Using subpopulation structure for barren-ground grizzly bear management

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Abstract: The subpopulation is an intermediate level of organization that is ecologically meaningful for research and management. We used location data (n = 1,235) from 54 barren-ground grizzly bears (*Ursus arctos*) monitored from 1974–78 (n = 12) using VHF (very high frequency) telemetry and from 2001–06 (n = 42) using GPS (global positioning system) telemetry to delineate subpopulation structure in the Mackenzie Delta region of the Northwest Territories, Canada. We used Ward's cluster analysis to group bears into 4 subpopulations using their geographical position in 4 seasons. We used the fixed-kernel method to bound subpopulation areas and to estimate the relative probability of use by each subpopulation for each geographic information system (GIS) grid cell. The Delta is the starting point for the proposed Mackenzie Valley Pipeline. To demonstrate how subpopulation structure can be used to partition potential anthropogenic disturbance across the population, we estimated the mean probability of use of the projected pipeline route for each subpopulation from the initial development to 2027. Mean estimates of the probability of use suggested that the future pipeline development would occur disproportionately among subpopulations. Improved understanding of subpopulation structure facilitates research, monitoring, and management initiatives in response to changing land use.

Key words: brown bear, development, grizzly bear, Mackenzie Delta, Northwest Territories, subpopulations, *Ursus arctos*, Ward's cluster analysis

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Effective conservation and management of wildlife populations requires an understanding of population structure and the establishment of boundaries at an ecologically meaningful scale (Thomas and Kunin 1999). Measurements taken at the scale of the population may be too coarse for some conservation and management purposes and measurements at the scale of the individual may be equally inappropriate for long-term management initiatives (Amarasekare 1994). Given that long-term management decisions cannot be based on the individual, developing an understanding of within-population structure allows for better estimation of rates of reproduction, mortality, immigration, and emigration and the spatial and temporal dynamics within populations (Amarasekare 1994, Baguette et al. 2000). Within-population structure (i.e., subpopulations) is a level of organization that is meaningful to management and facilitates the monitoring and measurement of ecological processes and population dynamics (Bethke et al. 1996, McLoughlin et al. 2002).

Defining a population is complex because it depends on the context and the question being posed (Waples and Gaggiotti 2006). Two population definition paradigms have emerged using (1) gene flow and the reproductive interactions of individuals (i.e., the evolutionary paradigm), and (2) demographics and the spatial affinity of individuals in space and time (i.e., the ecological paradigm; Andrewartha and Birch 1984, Crawford 1984, Waples and Gaggiotti 2006). For the evolutionary paradigm, a population includes individuals of the same species whose proximity permits mating with any other member (Crawford 1984, Waples and Gaggiotti 2006). Recent advances in genetics have enhanced our ability to group population units using allele frequencies (Hoelzel and Dover 1991, Moritz 1994, Kitchen et al. 2005). However, the task of

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teasing out whether the genetic structure is related more to historical relationships than to present-day resource use remains problematic (Goldstein et al. 1999, Paetkau et al. 1999, Virgl and Messier 2000). Contemporary geographic population structure may be the convergence of natural selection, gene flow between populations, and vicariant events that restricted gene flow (Bohonak 1999). Only the rare movements of a few individuals are needed to genetically homogenize a population and obscure the spatial structure within the population if it exists (Paetkau et al. 1995, Paetkau et al. 1999).

In the ecological paradigm, a population consists of a group of individuals of the same species that share similar geographical positions (Moritz 1994) and interact demographically (Andrewartha and Birch 1984, Waples and Gaggiotti 2006). Direct observation of animal movements provides the required details on the spatial and temporal heterogeneity of animal distribution across a species' range (Paetkau et al. 1999, Cronin 2007). Conventionally, delineating population boundaries has been accomplished by grouping individuals subjectively based on traditional knowledge, reconnaissance, and capture site (Paetkau et al. 1999, Mauritzen et al. 2002, Petersen and Flint 2002). Although the delineation of kin-related social structure within populations has been recognized for gregarious species (Hamilton 1964, Garza et al. 1997, Kitchen et al. 2005), it was only recently documented in more solitary species (e.g., Støen et al. 2005). For conservation or management initiatives, the ecological paradigm provides useful insight into the contemporary distribution and interactions of individuals in a population (Waples and Gaggiotti 2006).

Discontinuities within a population can be used to delineate subpopulations of animals that have similar spatial–temporal distribution, spatial contiguity, and an affinity to neighboring conspecifics or to regions (Wells and Richmond 1995). Delineation of geographical population boundaries is often facilitated by environmental and topographical landscape features such as watersheds, lakes, parks, and reserves (Andrewartha and Birch 1984). However, identifying subpopulations becomes more complex in undeveloped areas for free-ranging species that are unbounded by habitat fragmentation or when animal movements are unimpeded by natural landscape features and food resources are patchily distributed and temporally dynamic (Amarasekare 1994, Paetkau et al. 1995, Bethke et al. 1996).

