den (Leonard 1980, Paragi 1990). Their movements during the ensuing summer are restricted (Leonard 1980) and the fishers appear to maximize use of this portion of their home ranges (Powell and Leonard 1983). Several studies report that females with kits reduce their home range size (Johnson 1984, Arthur 1987, Paragi 1990). In my study, the female fishers that whelped kits had 90% UD summer home ranges that were <7.0 km^2, much smaller than females without kits. During February and March, the one male that was radio-collared moved extensively and was likely searching for potential mates (Powell 1982, Arthur 1987).

Summary

The transplant programme in the SBSdw east of Williams Lake in 1990-92 was successful in reinforcing the existing population of fishers within the study area. The transplanted fishers were released into an ecosystem which was similar to their natal ecosystems, and this was likely a major factor in the success of the programme. The area of the SBSdw into which the fishers were released had historically high harvests of fishers, indicating that the landscape was productive fisher habitat in the past. The soft-release transplant methods did not appear to enhance fidelity to the release site. The establishment of home ranges appeared to be mediated by reproductive requirements.

Spatial organization of the transplanted fishers in my study area loosely adhered to the typical mustelid system of intrasexually exclusive territories. This spacing pattern may have affected the transplants by causing them to avoid areas occupied by resident fishers and move extensively following release. Eventually, as fishers in my study area reproduce, I expect that population densities will increase and marginal areas will likely be colonized by new recruits. Monitoring of fisher abundance should be continued in the study area to assess population recovery. This information will provide insight into factors affecting fisher population growth.

Chapter 3

Scale Dependent Habitat Selectivity by Fishers

Introduction

Interpretation of previous studies on habitat use by fishers is constrained by 2 factors: differences in forest types and differences in scale. Across their geographic distribution, fishers inhabit a broad range of environments, from hardwood-dominated forests of New Hampshire (Kelly 1977) to extensive coniferous forests of the Western Cordillera (Hagmeier 1956). Major differences in vegetation, stand structure, and spatial characteristics among these forest types mean that habitat relationships from one region cannot be easily extrapolated to other regions.

Most studies of fishers have not defined the scale over which habitat relationships were examined. This has hampered comparisons of fisher biology among regions and impeded translation of findings into effective management strategies. Johnson (1980) hypothesized that resource selection by an individual animal occurs on at least 4 levels and Lofroth (1993) added an additional level of selection. First order selection is exhibited at the scale of the species' geographic range. In this respect, fishers are limited to northern hemlock-hardwood, western mountain, and boreal forests (Powell 1982). Second order selection occurs when an individual animal selects an area in which to establish its home range. Third order selection occurs when an animal selects particular stands within its home range. Because stands are not always homogenous, but span a range of ecological conditions, fourth order selection is nested within this third order in that animals may prefer patches within stands. Fifth order selection occurs when an animal selects particular habitat elements (e.g. wildlife trees) within stand types and patches.

The latter 4 levels of selection are similar to levels used to describe forest ecosystem dynamics (Pickett and Thompson 1978, Harris 1984), and can be classified broadly, from coarse- to fine-grained, into landscape, stand, patch, and habitat element scales. Within this system, habitat selection order is hierarchical: landscape level selection occurs when an animal selects an area within the landscape in which to establish its home range, stand level selection occurs in the selection of stands within the home range, patch level selectivity occurs for patches within stands, and habitat element selectivity occurs for habitat elements within a patch (Fig. 12).

Lack of expression of selectivity at a coarse scale does not preclude selectivity at a finer scale. However, selectivity for a resource requirement at a coarse scale may preclude detectability of selectivity for that resource at finer scales. This can occur because, from the animal's perspective, the resource can be distributed homogenously at any scale that is finer than that at which selectivity for that resource occurs.

Most studies of fisher habitat have attempted to quantify habitat selection solely at the stand scale (e.g. Kelly 1977, Powell 1977, Johnson 1984, Arthur 1987). This has lead to inconsistent or inappropriate applications when findings from one region are applied to management of fishers in other ecological contexts. For example, a resource requirement may be fulfilled at the patch or habitat element level in one study, but selectivity for this resource may be expressed at a different scales in another area, or even for a different stand type, due to differences in local forest conditions between

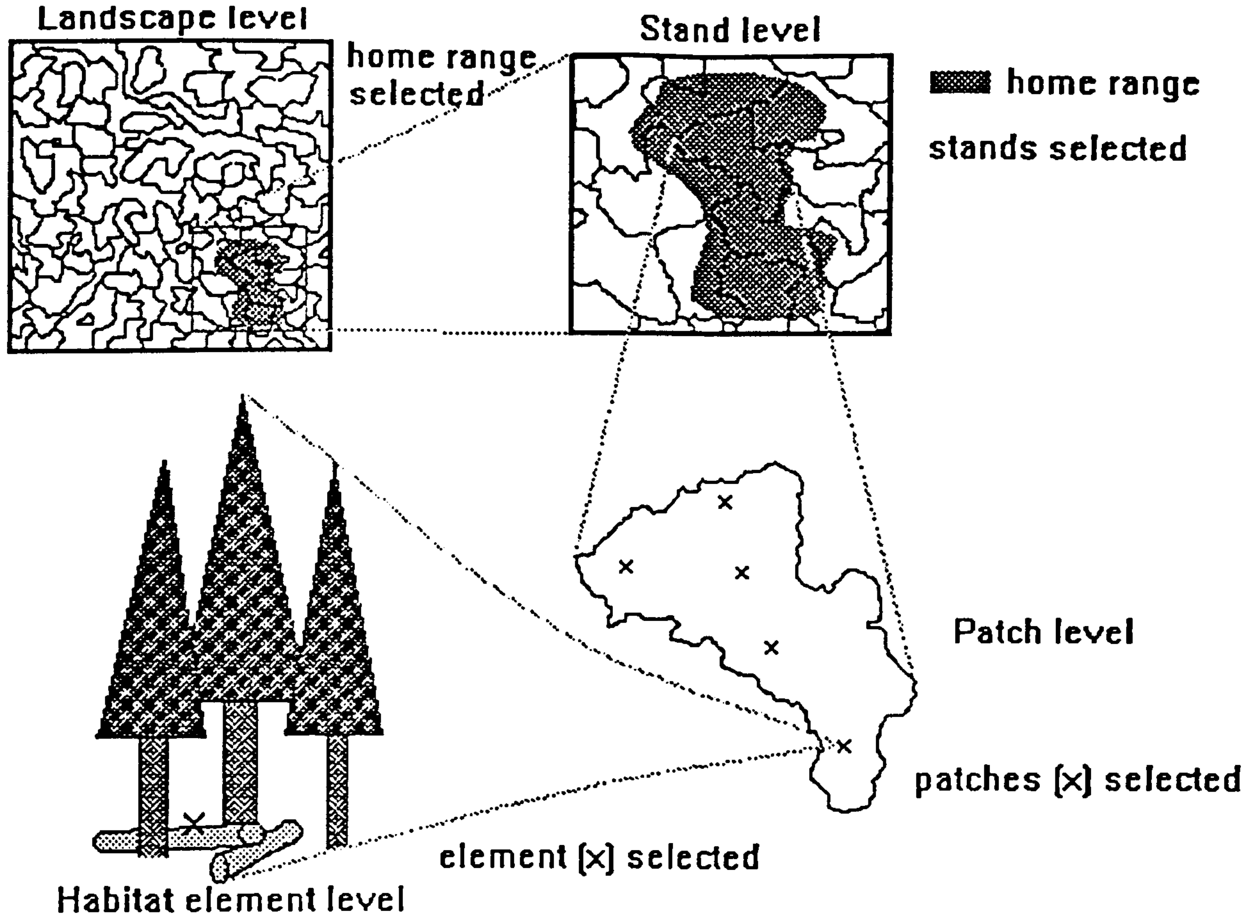


Fig. 12. The hierarchical nature of scale. Animals may select areas within the mosaic of stands in the landscape in which to establish home ranges (landscape level). They may use stands within their home ranges selectively (stand level). Because stands are not necessarily homogenous, animals elect to use patches within stands (patch level). Animals may also select particular habitat elements when using patches (habitat element level).

different geographical areas. Therefore, when selectivity is detected, it is important for the researcher to attempt to determine which resource requirements are being fulfilled at each level. Using this information, managers in different ecological areas can base management decisions on resource requirements, rather than on habitat use patterns from other areas.

My objective is to examine habitat selection by fishers in the dry-warm variant of the Sub-Boreal Spruce biogeoclimatic zone (SBSdw) of British Columbia, using four selection scales: landscape, stand, patch, and habitat element levels. Analyses of scale-dependent habitat requirements will facilitate scale-based management of habitats. Knowledge of the scale-dependent resource requirements of fishers will improve the effectiveness of habitat management, rather than limiting habitat management options to stand level prescriptions.

Landscape level

Selectivity at the landscape level can be detected in 2 discrete portions of a fisher's life cycle. Transient fishers will travel through the landscape prior to home range establishment, and make landscape-level decisions when selecting stands within the landscape. Transplanting fishers offers an opportunity to examine home range selection at the landscape level. Resident fishers also make landscape level decisions. Lofroth (1993) hypothesized that stand types included within marten home ranges reflect landscape level habitat selection. Ideally, stand types included within a home range should maximize the fitness of the individual (Buskirk and Powell 1994). Maximizing the proportion of good stands comprising the home range, while minimizing the inclusion of poor and marginal stands, should result in increased survival and reproduction of the individual, because energy costs of acquiring resources are lower in good habitat than in poor or marginal habitats (Thompson and Harestad 1994).

Allen (1983) proposed and Thomasma *et al.* (1991) tested a habitat suitability index model for fishers in eastern North America based upon an extensive review of the literature. They hypothesized that the suitability of habitat for fishers is determined by percentage tree canopy closure, mean stem diameter of overstory trees, number of vegetative strata, and percentage of overstory canopy comprised of deciduous trees. Therefore, at the landscape level, when transplanted fishers are establishing home ranges, they should search for and select arrays of stands in which these attributes occur at optimum levels. Presumably, resident fishers have already made appropriate landscape-level habitat selection decisions and their selectivity will be reflected in the composition of their home ranges.

I will test landscape level selection by examining stand use by transplanted fishers before home range establishment and stand composition of fisher home ranges for resident fishers. If landscape level selection occurs, fishers should show selectivity in their use of stands while they are transient. In addition, stands that are included within fishers' home ranges should be different from their availability in the landscape if landscape level selectivity is expressed when establishing home ranges.

Stand level

Fishers fulfil several requirements at the stand level. Fishers have been generally reported to select older seral stands with continuous canopy cover to provide security cover (Coulter 1966, Kelly 1977, Powell 1977, Arthur 1987). Fishers rarely use open areas for foraging (Raine 1981), and if crossing them, they usually run (Powell 1981). Fishers also use riparian stands for resting and foraging (Johnson 1984, Jones 1991). As well, the distribution, both spatially and temporally, of denning sites, prey, and snow packs have also been identified as habitat variables that affect selection of stand types (Powell 1982).

I will examine selectivity at the stand scale by comparing use of stands with availability of stands within each individual fisher's seasonal home range. If fishers exhibit stand level use, I expect them to use stands that have greater overhead cover and larger average diameter trees more often than other available stands. Furthermore, I expect fishers to select riparian stands.

Patch level

In part, the differences between stand level (selection of stand types within a home range) and patch level (selection of patches within a stand type) lie with the resolution of habitat classification invoked by the researcher. For example, a researcher may classify a forest stand as a mixed forest. This stand could also be regarded as a complex mosaic of conifer and deciduous forest types. Such stands are often classified as "mixed forest" because of the limited spatial resolution of mapping systems. Between site variability is high within such mixed-forest stand types. Patch level selection recognizes these limitations and allows the researcher to examine selectivity at a finer resolution of habitat classification.

Researchers have recognized implicitly that fishers select habitats on the basis of many variables expressed at the patch scale. This is one of the reasons for the difficulty in interpreting results of past fisher habitat studies. For example, Raine (1981) reported that fishers appear to alter their movements to avoid stands with deep, soft, snow which increases the energy costs of movement. He attempted to relate this phenomenon to a stand level selection process. However, during tracking periods, he recorded fishers making changes in their direction of travel *within* stands to locate patches with more supportive snow. Powell (1994b) reported that fishers in Michigan selected for patches with porcupine dens in otherwise "unsuitable" stands. Johnson (1984) suggested that edges are an important component of stands, and fishers may use them preferentially. Thus, patch-level selectivity occurs in fishers' use of stands, and this selectivity is expressed for many different habitat characteristics.

I will examine selectivity at the patch level by comparing use of patches within stands with the availability of patches within those stands. I predict that patches used by fishers will have greater volumes of coarse woody debris (Jones 1991), denser understory (Powell 1994b), and greater abundances of suitable habitat elements for denning (Arthur 1987) than those expected within the stand.

Habitat element level

Past studies of fishers have identified several structural features that fishers use at a habitat element level. Resting sites used by fishers can be snow dens, hollow coarse woody debris (Powell 1977), witches brooms, and tree cavities (Arthur 1987, Jones 1991). Maternal den requirements may be more stringent; all recorded natal dens are located in cavities in large diameter deciduous trees (Leonard 1980, Paragi 1990).

I will examine selectivity at the habitat element level by comparing use of elements by fishers to the availabilities of the elements within patches and across the landscape. I predict that fishers will use large diameter trees and snags in which to rest (Arthur 1987, Jones 1991), and whelp in cavities in the boles of large deciduous trees (Leonard 1980, Paragi 1990).

Methods

Fishers were live-trapped, radio-collared, and monitored as described in Chapter 2. I calculated home ranges (90% utilization distribution) of each fisher for each season in which enough locations were obtained (Chapter 2). I estimated seasonal home ranges by pooling locations by season across years to form multi-year seasonal home ranges.

Stand types within the study area were delineated using the biophysical classification system presented by Lea (1992). This system is a hierarchical scheme that classifies land into units based upon ecological factors and measurable or readily inferable features of the land. A biophysical habitat (i.e. stand) is a relatively homogenous unit with respect to bedrock geology, surficial materials, soils, climate, topography, and successional trend of vegetation (Lea 1992). Using the physical base of surficial materials, soils, and topography, known vegetation relationships are used to map and predict ecologically distinct biophysical units. Biophysical units are named based upon dominant tree and shrub species that are common to most seral stages and phases of that site association.

I classified stands according to biophysical unit, stand age, and forest phase. Stands were assigned one of seven seral stages ranging from non-vegetated to old growth (Table 5), and one of four forest phases (coniferous, deciduous, mixed coniferous-deciduous, or selectively-logged mixed coniferous-deciduous) was assigned to stands that were fully forested (> 10 yr). I delineated biophysical units using site associations as determined by Clements (1991) and B.C. Ministry of Forests (1987). I considered stands as relatively homogeneous assemblages of habitat with respect to coarse woody debris, closure of vegetation strata, and other structural attributes.

Biophysical mapping was performed for 405 km^2 of the total study area, covering the areas in which most fisher home ranges occurred. One half of the intensive study area was mapped in the fall of 1991 (Clements 1991), and I mapped the remainder during summer 1993. I estimated the availability of each stand type in the landscape from 1001 random point samples drawn from mapped areas and 14 random locations elsewhere in the study area (Appendix A), using Marcum and Loftsgaarden's (1980) non-mapping technique.

Table 5. Seral stages and corresponding stand ages used in the stand classification system.

Seral stage	Seral classification	Stand age (yr)
1	Non-vegetated	0
2-3	Herb-Shrub	1-10
4	Pole-Sapling	11-40
5	Young Forest	41-80
6	Mature Forest	81-250
7	Old Growth	251+

Landscape level

Stand types were determined for aerial locations and for ground telemetry locations at which 95% error polygons (Nams 1991) were less than 1.5 ha. I assessed landscape level habitat selectivity during two periods: the transient phase and after home range establishment. I determined selectivity during the transient phase by comparing use of stands before home range establishment (Chapter 2) to the availabilities of these stands in the landscape. I performed Chi-square goodness of fit tests and Bonferroni-adjusted Z tests (Nue *et al.* 1974) on pooled observations from all transplanted fishers.

For the period following home range establishment, I overlaid seasonal home ranges on biophysical maps of the study area and the percentage of each stand type within each home range was estimated using a digital planimeter. Stand compositions of the home ranges were compared to availabilities in the study area using Chi-square goodness of fit and Bonferroni-adjusted Z tests (Neu *et al.* 1974). I limited analyses to those stand types which comprised at least 5% of the landscape to eliminate interpretation problems associated with high use-availability ratios resulting from spurious locations in rare stand types (E.C. Lofroth, B.C. Ministry of Environment, *pers. comm.*).

