Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Research Progress Report
1 July 1996 - 30 June 1997

Furbearer Management Technique Development

Howard N. Golden

Grant W-24-5
Study 7.18
December 1997

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STATE OF ALASKA
Tony Knowles, Governor

DEPARTMENT OF FISH AND GAME
Frank Rue, Commissioner

DIVISION OF WILDLIFE CONSERVATION
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Federal Aid in Wildlife Restoration
Research Progress Report

FURBEARER MANAGEMENT TECHNIQUE DEVELOPMENT

1 July 1996 – 30 June 1997

Howard N. Golden

Job 1 — Distribution and Trend of Marten, Lynx, and Snowshoe Hare Populations

Job 2 — Densities, Trend, and Harvest Potential of Wolverine Populations

Job 3 — Distribution, Trend, Habitat use, and Harvest Potential of Coastal River Otter Populations

Job 4 — Applying the Lynx Tracking Harvest Strategy Through Rule-Based Modeling

RESEARCH PROGRESS REPORT

STATE: ALASKA **Study:** 7.18

COOPERATORS: WRANGELL-ST. ELIAS NATIONAL PARK, COPPER CENTER; KENAI NATIONAL WILDLIFE REFUGE, SOLDOTNA; CHUGACH NATIONAL FOREST, SEWARD; KENAI FJORDS NATIONAL PARK, SEWARD; AND R. TERRY BOWYER, GAIL BLUNDELL, MERAV BEN-DAVID, AND PAMELA GROVES, UNIVERSITY OF ALASKA, FAIRBANKS

GRANT: W–24–5

STUDY TITLE: FURBEARER MANAGEMENT TECHNIQUE DEVELOPMENT

JOB TITLES:

1. DISTRIBUTION AND TREND OF MARTEN, LYNX, AND SNOWSHOE HARE POPULATIONS
2. DENSITIES, TREND, AND HARVEST POTENTIAL OF WOLVERINE POPULATIONS
3. DISTRIBUTION, TREND, HABITAT USE, AND HARVEST POTENTIAL OF COASTAL RIVER OTTER POPULATIONS
4. APPLYING THE LYNX TRACKING HARVEST STRATEGY THROUGH RULE-BASED MODELING

PERIOD: 1 JULY 1996 – 30 JUNE 1997

SUMMARY

Each of the 4 jobs in this comprehensive study represents a separate research project to address the development of furbearer management techniques. Jobs 2–4 were active during this report period.

Job 2. We continued to focus on testing the accuracy and relative precision of 2 density estimation techniques for wolverine (*Gulo gulo*) populations, the transect-intercept probability sampling scheme (TIPS) and the sample-unit probability estimator (SUPE). We captured 4 new wolverines but still fell short of the requisite 10–13 animals needed to complete the original test. Of the 22 wolverines captured during this study, only an adult female is still known to be active in the study area. We reevaluated using the TIPS to test the accuracy of estimating wolverine density. The alternative plan devised during this report period is to assess the accuracy of the SUPE through replicate sampling and to compare through simulation modeling the efficacy of the TIPS versus the SUPE. The SUPE technique should allow surveys under poorer weather conditions, and radiomarked animals are not vital for the tests. We continued to monitor movements and habitat associations of radiocollared wolverines from fixed-wing aircraft. Telemetry flights were attempted approximately weekly during April–June, biweekly during July–September, and monthly during October–March. Using a GPS to record wolverine routes of travel, we supplemented our understanding of wolverine movements following snowfall by trailing marked and unmarked animals. Survival of radiocollared yearling and adult wolverines in the Talkeetna Mountains averaged 0.71

annually and 0.85 over 6 months. Mean survival for the 6-month period of April–September was 0.94, but it was 0.75 for October–March when wolverines were most susceptible to harvest from trapping. Expected survival of a wolverine from the beginning of the study to 6 months was 1.00. Survival dropped to 0.33 at 1 year and then continued to decline gradually to 0.13 at 5.5 years.