Barren-ground grizzly bears (*Ursus arctos*) within the Mackenzie Delta region, Canada, have large overlapping home ranges and, with the exception of the Mackenzie River and the Eskimo Lakes, there are no topographical features to impede movement or to suggest the presence of demographically or genetically distinct units. Unlike other bear populations where fragmentation allows for easily identifiable boundaries (e.g., Southeastern British Columbia, Yellowstone National Park, Scandinavia, Italy; Paetkau et al. 1998, Swenson et al. 1998, Proctor et al. 2002, Randi 2003), the bears of the Mackenzie Delta are part of a contiguous Arctic population that ranges from Alaska to Nunavut (COSEWIC 2002). Anthropogenic pressure in the form of subsistence and sport hunting is structured on a harvest quota system where tags are allocated to each community (Nagy and Branigan 1998). Because there are no permanent roads, access to the landscape is limited to aircraft, snow machines, all-terrain vehicles, and boats or the Mackenzie River ice road in winter. Human populations are centered in Aklavik, Inuvik, and Tuktoyaktuk.

Historically, Arctic North America has had relatively low levels of anthropogenic activity and, consequently, mammalian fauna tend to be sensitive to disturbance (Cardillo et al. 2006). Barren-ground grizzly bears may be sensitive to increased anthropogenic disturbance because of their low density in a region characterized by low primary productivity, high seasonality, and unpredictable food resources in space and time compared to lower latitudes (Ferguson and Messier 1996, Hilderbrand et al. 1999). The Mackenzie Delta is the starting point for a proposed pipeline and gathering system to transport oil and natural gas to southern markets (Truett and Johnson 2000, Cizek and Montgomery 2005). The development represents a substantial increase in the level of anthropogenic activity for this region, and there are concerns among wildlife managers and the affected communities regarding the potential effects of development on the bears.

Here, we use Ward's cluster analysis to group grizzly bears into subpopulations based on the spatial distribution of telemetry locations across the Mackenzie Delta region. We use GIS (geographic information system) and fixed-kernel methods to bound subpopulation areas and estimate the relative probability of use by each subpopulation. Oil and gas exploration in the Mackenzie Delta region has been limited since a moratorium on oil and gas

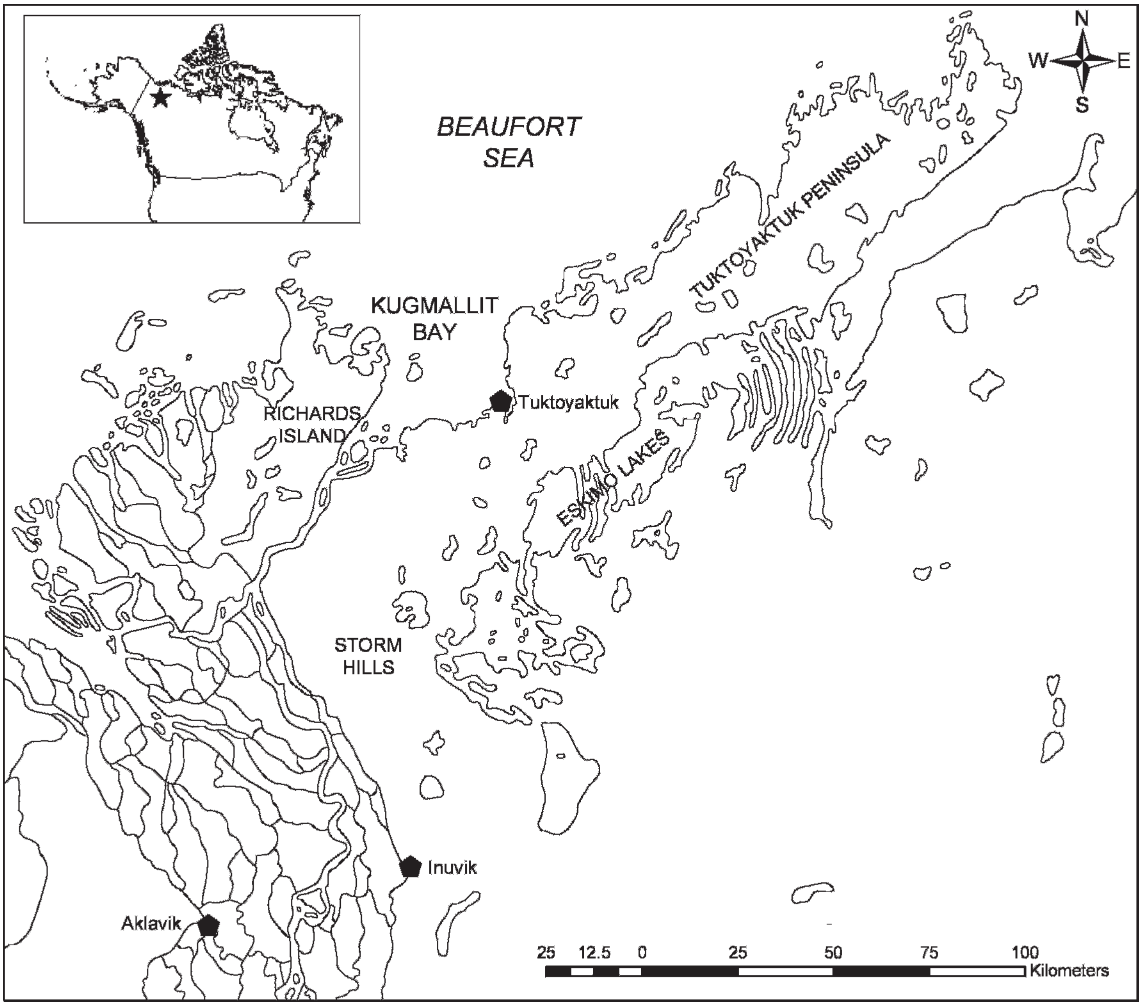

Fig. 1. The Mackenzie Delta region, located in the Northwest Territories of Canada's western Arctic.

development was invoked pending resolution of land claim settlements (Berger 1977). Development forecasts project that the pipeline will result in an increase in the number of exploratory and production wells, construction of trunk and feeder pipelines, compression facilities, liquefaction stations, airfields, and increased access to the landscape by winter and all-weather roads (Truett and Johnson 2000, Cizek and Montgomery 2005). Although the effects of a pipeline on the bear population are unknown, we use the proposed pipeline development from the initial stages to the end of pipeline construction as a case study to demonstrate how future impacts, if any, can be partitioned across the population and we suggest how subpopulation structure can be used to focus management.