I calculated Vanderploeg and Scavia's relativized electivity index (Lechowicz 1982) comparing the composition of each fisher's seasonal home range to that expected from availabilities within the landscape. I determined general trends in selectivity among fishers by comparing the mean electivity index for all fishers for each biophysical habitat type to zero (no selectivity) using t-tests, with significance occurring at $P \leq 0.05$.

Stand level

I determined stand level selection by comparing the use of each biophysical habitat type to its availability within each fisher's seasonal home range using Chi-square goodness of fit and Bonferroni-adjusted Z tests (Neu *et al.* 1974). Stand analyses were limited to those biophysical habitat types which comprised at least 5% of the individual fisher's seasonal home range. Also, I compared the use of stands by fishers to availability of stands classified by seral stage and forest phase.

I also determined stand level selectivity by comparing use to availability within each seasonal home range for stands grouped on the basis of similar mean habitat attribute values. I collected habitat attribute data for biophysical habitat types that comprised at least 5% of each home range. These stand-level data were collected at random locations within randomly selected stands throughout the study area. Each stand type was sampled at least twice, with many types sampled at least 5 times. I grouped stands by 13 habitat attributes based upon mensuration data for live and dead trees, percent closure of each vegetation strata, and volume of coarse woody debris (CWD) volumes estimated at each sample location (Lofroth 1992). Stand types were assigned to attribute classes (Table 6) based on mean values of the attributes at the stand description plots.

I calculated Vanderploeg and Scavia's relativized electivity index for each fisher's use of each of the 13 habitat attribute classes. I determined general trends in selectivity among fishers by comparing the mean electivity index for all fishers for each habitat class to zero (no selectivity) using *t*-tests, with significance occurring at $P \leq 0.05$.

Table 6. Habitat attribute classes used to group stands for stand level selectivity analyses. Each stand type was assigned to one class of each attribute based upon the mean value of that attribute at random points within that stand type. Mean electivity indices were calculated for each class of each attribute.

Attribute	Classes
Coarse woody debris (CWD)	(m^3/ha)
Total volume of CWD	0, 1-100, 101-200, >200
Volume of CWD >20 cm diameter	0, 1-25, 26-50, >50
Volume of CWD not resting on ground	0, 1-20, 21-40
Vegetation strata closure	(%)
Coniferous canopy	0, 1-20, 21-40, 41-60
Deciduous canopy	0, 1-20, 21-40, 41-60
High shrub (2-10 m)	0, 1-20, 21-40, 41-60
Low shrub (0.15-2 m)	0, 1-20, 21-40, 41-60, 61-80, >80
Stocking density	(stems/ha)
Total stocking density	0, 1-1000, 1001-2000, 2001-3000, >4000
Stocking of trees with rust brooms	0, 1-20, 21-40, >40
Stocking of >40 cm dbh trees	0, 1-50, 51-100, <100
Stocking of aspen trees	0, 1-400, 401-800, 801-1200, >1200
Stocking of spruce trees	0, 1-400, 401-800
Tree attributes	(cm)
Mean tree diameter	7.5-15, 15.1-22.5, 22.6-30, >30

Patch level

For each habitat attribute class, I determined patch level selection by comparing mean attribute values at fisher locations to mean attribute values of random stand description plots (stand mean) using Mann-Whitney U-tests. I defined patches as the area covered by a variable radius prism sweep (Luttmerding *et al.* 1990). Some stands that I examined did not have particular habitat attributes. For example, in some stand types, no coarse woody debris was recorded in any of the stand description plots (e.g. in a cultivated field). However, patches of the attribute may have existed within these stands, but I did not detect them in my random samples. These patches were rare enough (e.g. slash-piles) that they were not sampled, but because they existed within the stand, fishers could use them. Thus, in my results, I occasionally reported fishers using a particular attribute although the stand mean was zero for that stand type.

Habitat element level

Because it is often difficult to observe which components of the habitat that radio-collared animals use, the animal has to be definitively recorded using a particular element to determine habitat element selectivity. In my study, definitive use of habitat elements was only recorded for locations of stationary fishers. Habitat element data were collected for all resting and maternal dens that I located. Tree species, diameter-at-breast-height (dbh), tree (decay) class, height of den, and number of spruce broom rust (*Chrysomyxa arctostaphyli*) clumps were recorded for tree dens. Decay class, diameter and height above ground were recorded for CWD and slash-pile ground dens. Mann-Whitney U-tests were used to test for differences between characteristics of tree dens and characteristics of trees of the same species found within the same patch and across the landscape. Insufficient numbers of ground dens were located to permit comparisons between habitat elements used for ground dens. Significances of all statistical tests are reported at the $P \leq 0.05$ level.

Results

Landscape level habitat selection

I determined landscape use by transient fishers from 118 locations of 15 transplanted fishers. Transient fishers exhibited some selectivity when I used the biophysical habitat classification system, the highest level of resolution for habitat classification. Transient fishers' use of biophysical habitats was significantly different from expected ($\chi^2 = 37.4$, df = 5, $P < 0.001$). Fishers avoided cultivated fields (CF2) and the most abundant herb seral stage stand type (SF2). Fishers selected for the young forest seral stage of the spruce-falsebox biophysical unit (SF5; mesic, Douglas-fir - lodgepole pine overstory).

I also determined landscape level use by examining the stand composition of 16 seasonal home ranges. Only 9 of 12 fishers (7 F, 2 M) were included in these analyses because some of the transplanted fishers established home ranges outside of the mapped areas. Only 2 of 16 seasonal (1 summer, 1 autumn) home ranges included stands at frequencies significantly different from expected. In these 2 cases, both fishers avoided including mixed phases of young and mature spruce-falsebox stands (SF5m and SF6m) within their home ranges. One of the fishers also included cultivated fields (CF2) within its home range less than expected. Both fishers included the SF5 stand type in their home ranges more frequently than expected. Mean electivity indices were calculated for the biophysical habitat composition of home ranges in each season for all fishers. I did not detect any significant departures from random inclusion of stand types within seasonal home ranges.

Stand level habitat selection

I determined stand level use from 438 locations of 9 fishers in 16 seasonal home ranges. Fishers used stands at frequencies different than expected at the stand level in 6 of 16 seasonal home ranges. These differences were not because fishers exhibited preferences for stands, but all 6 were the result of avoidance of early seral stage stands (CF2, SF2, SF3, SF4, WS2), open water (OW), and deciduous (SF5d) stands.

Differences between the availabilities of various stand types within home ranges and those that were used by individual fishers became more pronounced when stands were classified by forest phase. Fishers' use of stands grouped by forest phase differed from expected in 11 of 16 seasonal home ranges. Avoidance of stands was more evident at this classification; all fishers that exhibited significant stand level selectivity avoided non-forested stands. Mixed selectively-logged stands were also avoided within two seasonal home ranges. Fishers used coniferous stands more frequently than expected in 3 of 7 winter home ranges. One fisher used mixed coniferous-deciduous stands more frequently than expected within its winter home range.

General trends in stand use within home ranges were examined using mean electivity indices for each stand type. During autumn, fishers avoided early seral stage SF2 stands within their home ranges. During summer, they used mixed phase, young forest, spruce-falsebox stands (SF5m) more frequently than expected, but avoided early seral stage wetlands (WS2) (Table 7). During winter, fishers did not exhibit any trend in selectivity of stand types within their home ranges.

When I examined stand use by seral stage, fishers exhibited selectivity by avoiding herb stage stands in all seasonal home ranges (Table 8). Fishers used mixed forest phases within their home ranges more frequently than expected during autumn and summer, but during winter, fishers avoided using non-forested and mixed-selectively logged stands (Table 9).

Fishers showed stand level selectivity when biophysical habitat types were grouped into habitat attribute classes. Figures 13 through 25 show selectivity of stands classified by habitat attributes. Fishers avoided stands with no coarse woody debris (CWD) during summer and winter, and preferred stands with over 200 m^3/ha of debris during summer (Fig. 13). I did not detect selectivity for volume of debris during autumn. Fishers also preferred stands with 1-25 m^3/ha of hard CWD >20 cm in diameter during summer, but during winter, stands with greater than 50 m^3/ha of CWD >20 cm diameter were preferred (Fig. 14). During summer, selectivity occurred for stands that had between 21-40 m^3/ha of CWD not resting on the ground. However, during both autumn and winter, mean electivity indices for any of the classes of above-ground CWD were not significantly different from zero (Fig. 15).

Fishers preferred stands with greater than 20% coniferous canopy closure during

Table 7. Mean electivity indices for biophysical habitat types that comprise >5% of fisher seasonal home ranges. Fishers avoided early seral stage stands, and selected for a mixed forest, young stage habitat. * indicates significant difference from zero ($P \leq 0.05$). - indicates insufficient data. Biophysical habitat type codes are defined in Appendix A.

Biophysical	Summer			Autumn			Winter		
habitat type	Mean	±SE	*n*	Mean	±SE	*n*	Mean	±SE	*n*
DT6m	-0.18	0.16	3	-	-		-	-	
SF2	0.50*	0.14	7	-1.00*	0.00	2	-0.58	0.18	3
SF3	-0.55	0.28	4	-	-		-0.89*	0.11	2
SF4	-0.55	0.19	3	-	-		-0.37	0.32	3
SF4m	-0.32	0.53	2	-	-		-0.30	0.22	2
SF5	0.09	0.10	6	0.19	0.11	3	0.21	0.08	6
SF5m	0.41*	0.06	3	-0.15	0.43	3	-0.34	0.26	4
SF6	-0.10	0.27	4	-0.32	0.68	2	-0.24	0.26	5
SF6m	0.04	0.12	4	-0.06	0.41	2	-0.02	0.08	4
WS2	-1.00*	0.00	2	-	-		-	-	
OW	-	-		-	-		-1.00*	0.00	2

Table 8. Mean electivity indices for stands classified by seral stage that comprised >5% of fisher seasonal home ranges. Fishers avoided early seral stage stands in all seasons. * indicates significant difference from zero ($P \leq 0.05$).

Seral stage	Summer			Autumn			Winter		
	Mean	±SE	*n*	Mean	±SE	*n*	Mean	±SE	*n*
Herb	-0.62*	0.09	7	-0.81*	0.19	3	-0.87*	0.08	6
Shrub	-0.29	0.15	6	-0.39	0.61	2	-0.38	0.12	4
Pole-sapling	-0.04	0.20	5	-0.13	0.44	3	-0.09	0.27	5
Young forest	0.18	0.06	7	0.10	0.27	3	0.18	0.06	6
Mature forest	0.10	0.11	7	-0.03	0.15	3	0.20	0.10	6

Table 9. Mean electivity indices for stands classified by forest phase that comprised >5% of fisher seasonal home ranges. Fishers selected for mixed stands in summer and autumn, and avoided non-forested and mixed selectively-logged stands during winter. * indicates significant difference from zero ($P \leq 0.05$). - indicates insufficient data.

Forest	Summer			Autumn			Winter		
phase	Mean	±SE	*n*	Mean	±SE	*n*	Mean	±SE	*n*
Coniferous	0.04	0.07	7	0.11	0.27	3	0.21	0.92	6
Deciduous	-	-		-	-		0.05	0.07	2
Mixed	0.18*	0.03	7	0.16*	0.02	3	0.11	0.10	6
Mixed-Selectively logged	-0.47	0.30	3	-	-		-0.94*	0.05	2
Non-forested	-0.52	0.15	7	-0.36	0.33	3	-0.72*	0.11	6

winter (Fig. 16), but I did not detect significant stand-level selectivity for coniferous canopy closure classes during summer and autumn. Fishers demonstrated relatively little selectivity for stands based on deciduous canopy closure during winter (Fig. 17). However, during summer, fishers avoided stands that had no deciduous component (class 0%), and preferred stand types with deciduous canopy closure between 21-40%.

Fishers exhibited little selectivity for stand types classified by percent cover of the high shrub stratum (2-10 m) (Fig. 18). The mean electivity index was significantly greater than zero for the 41-60% closure class during winter. During both summer and winter, the mean electivity indices were significantly less than zero for stands in which the percent cover of low shrubs (0.15-2 m) was greater than 80% (Fig. 19). The mean electivity indices were positive (but non-significant) for stands with closure of low shrub between 20-80% during summer and winter.

Fishers avoided stands without trees during summer and winter (Fig. 20). Although not significantly different from zero, mean electivity indices were positive for stands with stocking densities between 1-3000 stems/ha during winter, and 1001-3000 stems/ha during summer. Electivity indices were positive for all classes of stocking density of trees infested with rust brooms during autumn (Fig. 21). Fishers selected stands with 1-20 broom-laden trees/ha during summer. No significant selectivity was detected during winter.

Fishers selected stands classified by stocking densities of trees >40 cm dbh during autumn and winter, but not during summer (Fig. 22). Mean electivity indices were significantly greater than zero for stands with 1-50 stems/ha and 51-100 stems/ha of trees >40 cm diameter during winter. Fishers did not exhibit significant selectivity for

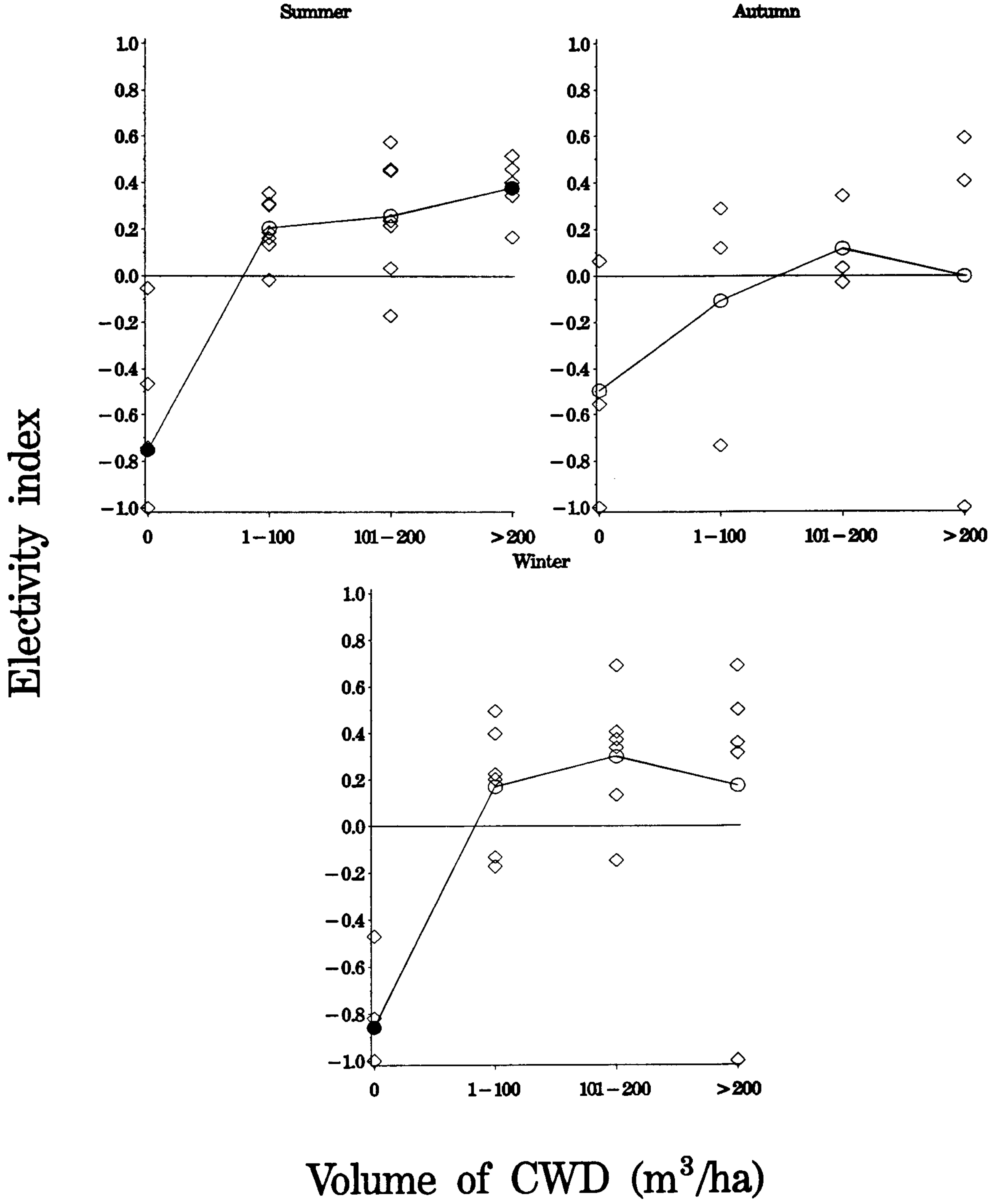


Fig. 13. Seasonal electivity indices for volume classes of coarse woody debris (m^3/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different (*P* ≤ 0.05) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