Job 3. We focused our efforts on completing the sampling of latrine sites on the south side of Kachemak Bay to determine latrine-site use and scat deposition rates. We continued to collect scats for diet analysis and to monitor the radiomarked river otters (*Lutra canadensis*). We increased our sampling in 1996 to 4 3-week intervals and 5 3-day intervals between 1 June and 26 September to measure the distribution and rate of latrine site use and to measure daily scat deposition. Although there was no observed trend in the scat deposition rate over time in 1995, there was a highly significant decline (R^2 = 0.99; $F_{1,2}$ = 450; P = 0.002) in scats/day between sampling periods in 1996. Scat deposition rates among 3-day samples in 1996 declined gradually over the summer but not significantly (R = 0.69; $F_{1,3}$ = 6.72; P = 0.08). Exploratory data analysis through median polish indicated few effects from differences among latrine sites of scat deposition rates (i.e., scats deposited/day). Effects from differences among sampling-period estimates reflected the strong decline in the scat deposition rates for the 3-week interval but no variation in rates among the 3-day intervals. In our preliminary analysis of river otter diet, we identified 38 unique food items among 90 river otter scats sampled in Kachemak Bay in 1995. Saffron cod, flatfish, rock sole, gunnels, and sculpins composed nearly 40% of the items identified among 38 latrine sites. Thirty of the food items were bony fishes. The remaining 8 items were snails, mussels, barnacles, clams, crabs, polycaete worms, chitons, and sea urchins. There may be a lower diversity of food for river otters in Kachemak Bay than in Prince William Sound, based on an earlier oil-spill study. River otters in Kachemak Bay generally preyed on fish no larger than a small rockfish (i.e., <30 cm).

Job 4. Annual progress on this job is presented in the Appendix as a manuscript, *An Expert-System Model for Lynx Management in Alaska*, which was submitted for publication to the Mammal Trapping Symposium held in Edmonton, Alberta, 17–19 August 1997. This manuscript presents the model's structure and mechanics along with a simulation of the model using data from a management area in Southcentral Alaska.

Key words: Density estimation, expert system, *Lynx canadensis*, food habits, *Gulo gulo*, habitat use, harvest, latrine site, *Lepus americanus*, line-intercept sampling, *Lutra canadensis*, lynx, movements, quadrat sampling, relative abundance, river otter, rule-based model, snowshoe hare, survival, wolverine.

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STUDY BACKGROUND

This is the second progress report in a comprehensive process to develop furbearer management techniques by (1) evaluating the scope of species-specific management problems, (2) designing methods to address specific management needs, (3) testing the reliability and usefulness of those methods, (4) refining methods where necessary, and (5) facilitating the implementation of suitable techniques. This research study encompasses 4 projects, or jobs, that represent furbearer management issues of greatest concern in Southcentral Alaska, other than those affecting wolves. The goals of these 4 jobs are as follows:

1. Develop ground and aerial techniques for counting tracks in winter to monitor the distribution and trend of marten (*Martes americana*), lynx (*Lynx canadensis*), and snowshoe hare (*Lepus americanus*) populations in Southcentral Alaska.

2. Assess the accuracy of density estimation techniques and develop techniques to monitor the trend and harvest potential of wolverine (*Gulo gulo*) populations in Southcentral Alaska.

3. Develop techniques to index river otter (*Lutra canadensis*) populations, determine the availability and use of their habitat, and assess their harvest potential in coastal environments of Southcentral Alaska.

4. Develop a rule-based lynx management model to use in the lynx-tracking harvest strategy.

Progress on Jobs 2–4 is reported here. Job 1 was inactive during this report period.

JOB 2 — DENSITIES, TREND, AND HARVEST POTENTIAL OF WOLVERINE POPULATIONS

BACKGROUND

Golden et al. (1993*a,b*) and Golden (1996) provided background for this project. Only Jobs 2.1 and 2.3 were active during this report period. We have continued to focus our efforts on testing the accuracy and relative precision of 2 density estimation techniques, the transect-intercept probability sampling scheme (TIPS) (Becker 1991) and the sample-unit probability estimator (SUPE) (Becker, in press). There is uncertainty concerning the validity of the assumptions basic to both of these methods for wolverines and, therefore, whether or not they are unbiased estimators. Once these techniques have been evaluated, wolverine density estimates may be compared among several trend areas in Southcentral and other regions of Alaska. Progress in determining the relationships among trends in wolverine density, harvest, and abundance of large predators will help in estimating sustainable harvest levels of wolverine populations. We have conducted most of the work on this project in the eastern Talkeetna Mountains but have also conducted density estimations on the Kenai Peninsula

(Golden 1993*a,b*) and surveyed wolverine populations in Wrangell-St. Elias National Park and Preserve.

OBJECTIVES

2.1 To assess the accuracy and relative precision of wolverine density estimates derived from line-intercept and quadrat sampling techniques.

2.2 To estimate the densities and trends of wolverine populations in different areas of Southcentral Alaska.

2.3 To determine if relationships exist between trends in wolverine density and trends in wolverine harvest, food availability, and abundance of large predators.

2.4 To estimate sustainable harvest levels of wolverine populations in Southcentral Alaska.

STUDY AREAS

The primary area used for testing the density estimation techniques is the eastern Talkeetna Mountains, which lie between the Chugach Mountains and Alaska Range and form the western Nelchina River basin. A description of this area is presented in Golden (1996). Study areas in the Kenai Mountains and Wrangell Mountains are described in Golden (1993*a,b*).