Study area

We conducted our study in the Mackenzie Delta region (approximately 50,000 km^2) in the western Arctic of Canada's Northwest Territories, including Richards Island, the lower and upper Tuktoyaktuk Peninsula, the Delta, and the area surrounding Eskimo Lakes (Fig. 1). The area is characterized by long, cold winters, and short, cool summers and can remain snow-covered from mid-October to late-May (Black and Fehr 2002). The region has numerous lakes and rivers and habitat features, including boreal forest in southern areas dominated by spruce (*Picea glauca* and *P. mariana*) which grade into tundra with scattered trees and shrubs (MacKay 1963, Black and Fehr 2002).

Methods

Grizzly bear location data

Telemetry locations were collected from grizzly bears monitored from 1974–78 and 2001–06. Most grizzly bears were captured in May after den emergence. Collar deployment was spatially stratified to provide equal geographic representation. Sampling was focused on females in the population because males are preferred for subsistence and sport hunting by nearby communities and because their large necks often resulted in dropped collars shortly after deployment. Pooling data from the 2 periods provided a more complete representation of regional grizzly bear distribution. Capture, collaring, and monitoring methods used in 1974–78 are described in Nagy et al. (1983). Very high frequency (VHF) transmitters, receivers, and accessories were developed by the Bioelectronics Section of the Canadian Wildlife Service (Ottawa, Canada). A survey grid was established at 8-km intervals and telemetry flights were conducted weekly to locate the bears. In 2001–06, tiletamine–zolazepam was used to immobilize bears (Woodbury 1996). Bears were fitted with Gen II or Gen III: TGW-3680 global positioning system collars (GPS; Telonics Inc., Mesa, Arizona, USA) linked to Argos satellites (Service Argos, Inc., Lynnwood, Washington, USA) programmed to acquire location coordinates every 4 hours.

Subpopulation structure

We analyzed location data using ArcGIS 9.1 (Environmental Systems Research Institute, Redlands, California, USA). We pooled telemetry data across years because the frequency of location acquisition varied over time. For the cluster analysis, we used the spatial affinity and distribution of seasonal median locations of individuals to identify subpopulation structure. Each bear contributed 1 location for each of 4 active seasons: spring (den emergence–Jul), early summer (Jul), late summer (Aug) and autumn (Aug–denning). Only bears with locations for all 4 seasons were included in the analysis. For each bear, the median easting and northing for universal transverse Mercator (UTM; zone 8N) locations were estimated for each season, creating 8 variables for the cluster analysis. The median location was used because it is less affected by small sample sizes and non-normal distributions with outliers (Sokal and Rohlf 2001). We used STATA 8.0 (StataCorp LP, College Station, Texas, USA) and PC-ORD 5.0 (McCune and Mefford 1999) statistical software to perform Ward's minimum variance cluster analysis to identify subpopulation structure (Ludwig and Reynolds 1988). Ward's method or sums-of-squares agglomerative clustering is based on the minimization of within-cluster variance versus between-cluster variance (Ludwig and Reynolds 1988). We used 3 diagnostic stopping tools to determine the optimal number of clusters for this dataset. First, we examined the linkage distances of the dendrogram and Wishart's (1969) objective function distance, which is a measure of the loss of information as subjects are aggregated into groups. We then examined the Duda and Hart index, the pseudo t^2 statistic (Duda and Hart 1973, Rabe-Hesketh and Everitt 2004), and the Calinski and Harabasz pseudo F-statistic (Calinski and Harabasz 1974) to determine the optimal number of clusters.

Following the cluster analysis and identification of subpopulations, variation in sampling regimes between the 2 periods required that location data be standardized to the lower frequency of data acquisition (i.e., the 1974–78 VHF dataset) for subpopulation delineation. We grouped location data for each bear by season and calculated the mean number of locations. We selected a random subsample of locations, stratified by season, for each bear equal to the mean seasonal number of locations for the 1974–78 VHF dataset. Those data were used to delineate subpopulation boundaries and calculate the relative probability of use by each subpopulation.