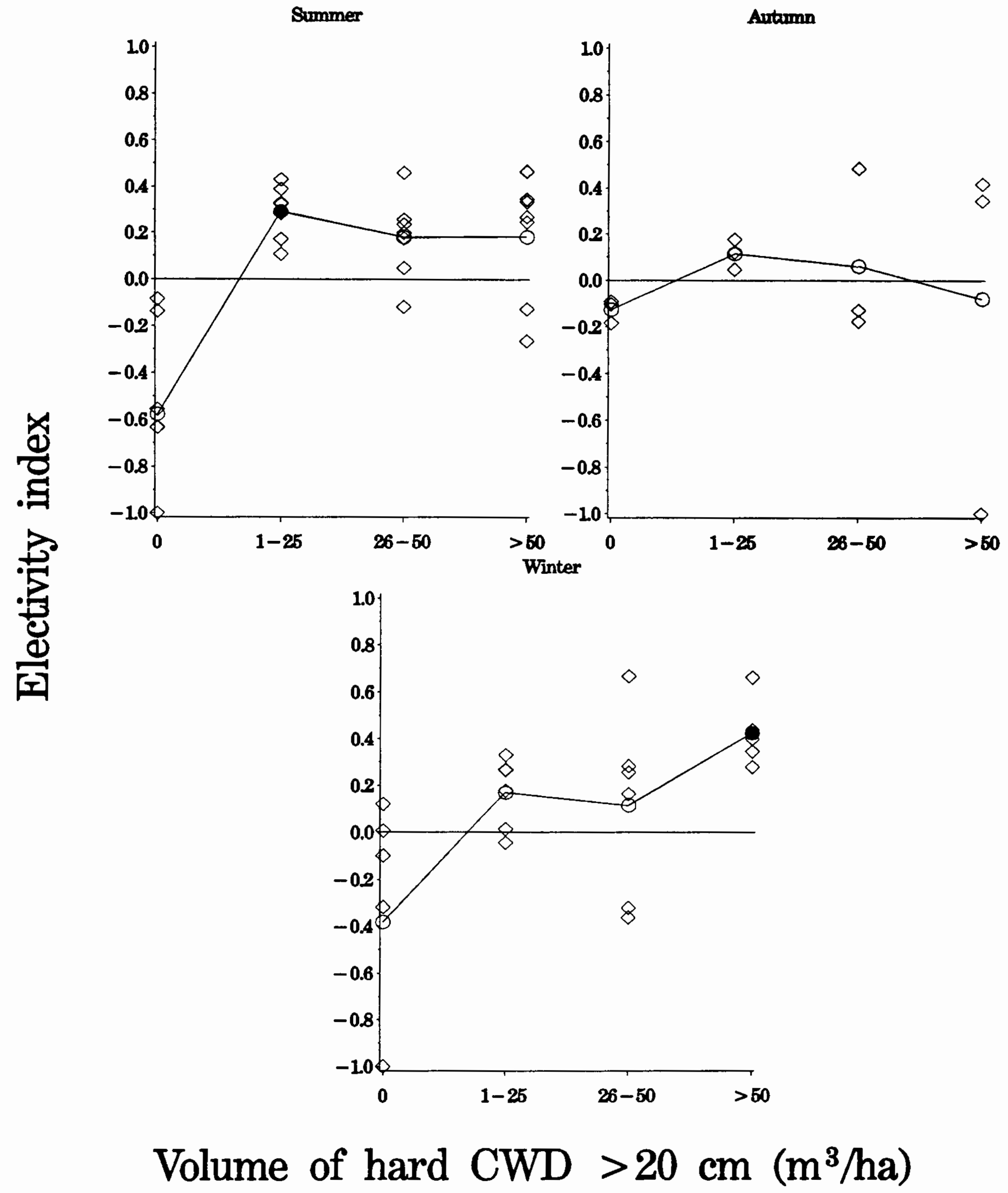


Fig. 14. Seasonal electivity indices for volume classes of hard coarse woody debris >20 cm diameter (m^3/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

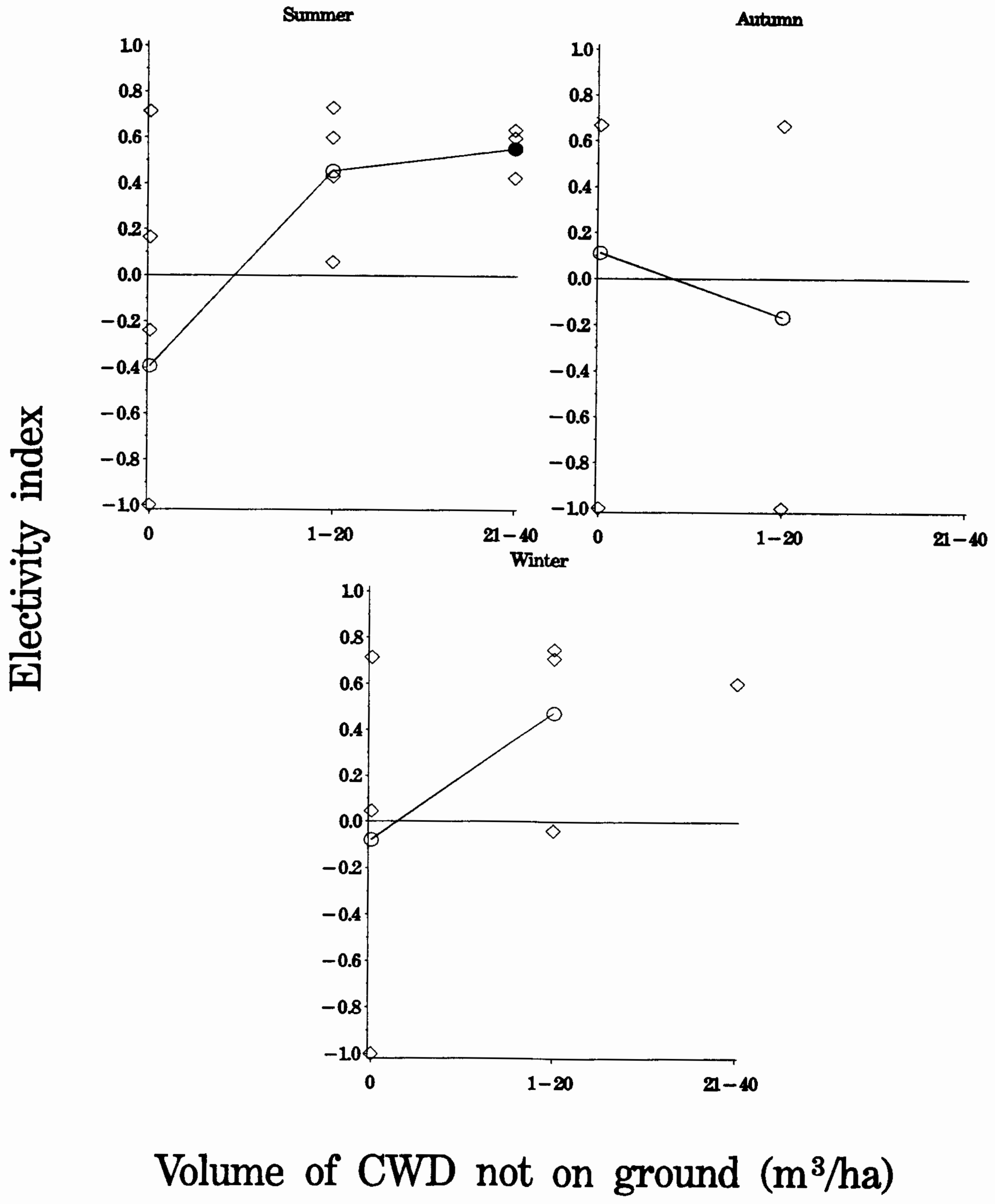


Fig. 15. Seasonal electivity indices for volume classes of coarse woody debris not resting on ground (m^3/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different (*P* $\leq$ 0.05) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

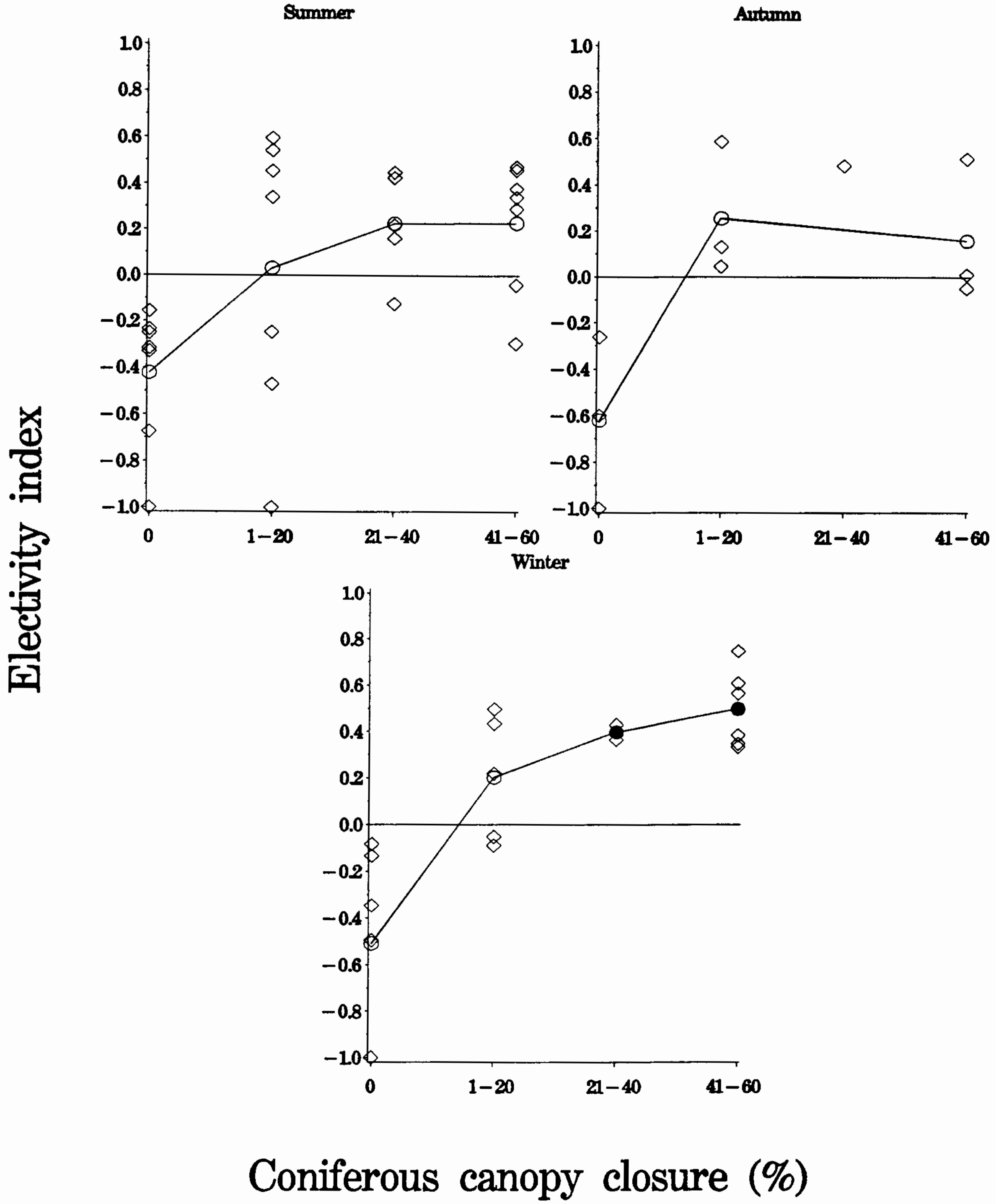


Fig. 16. Seasonal electivity indices for closure classes of coniferous canopy. Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

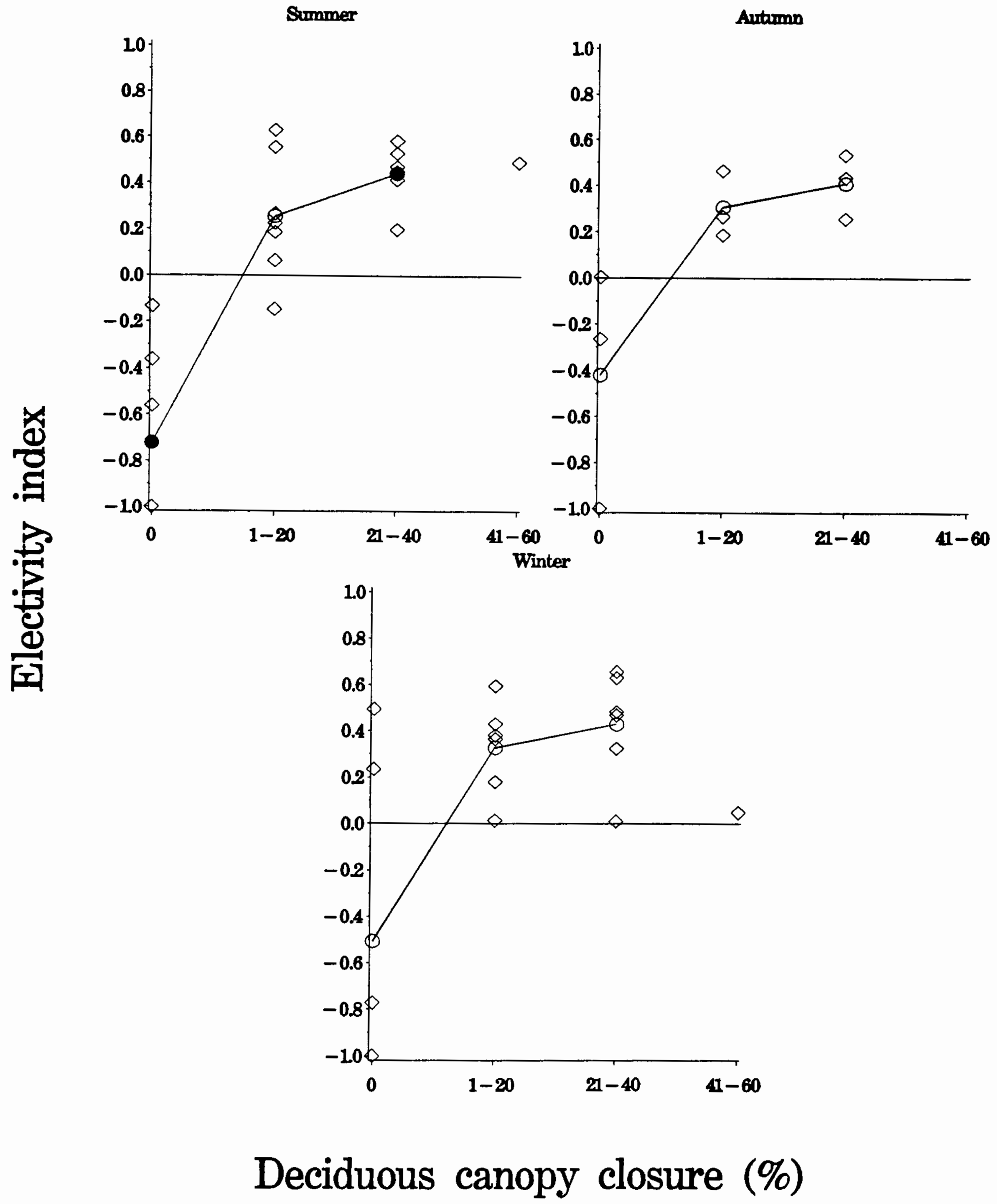


Fig. 17. Seasonal electivity indices for closure classes of deciduous canopy. Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