We constructed utilization distributions (Worton 1989) for each subpopulation using Home Range Tools for ArcGIS 1.1 (Rodgers et al. 2007). Estimating the utilization distribution required that the smoothing bandwidth h and the cell size be specified. We used the fixed-kernel technique to estimate the 95% and 75% isopleth for each subpopulation of bears (Worton 1989, 1995). Selecting an appropriate smoothing bandwidth is a primary step in deriving the kernel probability density estimate (Worton 1989). Although the least-square cross-validation approach has been recommended as the default method (Seaman et al. 1999), there is no consensus on the best approach (Silverman 1986, Millspaugh et al. 2006). The least-square cross-validation method may undersmooth the utilization distribution, identifying structure where there is none (Sain et al. 1994), or fail completely with large datasets that have clumped or overlapping points (Gitzen and Millspaugh 2003). The optimal reference (Silverman 1986), or the plug-in and solve the equation approaches (Jones et al. 1996), often oversmooth the utilization distribution or have not been thoroughly tested for wildlife applications (Millspaugh et al. 2006). Our dataset was large and had many overlapping points. Therefore, we used an exploratory approach of selecting the smoothing bandwidth where the optimal reference value was used as a starting point to iteratively determine the most appropriate smoothing bandwidth that represented the distribution of telemetry locations (Silverman 1986, Worton 1995, Millspaugh and Marzluff 2001). Seaman et al. (1999) found that the least-square cross-validation value was approximately 50% of the reference value; therefore, we used this as our starting h value and increased or decreased h until we achieved a utilization distribution where the 95% fixed kernel was one complete isopleth. A cell size of 100 x 100 m was used to calculate the probability density of bear locations for each subpopulation. The 100-m grid cell size represented the mean surface area of an oil well facility (Imperial Oil Resources Ventures Ltd. 2005). The area of overlap for adjacent subpopulations was calculated as the percent shared area of the combined areas (Baker et al. 2000).

Next, we calculated the relative probability of use of each grid cell by each subpopulation. Probability density estimates were combined and scaled to sum to 1 to create a cell vector of the probability of use by each subpopulation for each grid cell. Vector scaling equalized the influence of different numbers of locations in the subpopulations and converted frequency of use into a relative probability of use for each subpopulation for every grid cell.

To better understand how the number of bears included in the analysis and the frequency of data acquisition influenced the utilization distributions, we analyzed the full GPS-only dataset separately. We compared the number of subpopulations identified for the sub-sampled VHF–GPS dataset and the full GPS-only dataset and the resulting utilization distributions.

Case study

As a case study, we used the probability of use by each subpopulation for a grid cell to examine how subpopulation structure can be used to partition development across a population. We used GIS to overlay the initial pipeline route (R. Wilson, Mackenzie Gas Project, Imperial Oil Resources, Inuvik, Northwest Territories, Canada, personal communication, 2004) with future development projections (Cizek and Montgomery 2005) and estimated changes in the mean probability of subpopulation use of the development over time. Pipeline projections were estimated using the modeling techniques described in Cizek and Montgomery (2005) that predicted the path of resource development expansion based on a detailed natural gas supply forecast. We assumed that subpopulation structure would remain constant during 2010–27. We calculated the mean probability of use for each subpopulation over time by adding the probability values for all cells transected by the pipeline for each stage of development and dividing the sum by the number of cells transected.

Results

Subpopulation structure

We recorded 28,289 locations from 69 grizzly bears. Fifty-four (14 males, 40 females) of the 69 bears (5 males and 7 females from the 1974–78 monitoring period; 9 males and 33 females from the 2001–06 monitoring period) had locations for all 4 seasons and met our selection criteria. We used a total of 26,824 locations from the 54 bears to estimate seasonal medians for subpopulation identification using cluster analysis (Fig. 2). After standardizing the dataset to the lower frequency of data acquisition of the 1974–78 VHF dataset, 1,235 locations were available for delineating the subpopulation boundaries (Fig. 2). The mean number of locations per bear was 23 (range = 12–25).

Larger values for the Duda and Hart index and smaller pseudo t^2 statistics indicate the optimal number of clusters that best fits the data (Duda and Hart 1973). The t^2 statistic achieved minima at the 6-cluster level (Fig. 3). However, the largest value for the Duda and Hart index occurred at 4 clusters (Fig. 3). To explore this disagreement, we examined the dendrogram (Fig. 4) and estimated the Calinski and Harabasz pseudo F-statistic (Calinski and Harabasz 1974). Agreement across the dendro-

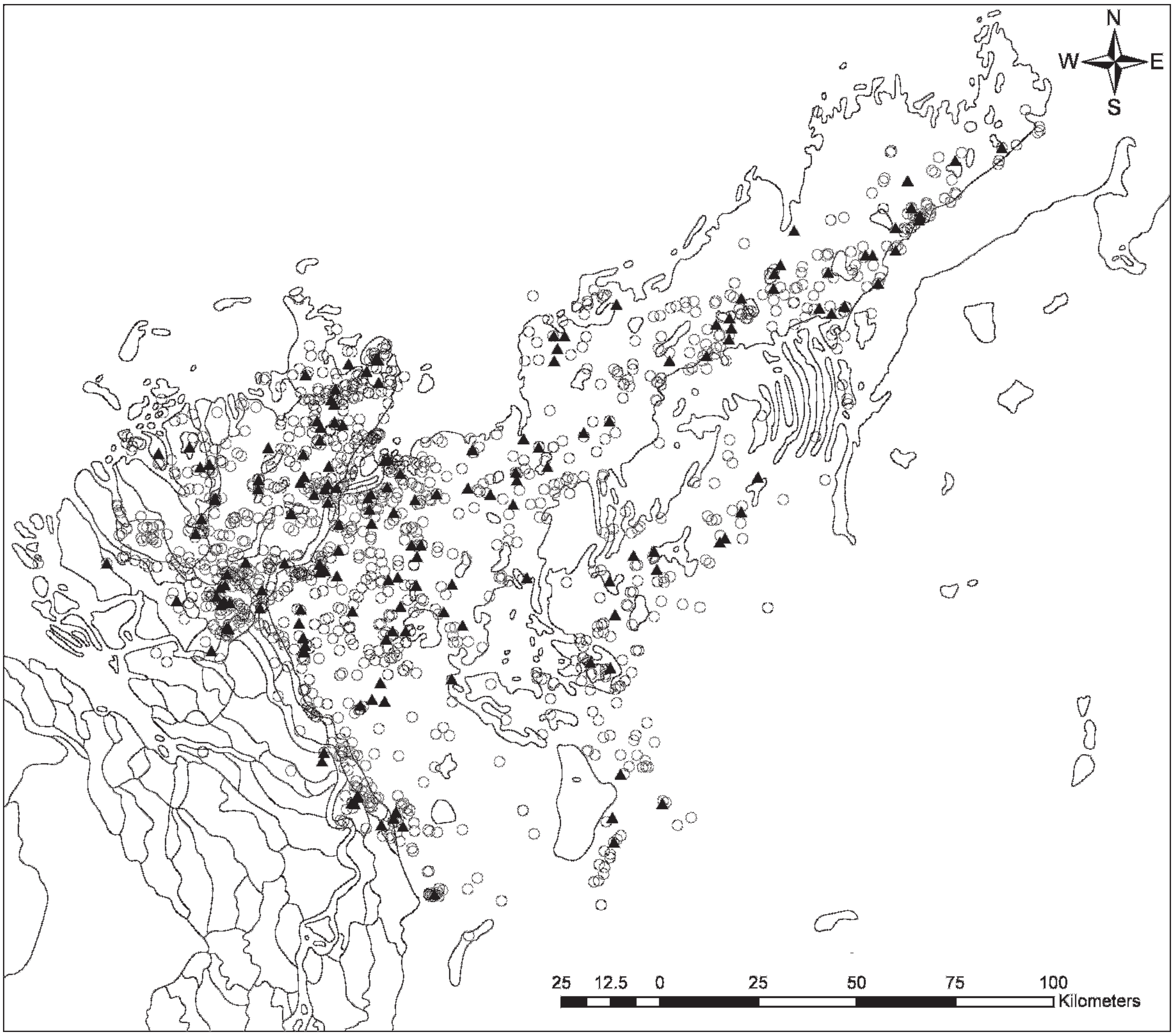

Fig. 2. Distribution of seasonal median locations (▲) and standardized telemetry data (○) for grizzly bears monitored from 1974–78 and 2001–06 in the Mackenzie Delta, Northwest Territories, Canada.

gram and the Duda-Hart and Calinski-Harabasz statistics, where the most distinct clustering was achieved, occurred at the level of 4 clusters. For descriptive purposes, we identified the 4 subpopulations based on their position on the landscape, which included Richards Island, Storm Hills, Eskimo Lakes, and the Tuktoyaktuk Peninsula (Fig. 5a). The mean overlap across the subpopulations was 8.4% (range = 5.8–12.1%).

Ward's cluster analysis of the full GPS-only dataset identified 3 subpopulations of grizzly bears (Fig. 5b). With the removal of the bears monitored from 1974–78, the Tuktoyaktuk Peninsula subpopulation was not differentiated, and the 2 remaining GPS-collared bears out of 42 (4.2%) were incorporated into the Eskimo Lake subpopulation. Using only bears monitored from 2001–06 reduced the number of bears available for the cluster analysis but increased the number of locations for delineating subpopulation boundaries and estimating the relative probability of use. The increased number of locations available with the full GPS dataset resulted in utilization distributions with slightly greater resolution for defining core areas of use than the sub-sampled VHF–GPS dataset.

Case study

Based on the probability of use of the projected pipeline route by the 4 grizzly bear subpopulations identified using the sub-sampled VHF–GPS dataset,

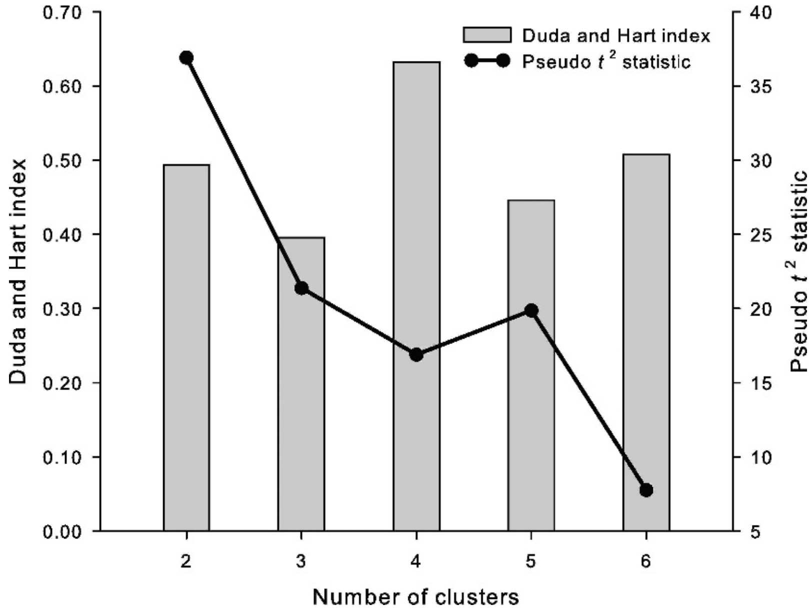

Fig. 3. The Duda and Hart index and t^2 statistic showing the optimal number of groups that best fits the subsampled VHF–GPS dataset for grizzly bear subpopulations in the Mackenzie Delta, Northwest Territories, Canada for data collected in 1974–78 and 2001–06.