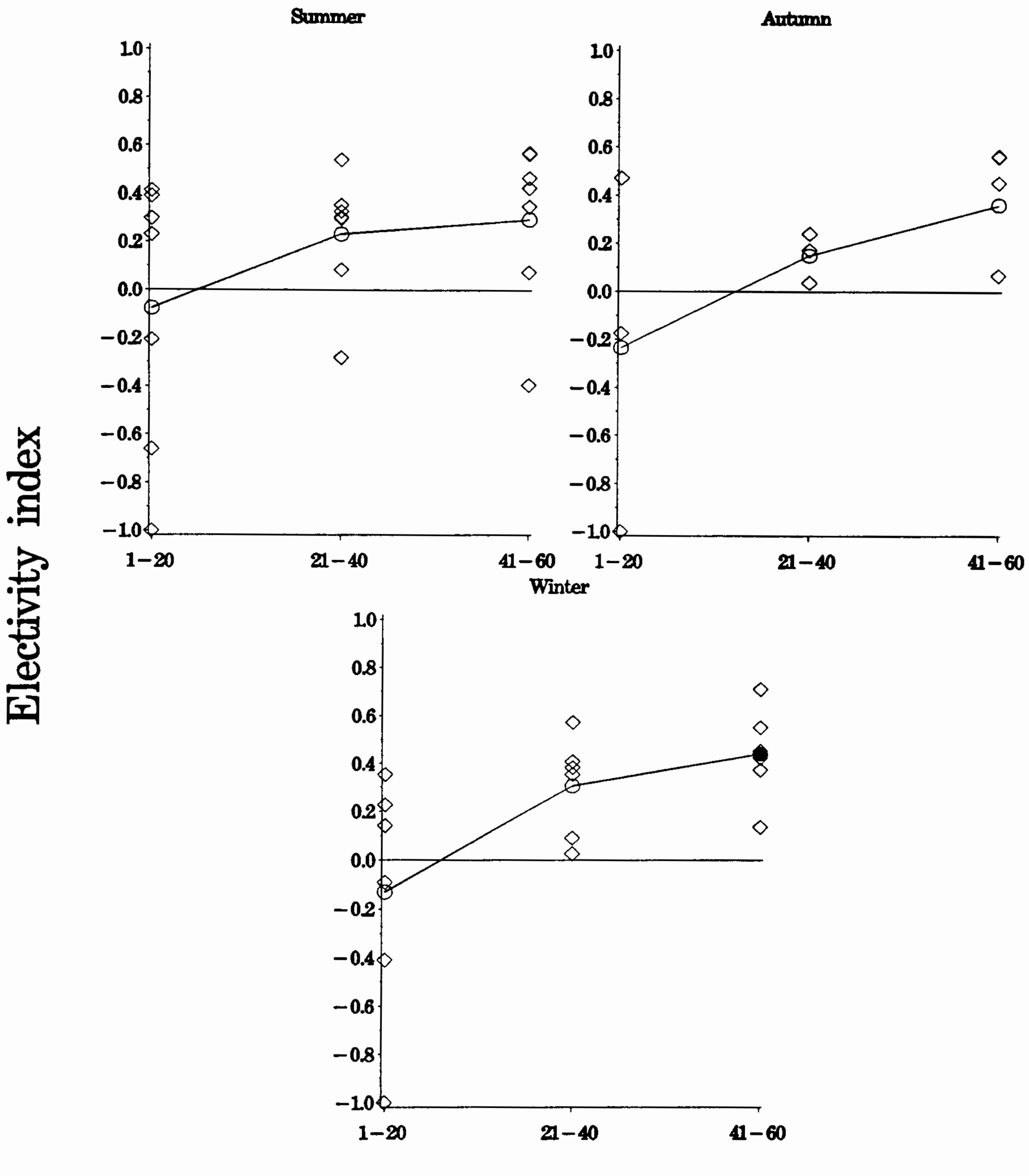


Fig. 18. Seasonal electivity indices for closure classes of high shrub (2-10 m). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

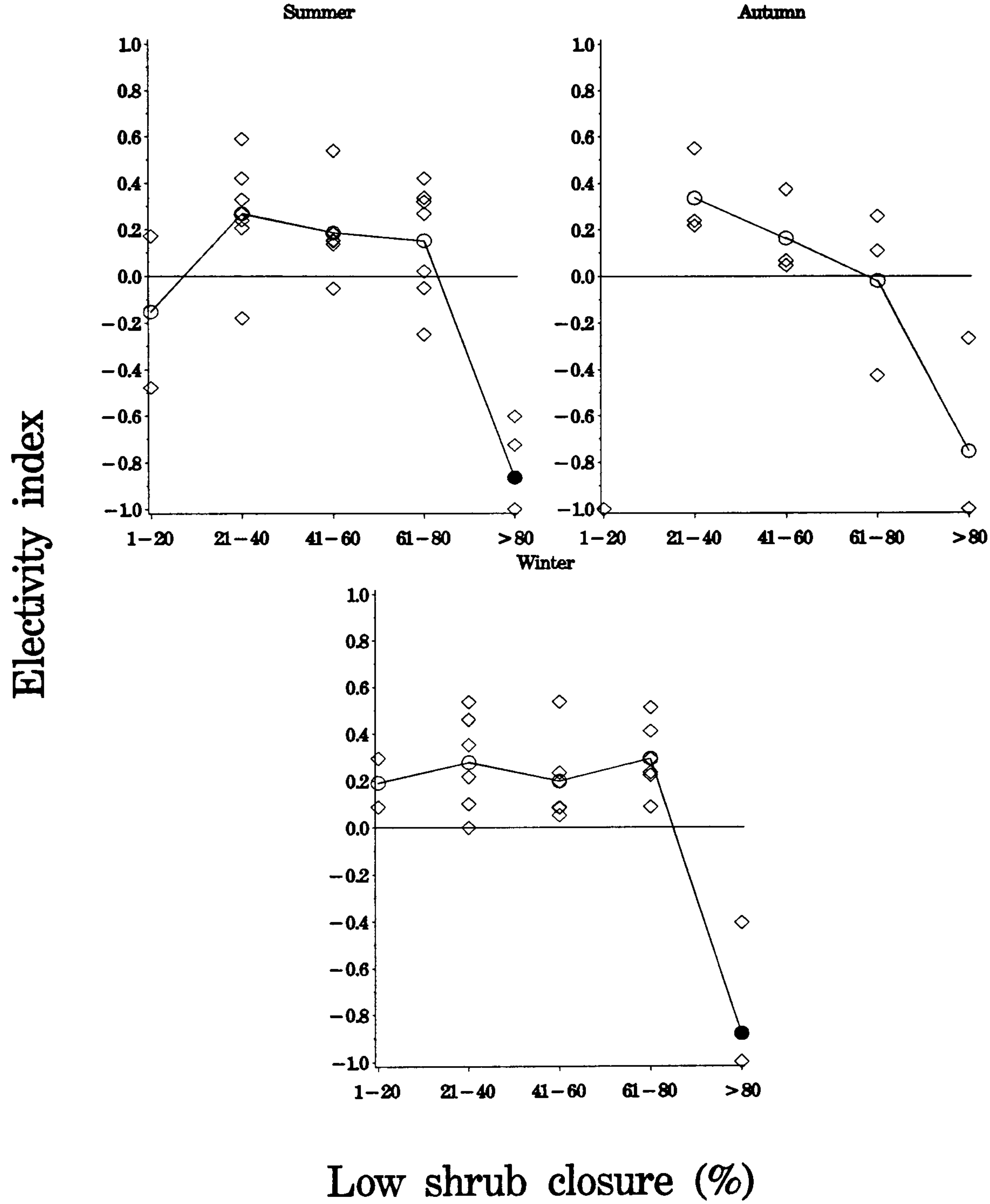


Fig. 19. Seasonal electivity indices for closure classes of low shrub (0.15-2 m). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

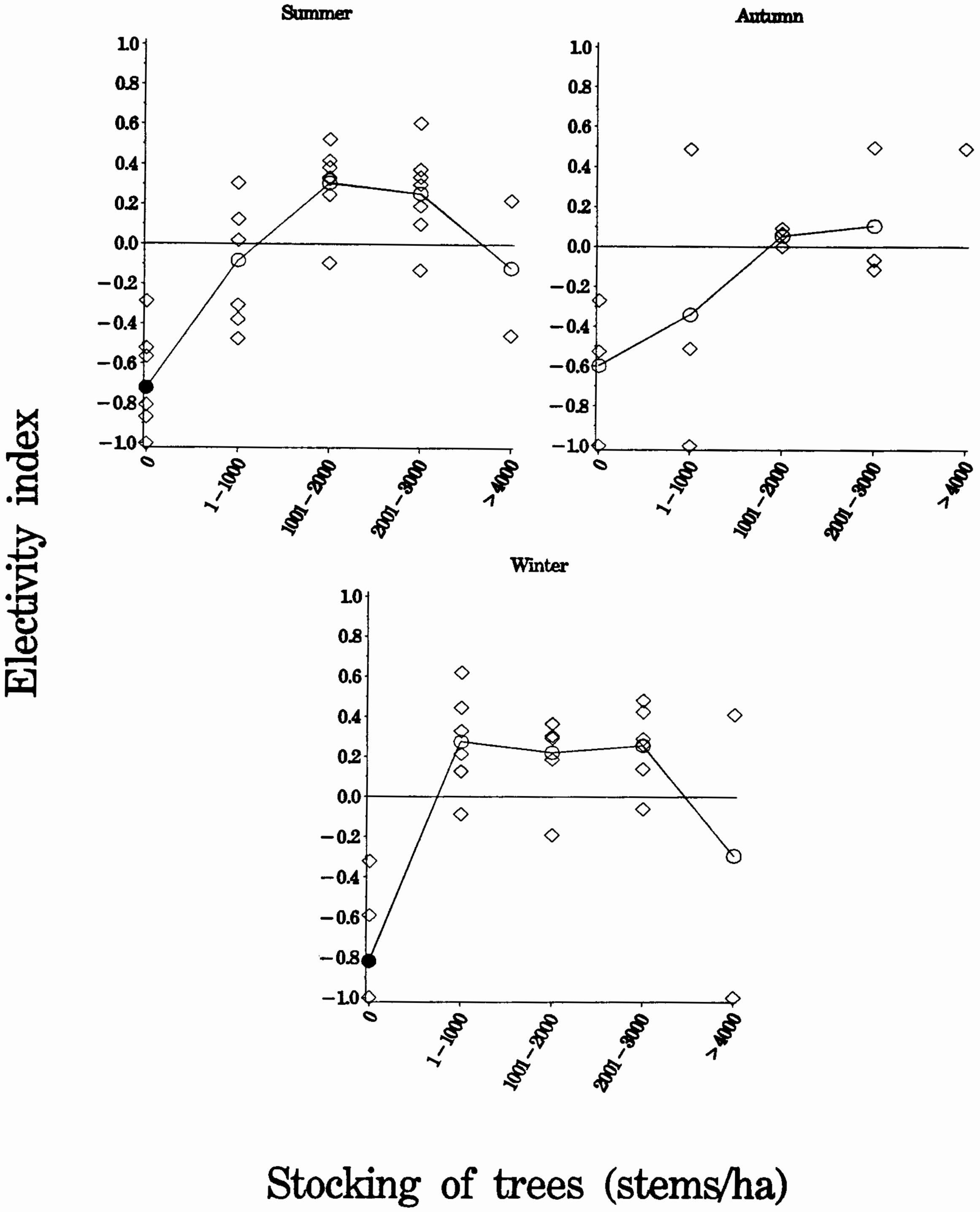


Fig. 20. Seasonal electivity indices for classes of total stocking density (stems/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

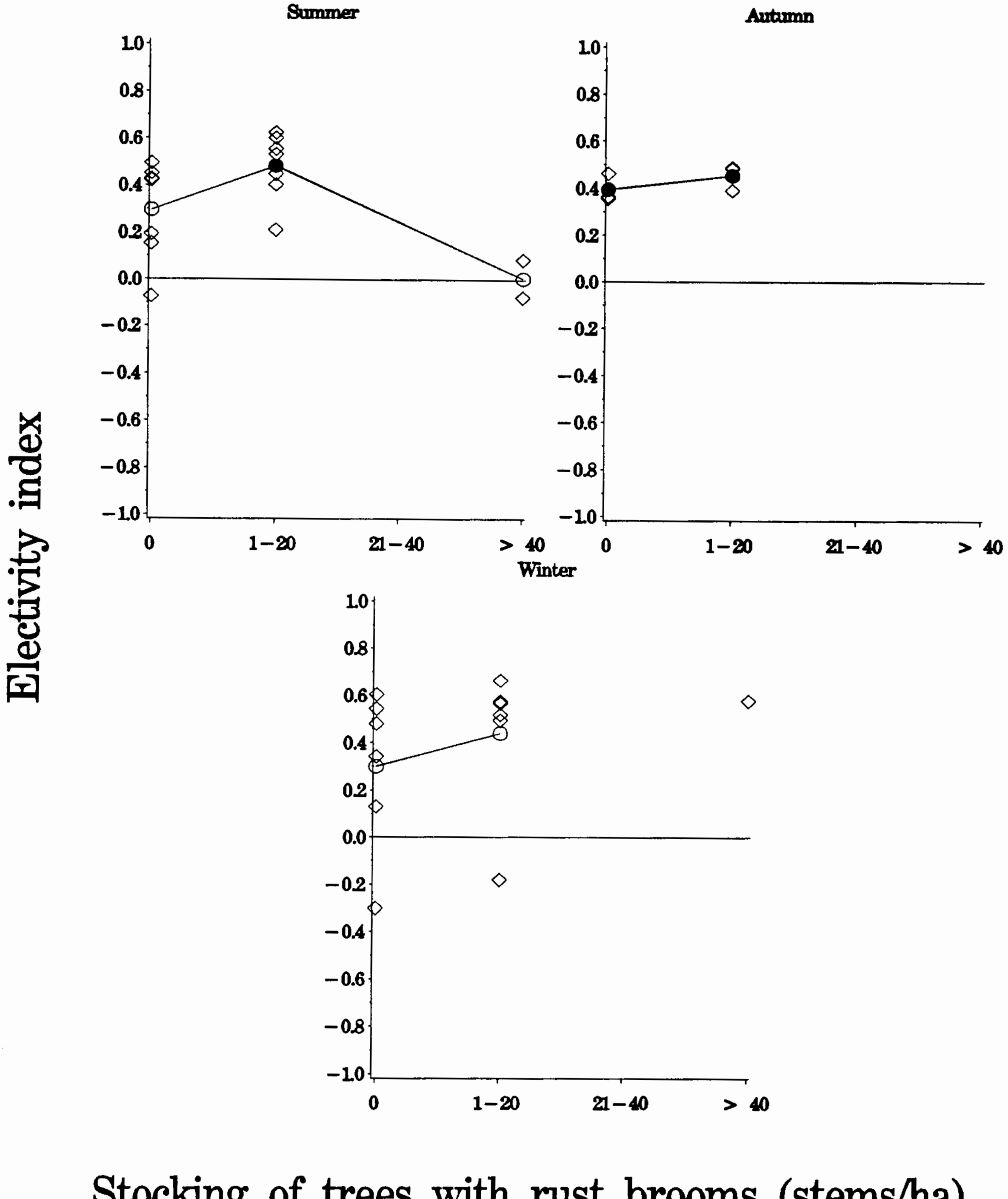


Fig. 21. Seasonal electivity indices for stocking classes of trees infested with broom rust (stems/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