development from the initial stage to 2027 will occur primarily in the area of the Richards Island subpopulation (Fig. 6). At the initial stage, development will primarily be divided between areas occupied by the Richards Island and the Storm Hills subpopulations. As development progresses to 2027, the pipeline is projected to expand from the natural gas fields at Taglu and Niglintgak on Richards Island (Cizek and Montgomery 2005) into areas occupied by the Eskimo Lakes subpopulation. Development in the area of the Tuktoyaktuk subpopulation will be negligible by 2027 given the current projected pipeline expansion scenarios.

Discussion

Based on seasonal geographical locations, grizzly bears of the Mackenzie Delta region were segregated into 4 subpopulations. Although landscape features did not appear to be barriers to bear movement, discontinuities on the landscape likely influenced the observed subpopulation structure. Such features include the Beaufort Sea to the north and possibly the boreal forest to the south, Sitidgi and Eskimo Lakes, the Mackenzie channels, and the Delta. Paetkau et al. (1998) suggested that landscape features, including the parallel orientation of mountains and valleys, low-level wetlands, rivers, and deltas, may restrict movement of bears across the landscape. Mountain caribou (*Rangifer tarandus caribou*) subpopulations in interior British Columbia, Canada, were naturally fragmented by non-forested areas such as icefields, barren and alpine areas, and water (Apps and McLellan 2006). Human activity at outpost camps, along traditional travel routes, around Inuvik and Tuktoyaktuk, and subsistence and sport hunting may also have influenced grizzly bear subpopulation structure. Proctor et al. (2005) differentiated between natural and anthropogenic fragmentation, and found that a transportation and settlement corridor was a source of fragmentation for bears inhabiting southern British Columbia and Alberta. The bears likely avoided the transportation corridor (Mattson et al. 1987) or were perceived as threats to human safety and killed in bear–human altercations over attractants such as garbage and human foods (McLellan et al. 1999, Proctor et al. 2005).

Each of our 4 subpopulations overlapped to varying degrees with its neighbors. For subpopulations that shared borders, disturbance in an area of overlap may influence bears from both neighboring subpopulations. For example, at the mouth of the Kugmallit Bay, development would occur in the area

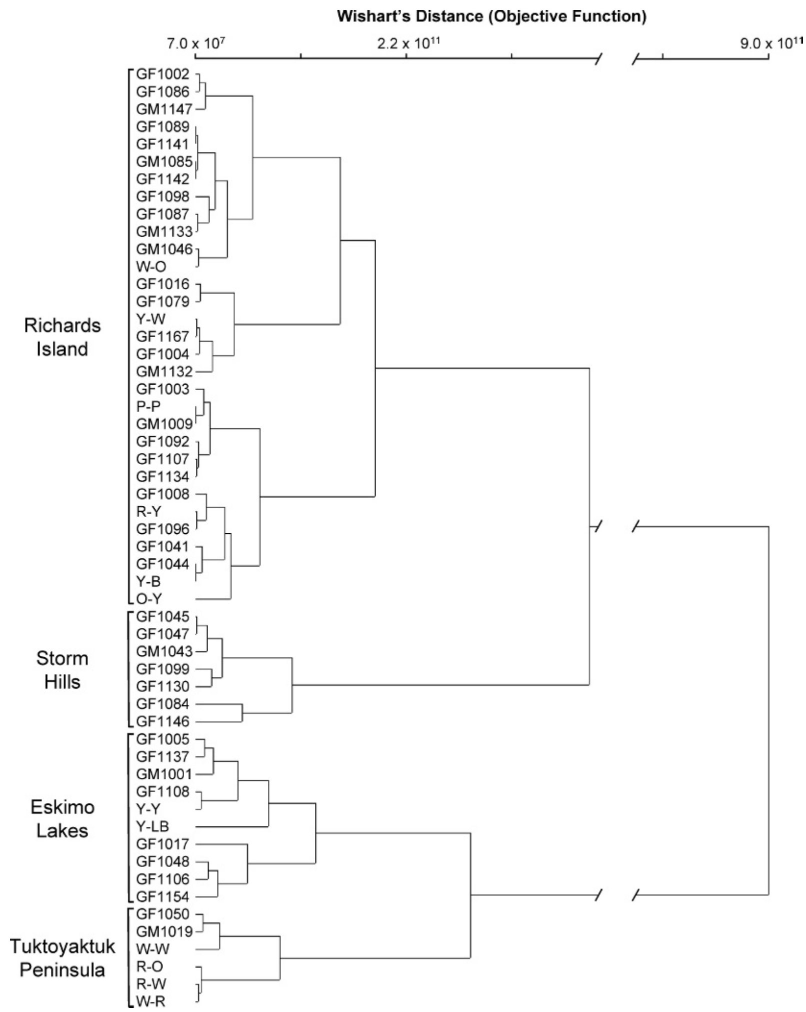

Fig. 4. Dendrogram from Ward's cluster analysis showing 4 subpopulations of grizzly bears in the Mackenzie Delta, Northwest Territories, Canada, for data collected in 1974–78 and 2001–06.

of overlap shared by the Richards Island and Eskimo Lakes subpopulations. In contrast, development in areas of no overlap would primarily be restricted to the area occupied by only one subpopulation (Fig. 5a). Although small, the overlap between the subpopulations also suggests that they are not distinct demographic units, which should be considered when estimating rates of reproduction, mortality, immigration, and emigration (Otis et al. 1978, Krebs 1989). By delineating subpopulation structure, management actions can be implemented along defined boundaries. However, managers should consider that the actions taken for one subpopulation will likely have ramifications for the neighbors (McLoughlin et al. 2002).