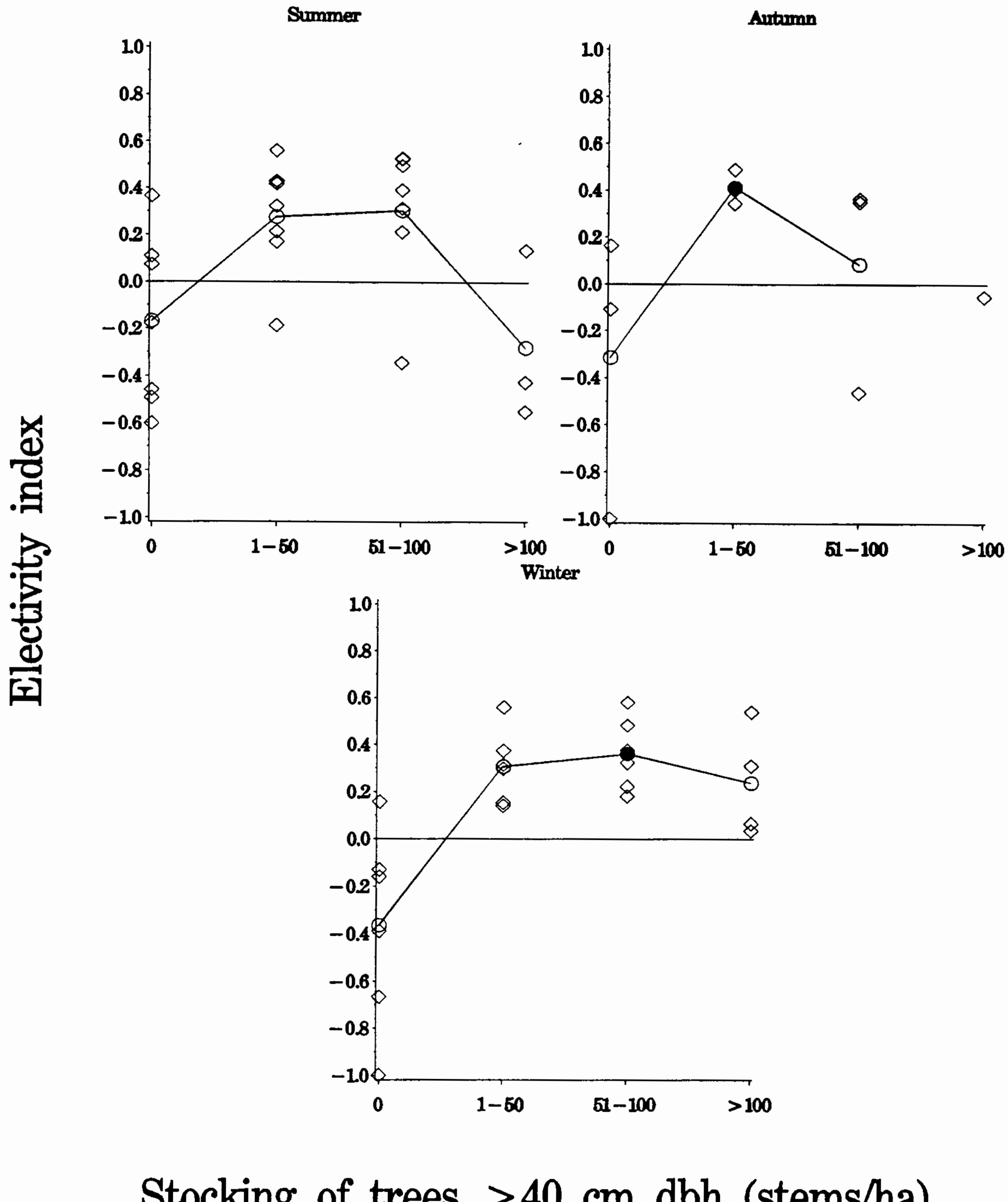


Fig. 22. Seasonal electivity indices for stocking classes of trees >40 cm dbh (stems/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different (*P* ≤ 0.05) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

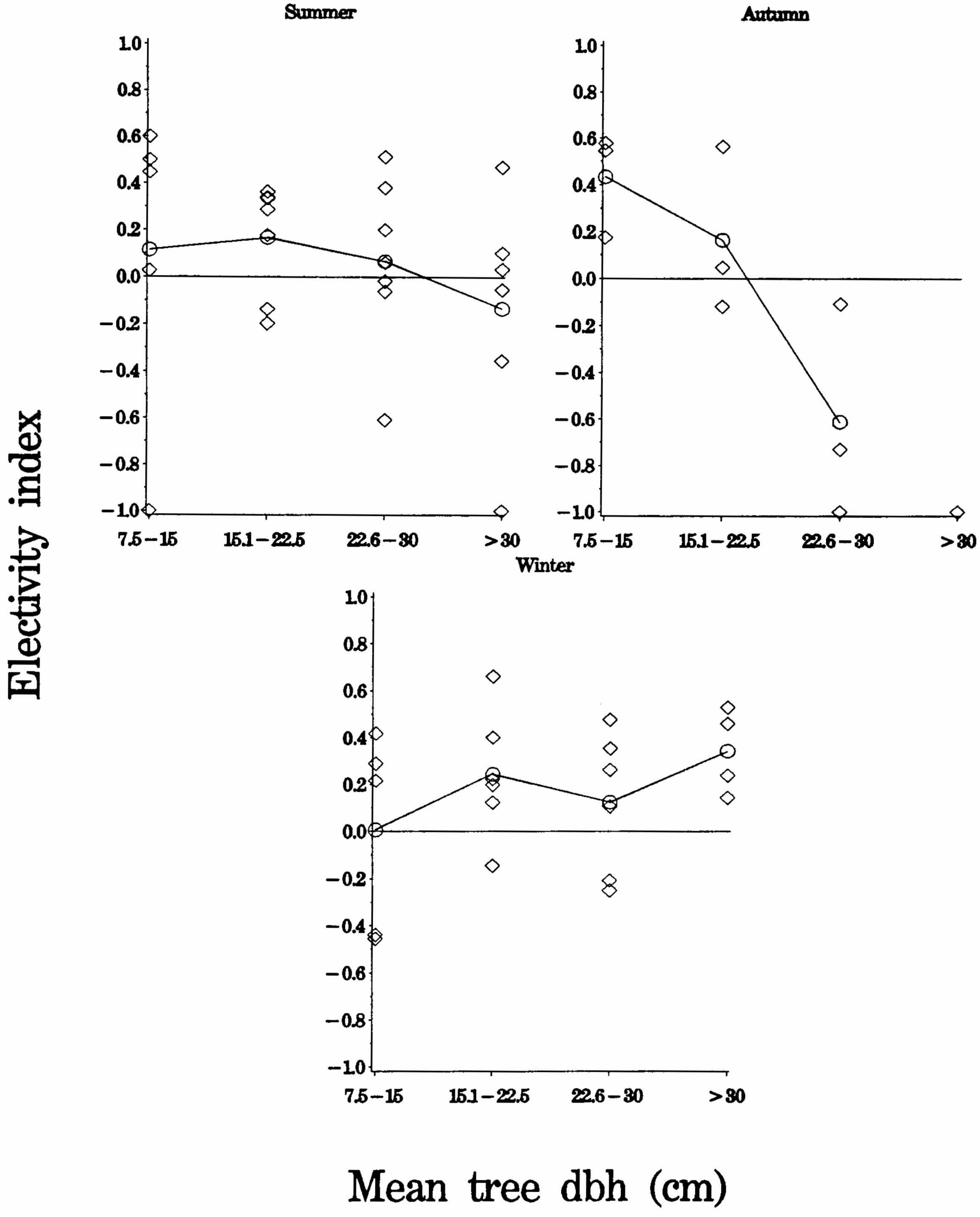


Fig. 23. Seasonal electivity indices for classes of mean tree diameter. Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

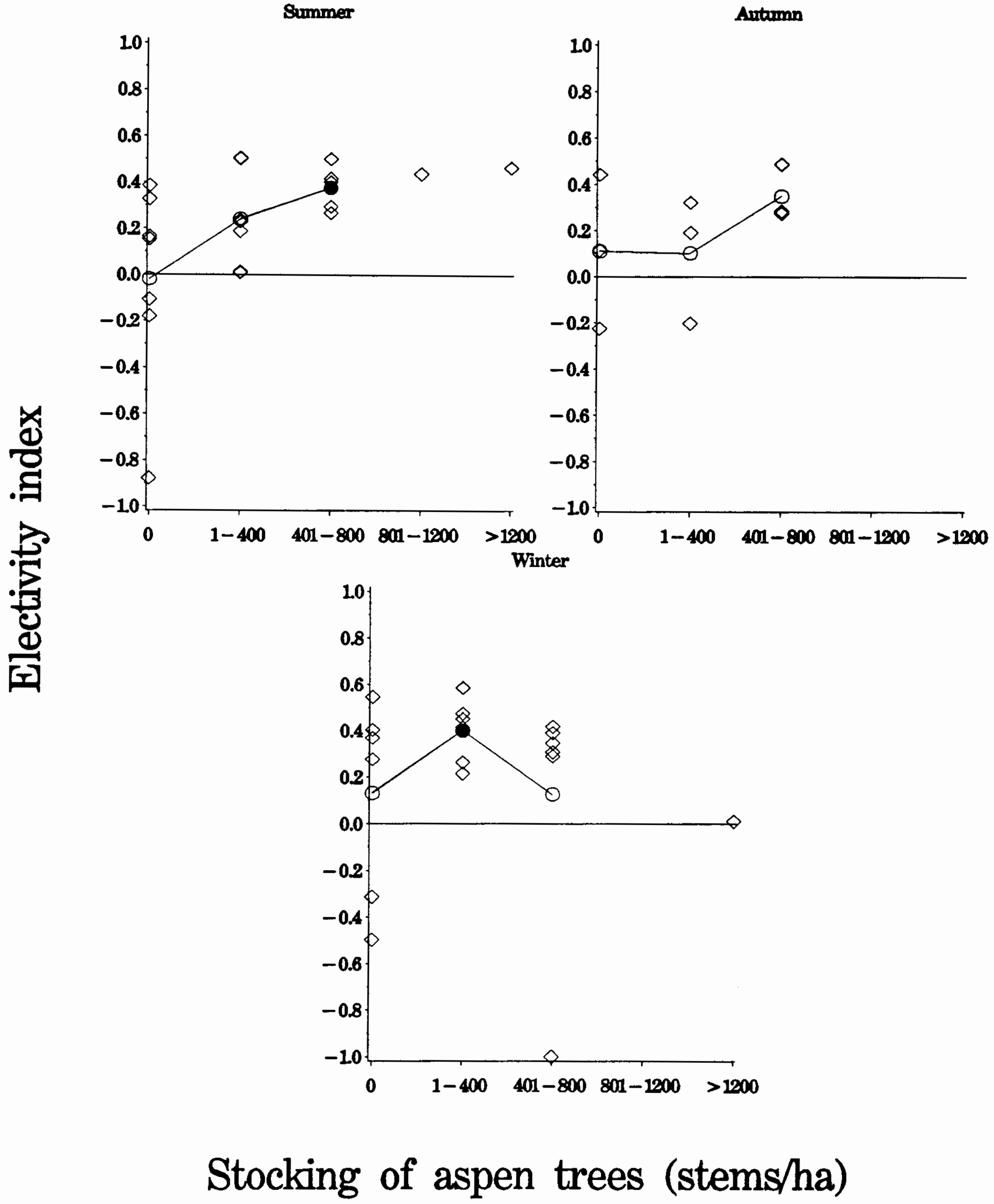


Fig. 24. Seasonal electivity indices for stocking classes of aspen (stems/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

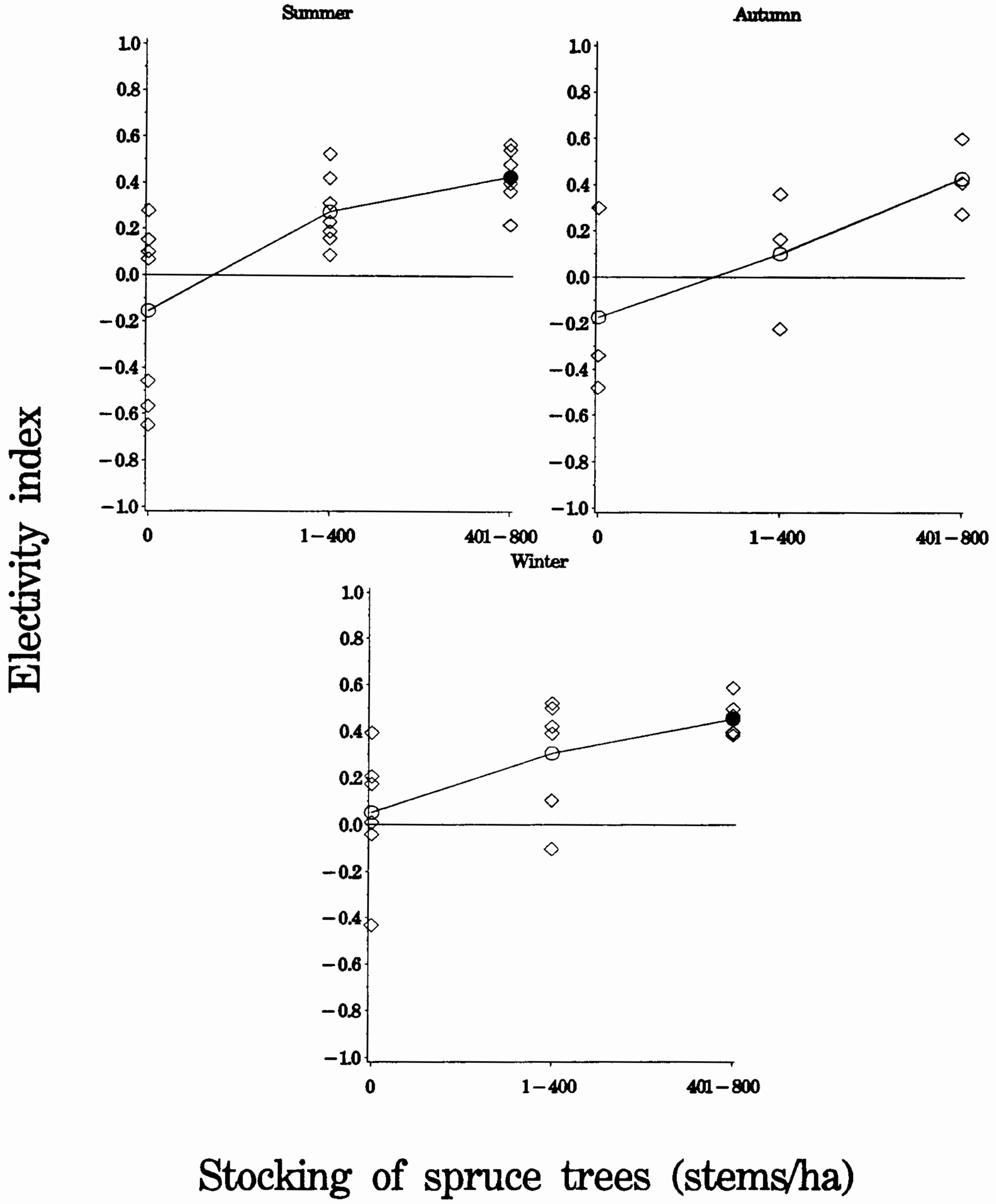


Fig. 25. Seasonal electivity indices for stocking classes of spruce (stems/ha). Open diamonds indicate electivity values for individual fishers. Circles indicate electivity values for pooled data. Filled circles indicate electivity values different ($P \leq 0.05$) from zero. Significantly negative values indicate avoidance. Significantly positive values indicate preference.

stands classified by mean tree diameter during any season (Fig. 23).

Fishers showed electivity indices significantly different from zero for stocking densities of aspen during summer and winter (Fig. 24). During summer, fishers selected stands with 401-800 aspen trees/ha significantly more than expected. During winter, however, fishers used stands with 1-400 aspen trees/ha significantly more than expected. Fishers selected for stands with 401-800 stems/ha of spruce trees during summer and winter (Fig. 25).

The selectivity by fishers of stands classified using the 13 habitat attributes is summarized in Table 10.

Patch level habitat selection

Patch level use was determined from 217 locations of 18 fishers. Selection at the patch level occurred for all habitat attributes that I examined with the exception of mean tree diameter (Tables 11 - 15). Volumes of hard CWD >20 cm diameter at sites used by fishers were significantly greater than the stand mean for the 0 m^3/ha, 1-25 m^3/ha, and 26-50 m^3/ha classes (Table 11). Fishers selected patches with above-ground CWD in stands where no debris of this attribute was detected in random plots (Table 11). Fishers showed patch scale selection by using patches with volumes of CWD significantly greater than the stand mean for stands in which mean total CWD volumes were 0 m^3/ha, 1-100 m^3/ha, and 101-200 m^3/ha (Table 11).

Coniferous canopy closure was significantly greater at sites used by fishers than the stand mean in stands with no recorded coniferous component at random plots (Table

Table 10. Seasonal selectivity by fishers of stands classified by habitat attributes in the SBSdw, 1990-1993. Fishers were detected being selective for more habitat attribute classes during summer than winter and autumn.

	Selection for		Avoidance of	
	Attribute	Class	Attribute	Class
Summer	Total volume CWD	>200 m^3/ha	Total volume CWD	0 m^3/ha
	Volume CWD >20 cm diameter	1-25 m^3/ha	Deciduous canopy closure	0%
	Volume CWD not on ground	21-40 m^3/ha	Low shrub closure	>80%
	Deciduous canopy closure	21-40%	Total stocking density	0 stems/ha
	Stocking of trees with rust brooms	1-20 stems/ha		
	Stocking of aspen	401-800 stems/ha		
	Stocking of spruce	401-800 stems/ha		
Autumn	Stocking of trees with rust brooms	0-20 stems/ha		
	Stocking of trees >40 cm dbh	1-50 stems/ha		
Winter	Volume CWD >20 cm diameter	>50 m^3/ha	Total volume CWD	0 m^3/ha
	Coniferous canopy closure	21-40,41-60%	Low shrub closure	>80%
	High shrub closure	41-60%	Total stocking density	0 stems/ha
	Stocking of trees >40 cm dbh	51-100 stems/ha		
	Stocking of aspen	1-400 stems/ha		
	Stocking of spruce	401-800 stems/ha		

Table 11. Mean volume of coarse woody debris (CWD) at sites used by fishers and at random stand plots. Volume classes are based upon volumes of CWD at random points within stands. *P* values are the results of Mann-Whitney U-tests.