Some authors advocate the inclusion of measures of uncertainty with kernel estimation using bootstrapping methods where the animal is re-sampled with replacement (Amstrup et al. 2004, 2005). The fast Fourier transform method provides a means of calculating an estimate of precision for the relative probability of use by each subpopulation that would otherwise be computationally limiting (Kern et al. 2003). We did not adopt this approach because it assumes that the individual animal is the only source of variability and fails to recognize other sources, such as changing resource use and availability across years, home range drift, the number of locations, the use of seasonal versus annual measures of central tendency for cluster analysis, and the selected

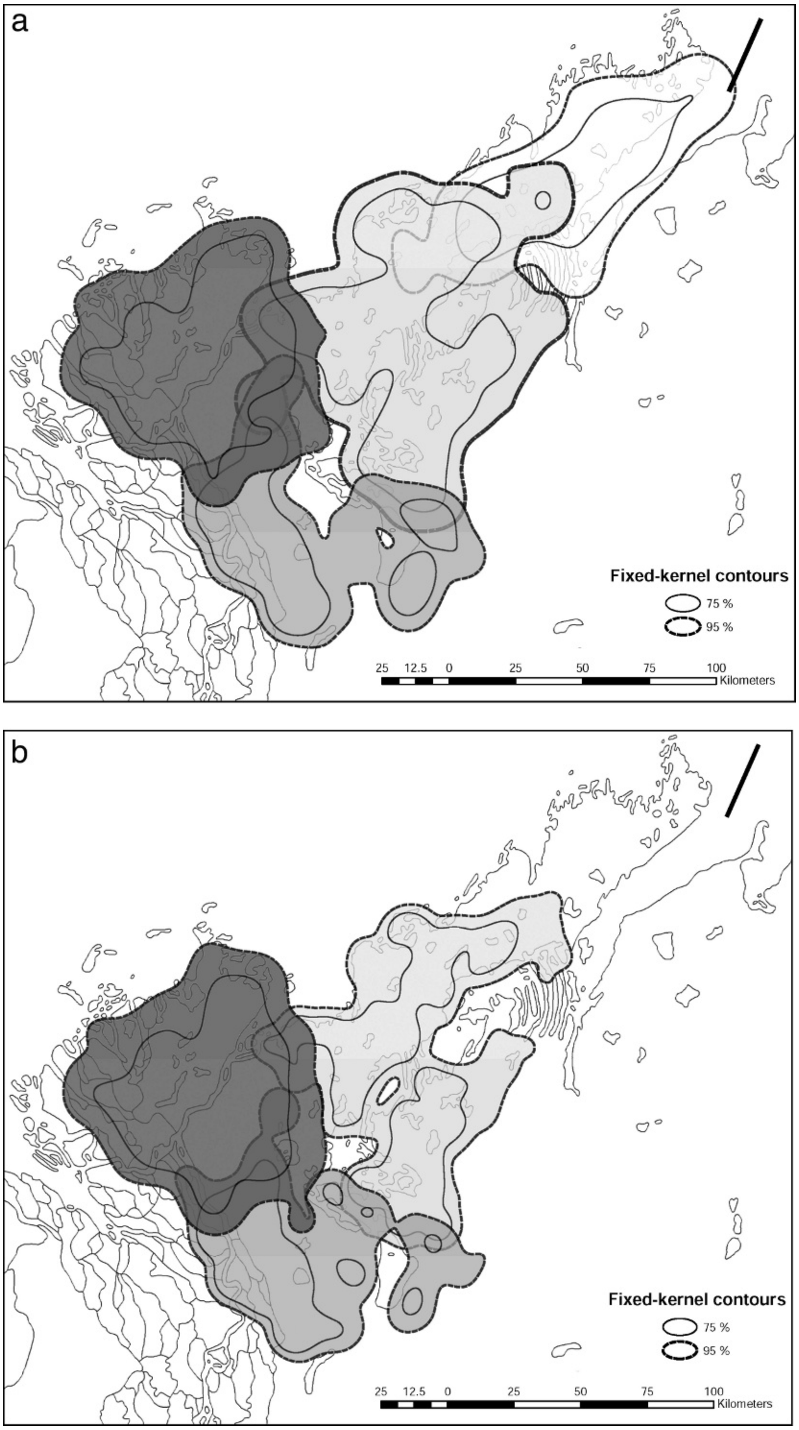

Fig. 5. Utilization distributions (fixed-kernel contours) showing 4 and 3 subpopulations for (a) the sub-sampled VHF–GPS dataset and (b) the full GPS-only dataset, in the Mackenzie Delta, Northwest Territories, Canada, for data collected in 1974–78 and 2001–06.

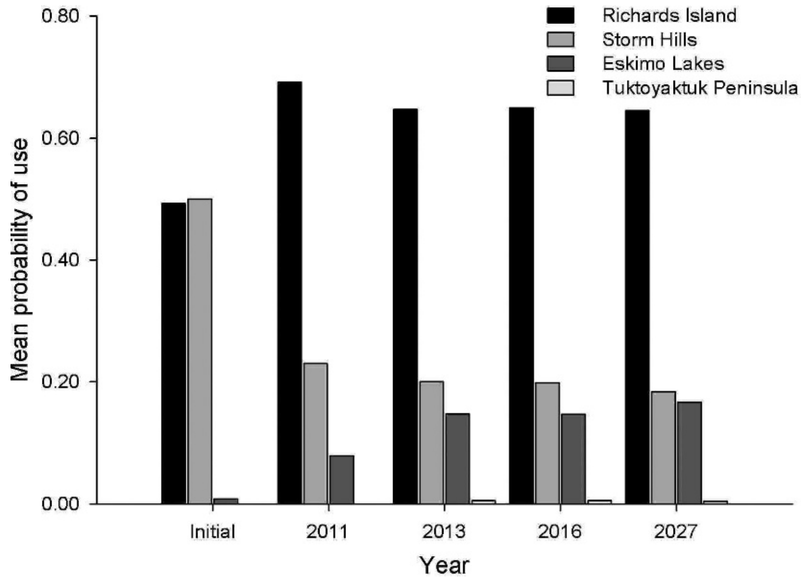

Fig. 6. Projected change in the mean probability of use of the pipeline route by the 4 grizzly bear subpopulations in the Mackenzie Delta, Northwest Territories, Canada, based on projected pipeline development from the initial phase to 2027.

bandwidth estimator and cell size. We recommend evaluating the effect of these other sources of error on measures of uncertainty.

To provide a more complete representation of the regional distribution of grizzly bears, we pooled data from monitoring programs conducted from 1974 to 1978 and from 2001 to 2006. Presently, grizzly bear harvest in the Mackenzie Delta region is managed under a tag-issuing system that was not in effect in 1974–78 (Nagy and Branigan 1998). As a result, bear distribution may differ from the 1970s to today in response to changing land use and harvest pressure. However, inclusion of the 1974–78 dataset provided information on bear distribution across the region, especially for bears living in the upper Tuktoyaktuk Peninsula, which otherwise would not have been available.

When the 1974–78 VHF dataset was excluded, the procedure failed to segregate the Upper Tuktoyaktuk Peninsula subpopulation, which demonstrated the importance of complete representation of species distribution for the population under consideration. By using the GPS-only dataset, we increased the number of locations available to estimate the utilization distribution and delineate subpopulation boundaries. For the Richards Island, Storm Hills, and Eskimo Lakes subpopulations, the GPS-only dataset resulted in more detailed contours than those produced using the sub-sampled VHF–GPS dataset. Seaman et al. (1999) reported that variation in sample size had the greatest influence along the peripheral areas of the utilization distribution where the least amount of data is available. By increasing the number of locations to some threshold value, we can reduce the amount of sampling error in home-range size estimation (Seaman et al. 1999). Although the recommended number of locations for kernel-based estimates of home-range size is 30–50 (Seaman et al. 1999, Kernohan et al. 2001), finer-scaled spatially explicit management applications would benefit from higher numbers of locations to provide subpopulation boundaries with greater resolution.

Mean estimates of the probability of use of the projected pipeline route suggest that development will be disproportionately distributed across different subpopulations. Pipeline-related development could include increased disturbance, fragmentation of habitats, changing availability of resources, increased risk of mortality, and changes in bear distribution (Harding and Nagy 1980, Tietje and Ruff 1983, Follmann and Hechtel 1990). Which population components are influenced by a disturbance will depend on the location of the disturbance and the relative probability of use of the area by bears.

Wildlife managers could use subpopulation structure to define ecologically meaningful boundaries to better measure and monitor wildlife responses to additional and changing land use and to mitigate potential impacts (Caughley et al. 1988, Thomas and Kunin 1999). Mauritzen et al. (2002) suggested that the spatial population structure of polar bears (*U. maritimus*) within the contiguous population of Norway and the western Russian Arctic could more effectively be defined by the geographical position of individuals for changes in bear–habitat relationships. Within the Mackenzie Delta region, harvest management could be re-structured to allocate grizzly bear tags to subpopulations, which would be more biologically meaningful than the present community-based harvest quota system (Nagy and Branigan 1998). Through co-management, subpopulation structure could be used to encourage hunters to concentrate subsistence and sport hunting activities away from areas where the potential risk of disturbance is highest. By assigning mortalities from harvests and problem-bear interactions to subpopulations, harvest quotas could be used to re-distribute the anthropogenic disturbance across the population. For example, Amstrup et al. (2005) used subpopulation structure to assign polar bear harvest quotas to communities within jurisdictions.

As hydrocarbon development progresses, the cumulative effects of increasing anthropogenic disturbance, recreation activities, sport hunting, and subsistence hunting will vary widely across the Mackenzie Delta bear population. Subpopulation delineation within the regional grizzly bear population is an intermediate level of organization that is meaningful to management and research and provides a tool to more reliably measure and monitor changes in life-history traits and population dynamics to better assist in mitigation plans.

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