	Fisher sites			Random stand plots			
Volume class (m^3/ha)	Mean	±SE	*n*	Mean	±SE	*n*	*P* value
CWD >20 cm diameter							
0	17.3	5.3	22	0.0	0.0	18	<0.01
1-25	66.9	21.6	69	13.9	2.0	41	0.06
26-50	74.5	27.5	76	29.4	9.4	30	0.05
>50	65.7	10.8	28	84.9	17.0	17	0.40
Above ground CWD							
0	3.5	1.8	8	0.0	0.0	10	0.02
1-20	23.0	6.2	17	11.6	2.3	19	0.39
21-40	71.1	8.3	23	36.4	17.3	12	0.11
Total CWD							
0	54.0	40.2	8	0.0	0.0	9	0.02
1-100	170.7	35.4	60	59.9	7.2	36	<0.01
100-200	215.3	23.5	112	132.1	15.1	48	0.01
> 200	222.5	38.7	15	235.9	26.2	13	0.61

12). Unexpectedly, in stands with 41-60% coniferous canopy closure, fishers used patches with significantly less coniferous closure than the stand mean. Deciduous canopy closure was significantly greater at sites than the stand mean for stands in which there were no deciduous trees recorded at random plots (Table 12). In stands with deciduous canopy closure between 21-40%, fishers selected patches with significantly less deciduous tree closure than the stand mean.

Sites used by fishers had significantly more high shrub closure than the stand means for the 1-20% closure class, and significantly less for the 41-60% class (Table 13). Low shrub closure was significantly less at sites used by fishers than the stand mean for the 61-80% closure class (Table 13).

Fishers exhibited patch level selection for several tree attributes (Table 14). Although fishers used stands which had no trees recorded at random plots, fishers located and used patches of trees within these stands. However, in stands with mean stocking density greater than 1001 stems/ha (1001-2000 stems/ha, 2001-3000 stems/ha, and 3001-4000 stems/ha classes), sites used by fishers had stocking densities significantly less than the stand mean. Fishers also used patches that had significantly greater stocking densities of trees infested with rust brooms when they were in stands that had no trees recorded with brooms at random plots. In stands with no recorded trees >40 cm dbh at random plots, fishers used patches with significantly greater stocking density of trees of this size class. In stands with stocking densities of >100 stems/ha of trees >40 cm dbh, fishers used patches with significantly less stocking density than the stand mean. Fishers did not exhibit patch level selectivity in stands classified by mean tree diameter.

Sites used by fishers had higher stocking densities of aspen trees than the stand

Table 12. Mean percent canopy closure at sites used by fishers and random stand plots. Closure classes are based upon percent closure at random points within stands. *P* values are results of Mann-Whitney U-tests.

	Fisher sites			Random stand plots			
Closure class (%)	Mean	±SE	*n*	Mean	±SE	*n*	*P* value
Coniferous canopy							
0	28.0	7.6	15	0.0	0.0	13	0.01
1-20	18.0	2.5	20	16.0	1.8	20	0.58
21-40	32.0	4.6	25	33.8	4.4	16	0.71
41-60	40.7	1.7	153	48.9	2.1	56	<0.01
61-80	55.0	9.6	4	70.0	1.0	2	0.47
Deciduous canopy							
0	8.8	3.1	16	0.0	0.0	13	0.02
1-20	13.7	1.2	133	14.7	1.4	64	0.41
21-40	21.5	1.9	65	32.0	2.8	25	<0.01

Table 13. Mean percent shrub closure at fisher sites and random stand plots. Closure classes are based upon percentage closure at random points within stands. *P* values are results of Mann-Whitney U-tests.

	Fisher sites			Random stand plots			
Closure class (%)	Mean	±SE	*n*	Mean	±SE	*n*	*P* value
High shrub							
1-20	34.5	3.9	40	17.9	2.6	19	0.01
21-40	33.6	1.8	141	29.7	1.9	64	0.34
41-60	34.7	4.4	34	50.0	4.0	18	0.03
61-80	70.0	10.0	2	75.0	13.3	3	0.54
Low shrub							
1-20	31.1	7.5	9	20.0	0.0	2	0.52
21-40	38.9	2.3	111	32.6	2.4	38	0.21
41-60	55.9	4.5	49	54.0	4.0	30	0.83
61-80	58.9	3.5	38	73.1	3.2	29	0.01

mean for stands in which aspen trees were not recorded in random plots (Table 15). However, sites used by fishers had significantly lower stocking densities of aspen trees than the stand mean for stands with stocking densities of 1-400 stems/ha and 401-800 stems/ha. In stands where spruce trees were not recorded in random plots, fishers selected patches in which spruce trees occurred.

Fishers were located at 37 resting and maternal dens. Fishers denned at sites with greater volumes of hard CWD >20 cm diameter than the stand means for stands that had mean volumes of 0 m^3/ha and 1-25 m^3/ha (Table 16). Fisher den sites had significantly greater stocking density of trees with rust brooms when they used stands in which no broom-laden trees were recorded at random plots (Table 17). Fishers also denned in patches with greater stocking density of trees >40 cm diameter than the stand mean for the 0 stems/ha and 1-50 stems/ha stocking classes (Table 17). However, fisher den sites had fewer stems/ha of trees >40 cm diameter when these dens occurred in stands with >100 stems/ha of this diameter class.

Fishers denned in patches of Douglas-fir trees in stands for which Douglas-fir trees were not recorded at random plots. However, densities of Douglas-fir trees at den sites were less than the stand mean for the 401-800 stems/ha class (Table 18). When fishers denned in stands with 1-400 stems/ha and >800 stems/ha of lodgepole pine trees, fisher dens were located in patches with significantly fewer stems/ha of lodgepole pine trees than the stand mean (Table 18). For stands classified as having no spruce trees based upon random plots, fisher dens were located in patches that included spruce trees (Table 18).

Table 14. Mean tree attributes at fisher sites and random stand plots. Classes are based upon values of that attribute at random points within stands. *P* values are the results of Mann-Whitney U-tests.

Attribute	Fisher sites Mean	Fisher sites ±SE	Fisher sites *n*	Random stand plots Mean	Random stand plots ±SE	Random stand plots *n*	*P* value
Tree stocking class (stems/ha)							
0	534.7	331.1	8	0.0	0.0	10	0.01
1-1000	1219.7	365.9	50	501.5	78.8	32	0.42
1001-2000	1116.9	19.2	75	1364.3	188.3	35	0.02
2001-3001	1479.8	10.8	60	2289.4	496.2	19	0.03
3001-4001	1335.3	330.6	12	3326.9	739.8	4	<0.01
Trees with rust brooms stocking class (stems/ha)							
0	5.6	2.0	74	0.0	0.0	10	<0.01
1-20	20.1	4.5	85	6.6	2.0	39	0.12
21-40	61.7	47.3	12	26.4	15.0	6	0.92
>40	32.2	10.7	23	122.3	47.9	8	0.09
Trees > 40 cm dbh stocking class (stems/ha)							
0	25.7	9.6	35	0.0	0.0	29	<0.01
1-50	48.4	12.4	84	14.3	4.0	31	0.33
51-100	94.4	17.3	79	68.1	10.7	35	0.59
> 100	79.1	22.1	19	142.2	23.6	12	0.04
Mean tree dbh class (cm)							
7.5-15	13.4	1.3	18	11.4	1.3	14	0.10
15-22.5	20.8	0.9	117	19.0	0.9	45	0.81
22.5-30	24.5	2.8	24	26.4	2.1	18	0.19
>30	30.2	3.1	26	37.8	4.1	14	0.09

Table 15. Mean stocking densities of trees at fisher sites and random stand plots. Stocking classes are based upon stocking densities of trees at random points within stands. *P* values are the results of Mann-Whitney U-tests.

	Fisher sites			Random stand plots			
Stocking class (stems/ha)	Mean	±SE	*n*	Mean	±SE	*n*	*P* value
Aspen trees							
0	197.0	167.5	61	0.0	0.0	34	0.03
1-400	21.6	6.0	112	92.6	34.3	47	<0.01
401-800	449.7	225.9	37	601.1	219.6	14	0.03
> 800	30.2	23.5	6	1098.7	531.1	9	0.22
Spruce trees							
0	316.7	156.3	38	0.0	0.0	29	<0.01
1-400	290.6	80.2	36	201.3	47.9	31	0.71
401-800	505.7	72.5	135	497.7	112.8	43	0.78
800-1200	142.7	55.6	4	978.4	978.3	2	0.99
>1200	868.3	189.4	4	4390.7	1400.2	2	0.10

Table 16. Mean volume of coarse woody debris (CWD) at fisher resting and maternal den sites and random stand plots. Volume classes are based upon volumes of CWD at random points within stands. *P* values are the results of Mann-Whitney U-tests.

	Fisher sites			Random stand plots			
Volume class (m^3/ha)	Mean	±SE	*n*	Mean	±SE	*n*	*P* value
<u>CWD >20 cm diameter</u>							
0	37.8	15.9	5	0.0	0.0	18	<0.01
1-25	80.4	17.0	10	13.9	2.0	41	<0.01
26-50	24.5	21.9	9	29.4	9.4	30	0.22
>50	28.2	16.1	2	84.9	17.0	17	0.26

Table 17. Mean tree attributes at fisher den sites and random stand plots. Classes are based upon values of that attribute at random points within stands. *P* values are the results of Mann-Whitney U-tests.

	Fisher sites			Random stand plots			
Stocking class (stems/ha)	Mean	±SE	*n*	Mean	±SE	*n*	*P* value
Trees with rust brooms							
0	22.3	15.5	7	0.0	0.0	51	<0.01
1-20	11.0	6.2	12	6.6	2.0	39	0.60
20-40	8.4	5.2	5	26.5	15.0	6	0.69
Trees > 40 cm diameter							
0	25.9	18.7	4	0.0	0.0	29	<0.01
1-50	56.1	21.3	11	14.3	4.0	31	0.03
51-100	49.8	25.4	7	68.1	10.7	35	0.36
> 100	42.1	13.5	5	142.2	23.6	12	0.05

Table 18. Mean stocking densities of trees at fisher den sites and random stand plots. Stocking classes are based upon stocking densities at random points within stands. *P* values are the results of Mann-Whitney U-tests.

	Fisher sites			Random stand plots			
Stocking class (stems/ha)	Mean	±SE	*n*	Mean	±SE	*n*	*P* value
Douglas-fir							
0	4.4	3.1	7	0.0	0.0	25	0.01
1-400	43.9	21.3	6	95.8	23.6	39	0.90
401-800	63.7	46.8	12	657.4	141.0	33	<0.01
> 800	353.1	330.6	2	2759.3	806.0	5	0.18
Lodgepole pine							
0	3.6	3.6	12	0.0	0.0	12	0.06
1-400	0.0	0.0	7	107.2	35.0	46	0.02
401-800	-	-	0	435.3	435.2	2	-
>800	130.0	94.6	8	2908.0	1657.1	16	0.03
Spruce							
0	183.8	183.8	4	0.0	0.0	29	0.01
1-400	81.8	81.8	2	201.3	47.9	31	0.52
401-800	583.8	267.6	21	497.7	112.8	43	0.71

Habitat element level selection

Fishers were located at 32 resting and 5 maternal dens (Table 19). Resting dens were associated with both live and dead trees, large single pieces of CWD, and small diameter slash-piles. All of the maternal dens were in branch-hole cavities of large diameter cottonwood trees. One maternal den was used in consecutive whelping seasons by one fisher. Females changed maternal den trees 4-6 weeks following parturition.

Fishers were recorded resting most frequently in large diameter spruce trees infested with rust brooms. The mean number of rust brooms per spruce den tree was 3.2 (SE = 0.7, *n* = 17). Fishers also rested in declining (Luttmerding *et al.* 1990) cottonwood trees, live and dead Douglas-fir trees, and in one aspen. Fishers also rested in ground CWD and slash-pile dens during periods of low temperatures (<-20 C).

Of the tree species used by fishers for denning, trees in which fisher dens occurred were generally the largest trees that were available. For example, in more than 98% of all random plots, either no cottonwood trees were present or the largest cottonwood tree was smaller in diameter than the minimum recorded den (Fig. 26). At random plots, none of the recorded cottonwood trees were larger in diameter than the largest cottonwood den. At the majority of random plots, Douglas-fir trees were either absent or were smaller than the minimum dbh Douglas-fir den. Dens that were located in spruce trees were in the trees which had the most rust brooms within that patch. The availability of trees that would be suitable as dens is greater for spruce trees than those for cottonwood or Douglas-fir trees. Spruce trees that had diameters large enough to be suitable for dens occurred at 42.1% of the random plots. However, their infestation with

Table 19. Attributes of maternal and resting dens of fishers.

Den use	Den type	Tree species	Den tree diameter (cm)		
			Mean	± SE	*n*
Maternal	Tree	Cottonwood	103.0	5.6	5
Resting	Tree	Aspen	77.0	0.0	1
	Tree	Cottonwood	103.1	16.9	5
	Tree	Douglas-fir	111.0	21.4	3
	Tree	Spruce	46.3	3.9	17
	CWD	-	80.3	11.8	4
	Slash	Lodgepole pine	12.3	3.2	2

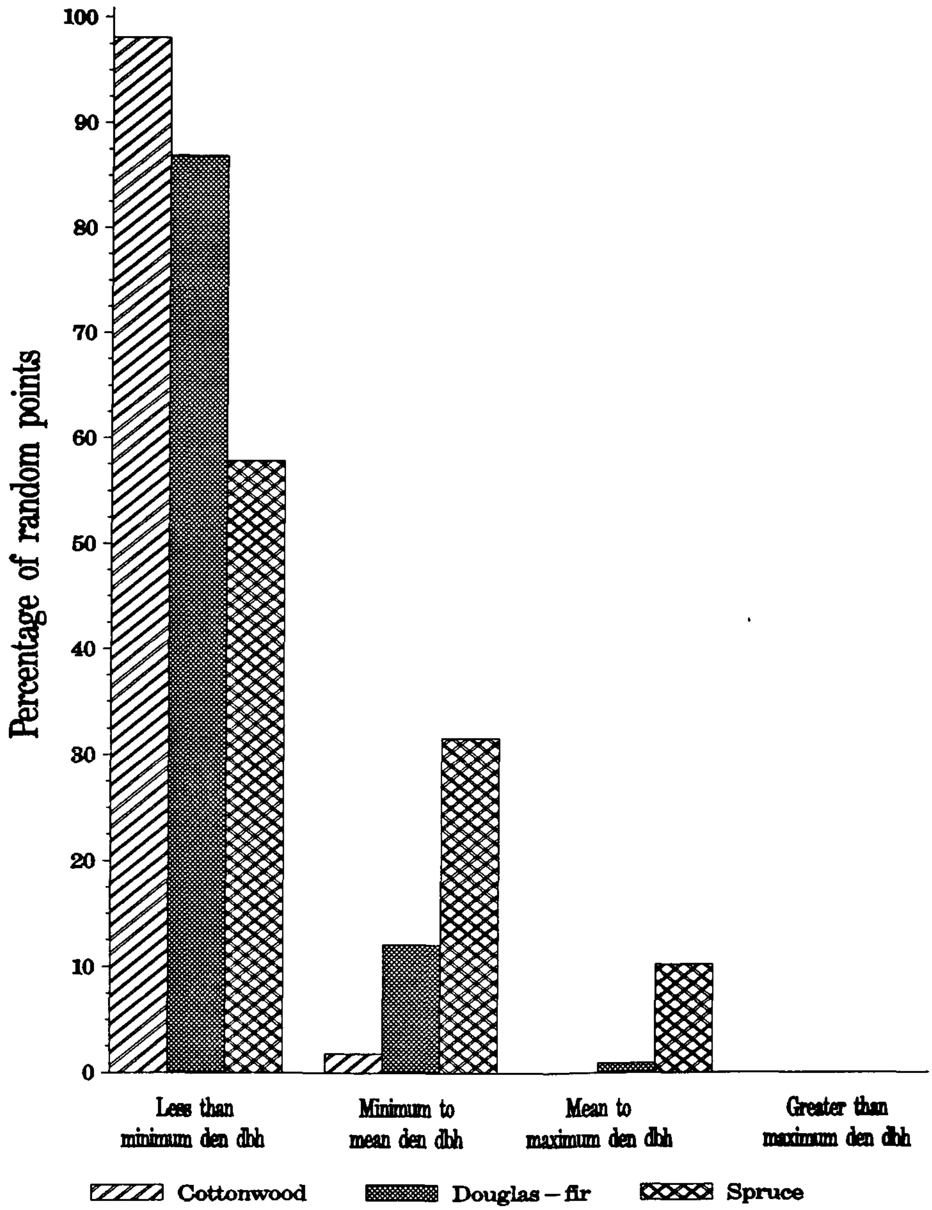


Fig. 26. Availability of suitable den trees at random plots within the SBSdw by tree species and diameter at breast height (dbh), relative to the minimum, maximum, and mean diameter of each den tree species. No cottonwood trees larger than the mean cottonwood den were recorded at random plots, but many spruce trees of suitable diameter occurred in the random plots. (*n* = 107 random plots, 31 tree dens).

spruce broom rust was low; only 12.5% of all spruce trees in random plots were infested with rust brooms.

Discussion

Although detected at all 4 scales, most of the habitat selectivity expressed by fishers in the SBSdw occurred at patch and habitat element levels. Fishers exhibited selectivity for different habitat variables at landscape, stand, patch, and habitat element scales. The most general resource requirements were fulfilled at coarse scales, whereas the most specific requirements were supplied by habitat at the patch and habitat element scales.

Landscape level selection

Very little landscape selectivity was detected, especially following home range establishment. Prior to home range establishment, as transplanted fishers moved extensively through the landscape, they avoided early seral stages and used young forest habitats more frequently than expected. The composition of fisher home ranges illustrated that very little landscape-level selection was exhibited for the inclusion of biophysical habitat types within their home ranges.

While transient, fishers avoided early seral stages with little overhead canopy closure. This selectivity is consistent with the findings of other studies (Kelly 1977, Powell 1977, Arthur 1987). Fishers' significant preference for the SF5 habitat type was surprising. These lodgepole pine-dominated forests have 21-60% canopy closure of lodgepole pine trees, and low structural and plant diversity. These characteristics are not consistent with characteristics of suitable fisher habitat described elsewhere (Kelly 1977; Powell 1977, 1982; Arthur 1987; Jones 1991). However, preference for SF5 forests may have resulted from habitat selectivity occurring at different scales while the fishers were transient. Patch-level analyses of habitat use indicate that fishers may be using suitable patches of habitat within otherwise unsuitable stands. Because there were few differences in use among habitat types by transient fishers, I conclude that habitat selection before home range establishment is not strongly expressed at the landscape level.

Several factors in my study area may have contributed to why fishers did not show any strong tendencies for inclusion or exclusion of particular habitat types within their home ranges. First, fishers in the dry-warm variant of the Sub-Boreal Spruce biogeoclimatic zone of British Columbia may not exhibit selectivity for habitats at the landscape level. Second, fisher home ranges may not accurately model an individual fisher's use of space, and so may include habitats that are not useful to the animal. Third, the criteria which are used by researchers to classify habitat, and their spatial characteristics, may influence the detectability of selection.

A habitat type can be defined as an area in which a resource, that is required by an animal, is distributed homogenously. However, because animals often require more than one resource, researchers attempt to incorporate 2 or more resource needs when they develop a habitat classification system. If habitats are defined on the basis that 2 or more resources occur evenly, it can lead to a proliferation of habitat categories. In my study, each biophysical habitat unit was considered an assemblage of areas with similar distributions of several potential resources (e.g. coarse woody debris, low shrub closure, tree stocking density). Using such a fine degree of habitat classification resulted in many habitats and the average habitat unit was small in size.

Habitat granularity, the ratio of the average habitat unit (i.e. stand) size to home range size, will affect the researcher's ability to detect selectivity and determine the scale at which selectivity is expressed. In fine-grained landscapes, where stands are small relative to home range size, landscape-level selectivity is unlikely to be exhibited because individual animals are not constrained by access to "good" habitat. This occurs because the landscape is comprised of many small interspersed stands and any point in the landscape is not far from suitable habitat. In coarse-grained landscapes, however, landscape level selectivity is likely to occur, because animals must search for and include within their home range areas of good habitat to ensure access to these habitats. Grouping habitats by similar features allows the researcher to increase the granularity ratio, and increase the likelihood of detecting landscape level selectivity.

My study area was a fine-grained mosaic of stands. As a measure of granularity, I developed an index based on the mean stand area compared to home range area. The mean granularity ratio (mean stand area:home range area) for the fishers examined was 0.011 (SE = 0.040, n = 7) during summer, 0.010 (SE = 0.039, n = 3) during autumn, and 0.009 (SE = 0.002, n = 7) during winter. On average, there were 149 stands within fishers' home ranges during summer (SE = 44, n = 3), 170 during autumn (SE = 93, n = 3), and 147 stands during winter (SE = 37, n = 7). Changing habitat classification variables to increase the habitat granularity ratio is an effective method of identifying habitat features that may be selected by the animal. When using a single habitat variable to classify habitats, if significant selectivity occurs, it allows the researcher to draw conclusions regarding the effect of that variable. Habitat granularity can also affect the detection of selectivity at the stand, patch, and habitat element scales.

In the SBSdw, fishers may not have exhibited consistent trends in landscape level selection because habitat granularity was too fine when I examined habitat selectivity using the biophysical habitat classification system. If I were able to use a classification system in which stands were larger, and the mean stand size relative to home range size increased, selectivity may have become apparent. For example, fishers avoid areas with no overhead cover (Kelly 1977, Powell 1977). Therefore, had stands in my study area been large tracts of similar percentages of overhead cover, the mean stand size would likely be large relative to home range size, and fishers would be expected to include open areas less frequently than expected within their home ranges. However, my study area was a fine-grained mosaic of stands. As the mean size of stands decreases, fishers will likely have to include unsuitable stands within their home ranges to ensure access to stands of suitable habitat.

Stand and patch level selection

Fishers in my study area exhibited some trends in the selectivity of biophysical habitat types across seasons. Within home ranges, most fishers avoided some logged (SF2 and SF3) and non-forested (WS2) habitat types. Fishers exhibited selection for one biophysical habitat type (SF5m) during summer but avoided herb seral stage habitats during all seasons.

Stand level selection was also analyzed by pooling biophysical habitat units with respect to mean values of 13 habitat attributes. Unfortunately, seasonal comparisons were limited because only 3 fishers could be monitored during autumn, so most of the analyses showed significant trends in habitat use only for summer and winter seasons. When I used this pooling method, fishers exhibited seasonal selectivity for coarse woody debris, closure of vegetation strata, and stocking densities of several tree attributes and tree species. Also, fishers displayed significant patch-level selection for 12 of 13 habitat attributes that I examined.

Fishers used stands classified by the volume of coarse woody debris (CWD) in both summer and winter. Volume of CWD (total, above ground, and >20 cm diameter) provides a measure of the structural complexity of a component of the forest floor, which is the primary foraging area for fishers (Buskirk and Powell 1994). In British Columbia, small mammals and snowshoe hares form a large percentage of fishers' diets (Chapter 1). Structural complexity of the forest floor provides cover for these prey species, especially snowshoe hares (Buskirk and Powell 1994). During summer, fishers used habitats with 21-40 m^3/ha of above-ground CWD more frequently than expected. During winter, this trend was not evident. Marten use habitats with large volumes of CWD during winter because they require subnivean access for foraging (Lofroth 1993). Because of their larger body size, fishers are restricted to supranivean hunting during winter (Powell 1982), so structurally complex debris, which provides subnivean access, may not be required. Although habitats with 21-40 m^3/ha of CWD were not selected by fishers during winter, their use of habitats with >50 m^3/ha of large debris (>20 cm diameter) was greater than expected. Fishers use large diameter logs as subnivean dens during periods of thermal stress during winter (Arthur 1987, Jones 1991). Selection for habitats in my study area that have high volumes of large CWD during winter may indicate use of these subnivean CWD dens.

Some fishers used stands where CWD was absent based upon random plots (Figs. 13-15). In these stands, fishers selected patches that had significantly volumes of each of the 3 CWD attributes. As well, fishers selected patches with greater volumes of CWD in stands where the mean volume of CWD >20 cm diameter was less than 50 m^3/ha, and in stands where the total volume of CWD was less than 200 m^3/ha. These findings indicate that the volume of CWD is a factor in habitat selection, and selectivity can occur at the stand or patch level. In stands with suitable volumes of CWD, fishers do not select at the patch level, but in stands with insufficient CWD, fishers will seek out and use patches of debris.

Fishers select stands based on the amount of coniferous overstory (Kelly 1977, Powell 1977, Arthur 1987). In my study area, fishers selected for stands with a mean coniferous canopy closure between 21-60% during winter, but when they were in stands with 41-60% coniferous canopy closure, they used patches with less coniferous canopy closure. This affinity for habitats with intermediate coniferous canopy closure emerges again in stands where no coniferous canopy closure was recorded at random plots. Within these stands, fishers located and used patches of conifers.

Fishers alter their movement patterns to avoid areas with soft snow that inhibits their movements (Leonard 1980, Raine 1981). Coniferous trees intercept snow (Harestad and Bunnell 1981), and in the SBSdw, snow packs in coniferous habitats were denser and provided greater support than those in other habitat types (*unpubl. data*). During winter, fishers may select stands and patches with moderate canopy closure of conifers because these habitats intercept snow and have denser snow packs and thus permit more efficient locomotion.

Several studies of fishers in eastern North America report that fishers avoid deciduous habitats (Kelly 1977, Arthur 1987). Fishers in my study area did not select for habitats on the basis of the percentage of deciduous canopy closure during winter. During summer, however, fishers avoided stands with no deciduous trees recorded at random plots and selected for stands with 21-40% closure of deciduous species. While in these deciduous stands during summer, fishers selected patches with less deciduous overstory. This selection for intermediate amounts of deciduous trees is also revealed in the use of patches by fishers when they were in stands with no recorded deciduous component. In these stands, fishers used patches where deciduous trees were present. In stands and patches with a modest deciduous component, prey may be more abundant and diverse than in monotypic stands. Hence, fishers may direct their foraging to these habitats.

Foraging may be an important factor influencing habitat use by fishers. Areas with dense conifers and shrubs are the primary habitats used by fishers in which to forage for snowshoe hares (Coulter 1966, Powell 1977, Arthur 1987). Both high and low shrub vegetation strata provide food and cover for snowshoe hares (Litivatis *et al.* 1985). During winter in my study area, fishers may use habitats with high shrub closure between 41-60% more than expected because they provide habitat for snowshoe hares, as well as intercept snow. However, while in these stands, fishers use patches with fewer shrubs than the average closure. Again, perhaps this patch level selection reveals within stand differences in the abundance and diversity of prey. Intermediate degree of canopy closure of high shrubs may provide a balance between habitats that provide foraging areas with those that are overly complex. Fishers may avoid habitats with high stocking densities of trees for the same reasons.

Structural complexity of the forest floor may affect the foraging efficiency of fishers. Fishers used habitats with >80% closed canopy of low shrubs less frequently than expected, based upon availability. Although fishers were not selective at the stand level for the lower closure classes, they were selective at the patch level. When in habitats with 61-80% canopy closure of low shrubs, fishers used patches which had significantly less low shrub closure than the habitat mean. Patch selection exhibited in stands with >80% low shrub closure may be related to the fisher's hunting success. An overly complex forest floor may affect fishers' hunting success by reducing the likelihood of capturing prey.

The availability of resting sites may also affect the habitat use patterns of fishers. Rust brooms are used by fishers as resting sites during spring and fall (Arthur 1987, Jones 1991). In my study, fishers selected for this habitat element at the stand and patch levels. During autumn, fishers selected for habitats that had 0 stems/ha and 1-20 stems/ha of trees with rust brooms at random plots. Fishers were recorded resting at 66.3% of all locations during autumn, so this high selectivity may be the result of an increased likelihood of recording fishers resting. During summer, habitats with 1-20 stems/ha of rust brooms were used more frequently than expected. Patch level selectivity of these stocking classes was also significant. However, fishers did not appear to avoid habitats based upon the presence or absence of rust brooms in a stand. This result likely occurred because locations of resting and active fishers were pooled. Fishers probably do not base habitat selection while foraging upon the presence or absence of resting habitat elements within stands or patches.

Fishers' requirement for den trees is evident in selectivity of habitats classed by tree diameter. Fishers selected for habitats with stocking densities of trees >40 cm dbh during both winter and summer. During winter, fishers may have used habitats with more large trees because the overstory closure provided by larger trees may have increased snow interception and improved locomotion. During summer, habitats with fewer large trees were used by fishers more frequently than expected. These habitats may have allowed increased understory development, and prey availability in these habitats may have been greater.

Habitat element selection

Fishers selected den sites at the habitat element level, although stands and patches with high mean values of den attributes were used by fishers as well. Fishers appear to have stringent requirements for the structural attributes needed for both maternal and resting dens. Fishers selected habitat elements that were significantly different from the typical elements within patches. Two maternal dens were in large diameter, declining cottonwoods in patches with no other cottonwoods or other large trees. Resting dens were often located in patches in which the den tree was the only tree within the patch that had suitable den attributes.

Habitats in which fishers rest and whelp are less variable than habitats they use for other activities (Arthur 1987, Paragi 1990, Jones 1991). Fishers in my study area used many different habitat types in which to den, but the habitat elements they used as dens were similar among these varied habitats. Fishers in the SBSdw appear to require large diameter declining cottonwood trees with branch hole cavities in which to rest and whelp. Cavities in large Douglas-fir trees were also used as resting dens. The most frequently used habitat elements were rust brooms in spruce trees. In the SBSdw, these habitat elements occur primarily on large diameter spruce trees in areas with wetter moisture regimes.

Fishers may use ground dens during winter to reduce thermal stress. For small endotherms, microhabitats such as tree cavities or burrows provide microclimates that are quantitatively and qualitatively different from other sites in their environment (Taylor 1993). Furthermore, Taylor (1993) determined that subnivean cavities offered the warmest micro-environment during severe winter weather. Fishers in my study area used ground dens only during winter, and only then when temperatures dropped below -20 C. Fishers used tree and tree cavity resting dens when the ambient temperature rose above -20 C, which is consistent with Taylor's (1993) hypothesis that snags and branches offer an adequate thermal environment under most winter conditions. Arthur (1987) reported that fishers' use of particular habitat attributes for resting was seasonal; during winter, fishers primarily rested in ground dens, but used tree dens more frequently during spring and fall. Large pieces of coarse woody debris may be a critical habitat element for fishers which face extended periods of severe thermal stress.

The large brooms in spruce trees caused by spruce broom rust appear to be an important habitat component to fishers in the SBSdw. The brooms often form flat-topped clumps upon which the fishers sleep. Spruce broom rust is the aecial state of

Chrysomyxa arctostaphyli, and requires kinnikinnick to complete its life cycle (Ziller 1974). Spruce broom rust is not often a lethal pathogen on spruce trees, but is associated with spiketops, dead branches, bole deformation and loss of increment (Ziller 1974). The brooms caused by *C. arctostaphyli* can form on spruce at any age, but are on predominately older, large diameter trees (*pers. obs.*). The mean age of spruce den trees used by fishers for resting was 90.1 years (SE = 7.9, *n* = 13), however, the four largest diameter den trees could not be aged because of heartwood decay. Consequently, the mean age of spruce den trees would likely be older than 90 years. The importance of brooms may be seasonal; fishers used rust brooms predominately during autumn, which is consistent with Arthur's (1987) and Taylor's (1993) hypotheses that at warmer temperatures, branch nests offer adequate thermal environments. During snow free periods, the most energy favourable den location may be a branch nest because of increased solar radiation and temperatures (Taylor 1993).

Fishers that whelped offspring in my study area appeared to be specific in their selection of habitat elements used for maternal dens. They selected large diameter cottonwood trees that had heart-rot and several branch hole cavities. My observations are consistent with other studies, which report that fishers whelp only in cavities in deciduous trees (Leonard 1980, Paragi 1990). Female fishers in my study whelped in branch-hole cavities in deciduous trees, but the trees they used were much larger than those reported elsewhere. Paragi (1990) reported that females in his study area had maternal dens in trees with a mean dbh of 45 cm, whereas females in my study area had maternal dens in cottonwood trees with a mean diameter of 103.0 cm dbh. In the SBSdw, these habitat elements were generally the largest diameter trees available and occurred infrequently in the fishers' home ranges.

The attributes of trees that fishers use for maternal and resting dens may be limited to large cottonwood trees, and so may be a critical habitat component. At maturity, black cottonwood trees are the largest deciduous tree in British Columbia. In the interior of British Columbia, cottonwood trees reach maturity at 60-70 years and under ideal conditions can live to 200 years (Simard and Vyse 1992). Cottonwoods are early successional shade-intolerant trees that exhibit very rapid juvenile growth, and have a long, straight bole that is free of branches for more than two-thirds of its length (Maini 1968). Cottonwoods generally grow best in subhygric sites, where the roots reach a permanent moisture supply. Cottonwoods are shade- and drought-intolerant, and are replaced by later successional shade-tolerant species unless periodic disturbances (e.g. flooding) occurs (Simard and Vyse 1992). Cottonwoods are very susceptible to non-lethal pathogens; decay of the heartwood by fungi begins by about 60-70 years (Simard and Vyse 1992). Consequently, heart-rot can become very advanced in large, old trees.

Fishers in my study area used cottonwood trees that had begun to decline in viability, and each den was in a tree cavity formed by branch-holes leading into decayed heartwood. Fishers may use large diameter declining cottonwood trees for several reasons. First, the cavities within the tree bole may have micro-environments suitable for denning. Second, because cavities form primarily through branch-holes in the upper bole, maternal dens are located well above ground. Leonard (1980) hypothesized that female fishers select maternal dens at least 10 m above ground to minimize the chance of predation of the kits by male fishers. In my study, the mean height of maternal dens was 25.9 m (range = 17.7 - 30.0 m, *n* = 5) up the tree bole. Perhaps black cottonwoods are suitable den trees because the long, straight bole, free of branches, may make climbing to dens more difficult for the larger males.

Conclusions

An animal acquires resources from its environment and those areas which the animal uses to successfully sequester resources are regarded as suitable habitats. Habitat types are often defined implicitly as areas in which one resource that is required by an animal is homogenously distributed. However, resources often occur as continuous variables (e.g. percentage of overhead cover) and are not distributed homogenously across an area. Thus, to define habitat types, researchers must group sites into habitat types based upon a range of values for the variable (e.g. 21-40% overhead cover). This provides a convenient technique for classifying habitat.

This method of grouping sites into discrete habitat types can introduce sources of error other than chance variation into analyses of habitat use. Many of the habitat attributes that were used for classifying stands are correlated; stands with no coniferous canopy closure also had, by default, a stocking density of 0 spruce trees/ha. Drawing conclusions based upon examination of a few habitat attribute grouping procedures may be misleading, if it is assumed that the attribute that is examined is the reason for which the selectivity occurred.

The detection of selectivity depends upon scale related factors. Habitat classification schemes and use-availability analyses must be appropriate for the scales at which dispersion of habitat types and intra-type spatial variation occur in the environment. It is up to the researcher to examine relationships at appropriate scales that are biologically relevant.

Fishers in the SBSdw appear to select habitat at several different scales. Because the landscape was a mosaic of small researcher-defined stands, habitat granularity was low and the fishers did not exhibit much landscape level selectivity. In different ecosystems with different spatial characteristics of habitats, the method by which habitat is classified may change the likelihood of detecting selectivity, and influence conclusions made from analyses of habitat use. Although strong landscape level selection does not occur by fishers in my study area, this does not mean that selectivity at this level will not occur elsewhere. Expression of selectivity is dependent upon the spatial context and between-stand variation in geographically distinct areas.

Examination of habitat selectivity at a stand scale will be influenced strongly by the definitions of habitat invoked by the researcher. For my study, the minimum stand size was defined as 1.5 ha. This likely influenced my conclusions about stand scale selectivity, because a stand to a fisher may be limited to 1 ha or less. The size of stands defined by researchers may be substantially different than to which the study animal responds.

Patch and habitat element level selectivity are less likely to be influenced by the researcher's definition of habitat type. In my study, a patch was the area covered by a variable radius prism sweep. This may be close to a fisher's definition of a patch. Researcher-defined habitat elements will likely be identical to those perceived by the animal, even if the reasons for its use may not be understood by the researcher.

Fishers acquire resources from habitats at several scales. Fishers require overhead cover, and the selectivity for this feature is exhibited at the landscape and stand levels. Foraging habitat is provided by structurally diverse stands and patches that provide food and cover for their prey.

Resting habitat requirements are specific and are selected for at the stand, patch, and habitat element levels. Fishers often selected stands which had greater values of resting habitat attributes than other stands. Fishers rested in patches that had higher volumes of coarse woody debris, stocking densities of spruce trees infested with rust brooms, and stocking densities of Douglas-fir and spruce than the habitat mean. Fishers exhibited selectivity for habitat elements by selecting either branch nests, branch-hole cavities, or coarse woody debris in which to rest. These habitat elements are associated with large diameter spruce, cottonwood, and Douglas-fir trees.

Female fishers require large, declining cottonwoods in which to whelp. Black cottonwoods begin to exhibit decay of heartwood by maturity, and appear to be capable of providing suitable dens at 90 cm dbh. As well, cottonwood trees may be good maternal dens because they may provide protection from predation by males.

Many forested stands do not reach mature or old-growth stages because of frequent fires. In the SBSdw, stands with sub-hygric and wetter moisture regimes burn less frequently than drier stands. Consequently, habitat elements that are associated with older-age stands, such as large diameter spruce and cottonwood trees, occur primarily in these riparian and riparian-associated habitats, and fishers use these trees in which to rest and whelp (Weir *in press*). Fishers' selectivity for riparian habitats is the result of selectivity for habitat elements that occur primarily in these habitats.

My results provide a stronger ecological basis for the management of fishers in

British Columbia than currently exists. Because fishers select habitats at several scales, knowledge of which habitat requirements are fulfilled at each scale allows for more appropriate scale-based management of fisher habitat. Fishers rely upon features of stands, patches, and habitat elements provided by stages of forest development. Forests that provide structural complexity and diversity through the natural processes of growth, disease, death, and decay are required by fishers to fulfil many of their needs. To ensure fisher habitat is maintained, forest harvesting prescriptions must be developed which provide for the retention of appropriate habitat attributes in all stages of forest development.

Chapter 4

Summary and General Discussion

I examined the diet, spatial organization, and habitat relationships of fishers in south-central British Columbia using fisher carcasses and a field study of transplanted and resident radio-collared fishers. My objectives were to: 1) compare fisher diets among age and sex classes; 2) examine home range establishment patterns of transplanted fishers in the dry-warm subzone of the Sub-Boreal Spruce biogeoclimatic zone (SBSdw); 3) determine the effects of season and reproductive status on the size and arrangement of fisher home ranges; and 4) determine whether fishers selected habitats at landscape, stand, patch, and habitat element scales (*sensu* Johnson 1980), and identify which habitat components were selected at each scale.

I determined the winter diet of fishers in central British Columbia from stomach contents of 261 fisher carcasses collected during the winter trapping seasons between 1988-1993. Snowshoe hares, squirrels, and red-backed voles occurred more frequently in the stomachs than did the other 16 prey species. Small mammals (mice, voles, and shrews) and squirrels occurred more frequently in the diet of females than in the diet of males. Mustelids occurred more frequently in the diet of males than in the diet of females. The difference in diet between sexes is likely the result of sexual dimorphism. Males are larger, and thus can prey upon a wider range of foods. The smaller body size of females allows them to be more successful at hunting smaller prey. The differences in diet likely affect the foraging behaviour and consequently the habitat selection patterns exhibited by each sex.

Fifteen fishers were radio-collared and transplanted into the SBSdw study area and monitored between December 1990 and August 1993. Although fishers were soft-released, they did not remain in the vicinity of their release sites. This may be caused by insufficient incentives for them to remain at their release sites. Adequate food, water, and cover, and other incentives, such as dependent offspring, may increase the likelihood of a successful soft-release. However, confining fishers to their cages for extended periods may affect their post-release behaviour and induce large movements upon release. Maximizing the incentives to remain within the release site, while reducing the duration of captivity, could improve the success of soft-release techniques.

Although transplanted fishers wandered extensively following release, by mid-April, most fishers had established home ranges. Home ranges were established at the start of the breeding season, but none of the transplanted female fishers whelped offspring successfully in the spring following release. Home range establishment may be important for breeding. Female fishers will increase the likelihood of mating if they are easily located within the landscape. By having a well-marked home range, they will increase the probability being located by males.

Size and orientation of 6 annual and 21 seasonal home ranges were compared for 13 fishers (10 F, 3 M) to determine the effect of sex and reproductive status on the spatial organization of fishers. Mean annual home ranges size of fishers in the SBSdw was 26.4 km^2 for females (SE = 9.2, n = 5) and 46.5 km^2 for the one male. Seasonal home ranges of fishers were smallest during winter (mean home range size: females = 25.0 km^2, SE = 2.6, n = 6; males = 73.9 km^2, n = 1) and largest during summer (mean home range size: females = 33.0 km^2, SE = 10.7, n =8; males = 122.1 km^2, SE = 66.5, *n* = 3). Female fishers with kits had smaller home ranges than those without offspring, and concentrated their activities around their natal dens. During winter, overlap among female fisher home ranges was extensive, but was reduced during summer. Fishers did not have intrasexually exclusive home ranges, but rather exhibited temporal avoidance of members of the same sex.

Selectivity at the landscape level occurred for only the most broad resource requirements. Overhead cover was selected at the landscape and stand levels. Early seral stage habitats were avoided by transient fishers and non-forested and early seral stage stands were avoided after home ranges were established. Perhaps, these habitats provide insufficient overhead cover for fishers.

Selectivity for habitat attributes occurred at the stand and patch levels to fulfil several resource requirements (Table 20). Coarse woody debris (CWD) was selected for at the stand and patch levels, although direct use of CWD occurs at the habitat element level. Fishers may use large pieces of CWD as dens because they provide thermally efficient micro-environments. Fishers were restricted to these dens for 4-5 days when temperatures were below -20 C, so retention of large (>20 cm diameter) CWD during all phases of forest development may be important for providing thermal cover for fishers during winter. Above ground CWD, along with high and low shrub closure, provides structurally complex habitats that provide food and cover for many of the fisher's primary prey.

Selectivity for coniferous and deciduous canopy closure was expressed at the stand and patch levels as well Fishers in my study used stands and patches with intermediate closures of coniferous canopy during winter, when deep, soft snow may inhibit fishers'

Table 20. Summary of the resource requirements of fishers fulfilled by attributes selected at the stand and patch scales.

Attribute	Resource requirement
Above-ground CWD Deciduous canopy High shrub Low shrub	Foraging habitat
CWD > 20 cm diameter Stocking of rust broom trees Stocking of trees >40 cm dbh	Resting habitat
Stocking density of trees	Overhead cover
Coniferous canopy strata	Snow interception

mobility. During summer, fishers used stands and patches of deciduous canopy closure because these habitats may support more abundant and diverse prey. Fishers selected resting and maternal dens at both the patch and habitat element levels, although den use occurred at the habitat element level only. Fishers rested and whelped in habitat elements that were associated with large diameter, diseased or dead trees. Fishers rested primarily on clumps caused by spruce broom rust, but also used cavities in the boles of large diameter aspen, cottonwood, and Douglas-fir trees. Fishers whelped exclusively in branch-hole cavities in declining cottonwood trees.

Fishers appear to fulfil many of their resource requirements by selecting resources at 4 scales (Table 21). The most broad requirements are met at coarser scales, while very specific habitat requirements are fulfilled at the finer scales.

The diet, habitat use, and denning requirements of fishers in coniferous forests of central British Columbia are broadly consistent with those of fishers in eastern North America. However, their spatial organization appeared to be dictated by temporal avoidance, and does not fit the current paradigm of mustelid use of space. Theoretical models of space use by mustelids are too strict and must be modified to include behaviour of the species across their geographic range.

Fishers in the SBSdw rely upon structurally diverse forests in which to acquire resources. Many attributes that are the result of natural processes of growth, disease, and decay of forested stands are important for providing habitat for fishers. Management of forested land which emphasizes tree growth and suppresses disease, death, and decay of trees will negatively affect the quality of fisher habitat. Monotypic stands that are low in structural and plant diversity fulfil few life requisites for fishers. An ideal forest to a

Table 21. Summary of scale-dependent resource requirements for fishers in the SBSdw, 1990-1993. General requirements were satisfied at the landscape level, whereas the most specific requirements were met at the habitat element level. X indicates selectivity. - indicates no selectivity.

	Scale			
	Landscape	Stand	Patch	Habitat Element
Overhead cover	X	X	X	-
Foraging habitat	-	X	X	-
Snow interception	-	X	X	-
Resting habitat	-	X	X	X
Whelping habitat	-	-	X	X

fisher would likely appear quite "unhealthy" and decadent to a silviculturist. Hopefully, through appropriate stand, patch, and habitat element prescriptions, management of the forested land in British Columbia can be compatible with maintaining structurally diverse and productive fisher habitat.

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Appendix A. Habitat types occurring in the study area.

Habitat Type			Symbol	Percentage of study area
Biophysical Unit	Phase †	Seral Stage		
Spruce - falsebox		Herb-Shrub	SF2/SF3	11.9
	Coniferous	Pole-Sapling	SF4	4.6
		Young Forest	SF5	13.0
		Mature Forest	SF6	7.3
		Old Growth	SF7	0.2
	Mixed	Pole-Sapling	SF4m	1.4
		Young Forest	SF5m	10.1
		Mature Forest	SF6m	13.3
	Deciduous	Pole-Sapling	SF4d	0.3
		Young Forest	SF5d	1.4
	Selectively-logged	Young Forest	SF5s	0.3
		Mature Forest	SF6s	0.3
	Mixed Selectively-logged	Pole-Sapling	SF4ms	< 0.1
		Young Forest	SF5ms	1.0
		Mature Forest	SF6ms	0.5
Douglas-fir - saskatoon		Herb-Shrub	DS3	< 0.1
	Coniferous	Pole-Sapling	DS4	< 0.1

Habitat Type			Symbol	Percentage of study area
Biophysical Unit	Phase †	Seral Stage		
Douglas-fir - saskatoon	Coniferous	Young Forest	DS5	0.2
		Mature Forest	DS6	0.2
		Old Growth	DS7	0.1
Douglas-fir - kinnikinnick		Non-vegetated	DK1	0.1
		Herb-Shrub	DK2/DK3	0.2
	Coniferous	Pole-Sapling	DK4	0.8
		Young Forest	DK5	0.6
		Mature Forest	DK6	0.3
		Old Growth	DK7	< 0.1
	Mixed	Pole-Sapling	DK4m	< 0.1
		Young Forest	DK5m	0.1
Douglas-fir - thimbleberry		Herb-Shrub	DT3	1.7
	Coniferous	Pole-Sapling	DT4	< 0.1
		Young Forest	DT5	1.7
		Mature Forest	DT6	1.3
		Old Growth	DT7	< 0.1

Habitat Type			Symbol	Percentage of study area
Biophysical Unit	Phase †	Seral Stage		
Douglas-fir - thimbleberry	Mixed	Pole-Sapling	DT4m	0.3
		Young Forest	DT5m	4.0
		Mature Forest	DT6m	5.1
	Deciduous	Pole-Sapling	DT4d	0.2
		Young Forest	DT5d	0.6
	Selectively-logged	Young Forest	DT5s	< 0.1
		Mature Forest	DT6s	< 0.1
	Mixed Selectively-logged	Young Forest	DT5ms	0.2
		Mature Forest	DT6ms	0.1
Douglas-fir - moss	Coniferous	Young Forest	DM5	0.4
		Mature Forest	DM6	0.1
Spruce - twinberry		Herb-Shrub	ST3	0.2
	Coniferous	Pole-Sapling	ST4	0.6
		Young Forest	ST5	0.2
		Mature Forest	ST6	0.2
	Mixed	Pole-Sapling	ST4m	0.1
		Young Forest	ST5m	0.2
		Mature Forest	ST6m	1.0

Habitat Type			Symbol	Percentage of study area
Biophysical Unit	Phase †	Seral Stage		
Spruce - twinberry	Deciduous	Pole-Sapling	ST4d	0.2
		Young Forest	ST5d	< 0.1
		Mature Forest	ST6d	< 0.1
	Mixed Selectively-logged	Young Forest	ST5ms	< 0.1
Willow - sedge		Herb-Shrub	WS2/WS3	3.4
Alder - horsetail		Shrub	AH3	1.1
Cultivated Field		Herb	CF2	5.1
Open Water			OW	3.1

† Forest phase for units which have reached the pole-sapling stage is indicated by lower case letters:

Coniferous	none
Mixed	m
Deciduous	d
Selectively logged	s
Mixed - Selectively logged	ms