METHODS

Job 2.1. Tests of Wolverine Density-Estimation Techniques

Captures. We used helicopter darting to capture wolverines in the eastern Talkeetna Mountains study area. Capture and collaring techniques are described in Golden et al. (1993*b*) and Golden (1996).

Density Estimation Tests. Snow and weather conditions were unsuitable for capturing the required number of wolverines to conduct and test the TIPS. We reevaluated the efficacy of using the TIPS to test the accuracy of estimating wolverine density.

Track Trailing. On 12 occasions between 27 February and 3 April 1997, we opportunistically monitored marked and unmarked wolverines to determine their movements following snowfall. We used Super Cub aircraft to follow the tracks from the air and recorded their routes with a global positioning system (GPS). These data should improve our estimate of average daily movement, which is needed in calculating a density estimate (Becker, in press). We will analyze the data through ArcView during the next report period.

Job 2.3. Wolverine Harvest and Habitat Relationships

We monitored movements and habitat associations of radiocollared wolverines from fixed-wing aircraft. Telemetry flights were attempted approximately weekly during April–June, biweekly during July–September, and monthly during October–March. Before and during captures and density estimations, wolverines were located nearly daily. Data on wolverine associations with habitat and other animals were collected for each location. Location and attribute data were entered into an ArcView database and will be analyzed the next report period.

Job 2.4. Wolverine Population Model

We estimated the survival of radiocollared yearlings and adults using the Kaplan-Meier procedure modified for staggered entry of additional animals (Pollock et al. 1989). This procedure accounted for animals that were lost due to dispersal or to radiotransmitter failure and allowed for the addition of newly marked animals. We estimated survival rates for 6-month periods beginning in April 1992 and extending for 5.5 years to September 1997. We also calculated mean annual survival and mean survival for periods April–September and October–March.

RESULTS AND DISCUSSION

Job 2.1. Tests of Wolverine Density-Estimation Techniques

Captures. We captured and radiocollared 2 male and 2 female wolverines on 1 March 1997. These captures increased the total number of study animals caught to 22, 13 (59%) males and 9 (41%) females (Table 1). Mean ages of the wolverines at time of capture, based on cementum annuli determined from premolars (Matson's Lab, Milltown, Montana) or estimated from tooth wear and teat or testes size, were 1.6 years (SD = 0.9) for females and 2.1 years (SD = 1.3) for males. Among 7 females and 11 males whose ages were known, there were 0.8 juveniles (i.e., <2 years old) per adult and 4 adult males, 1.5 juvenile males, and 2.5 juvenile females per adult female. The average age of radiocollared wolverines at the time they either died or their signal was lost or that were still alive before 1 October 1997 was 2.7 (SD = 1.3) for females (n = 9) and 2.5 (SD = 1.3) for males (n = 13). The oldest radiocollared animals (1 male and 1 female) were 5 years old.

Males were significantly heavier than females ($P < 0.001$; $t = -8.46$; df = 19), with no overlap in weight between the sexes (Table 1). Mean capture weight of males (n = 13) was 15.0 kg (SD = 1.2 kg) and 10.6 kg (SD = 1.0 kg) for females (n = 9). These weights were similar to those reported for wolverines in Alaska by Gardner (1985) and Magoun (1985) but heavier than those reported for wolverines in Yukon (Banci 1987) and Idaho (Copeland 1996).

One female (TF9) caught in March 1997 had nursed kits in the past and may have been pregnant at the time of capture, based on her large teats and the full appearance of her abdomen, but no kits could be palpated. We obtained additional evidence of this adult female having at least 1 kit through aerial tracking on 21 May 1997 when we saw her tracks in a snow bank with a small set of kit-sized wolverine tracks . TF9 and TF1 have been the only 2 females to exhibit signs of reproductive activity at capture. TF1 was lactating at her first capture in April 1992, and we saw her with 1 kit in May and with 2 kits in June of that year (Golden 1996). We do not have survival data for these 3 kits.

Density Estimation Tests. Estimating the accuracy of the TIPS would require 10–13 radiocollared wolverines within the study area to determine the proportion of animals that may be missed during TIPS surveys. Once the test animals had been marked, 2–3 TIPS surveys would be needed to assess the accuracy of the technique. After 3 years of attempting this test, I determined it was unworkable because (1) capture success fell short of the requisite 10–13 animals, (2) suitable weather and snow conditions did not occur to allow both capture and survey tests, and (3) the TIPS required nearly ideal survey conditions over the entire study area, which did not occur.

The alternative plan devised during this report period is to assess the accuracy of the SUPE through replicate sampling and to compare through simulation modeling the efficacy of the TIPS versus the SUPE. The SUPE technique offers important advantages over the TIPS technique. Because the sample units (SUs) are flown in a circular pattern, the ability of observers to see tracks from different angles is increased, which improves the chances of their initial observation and subsequent tracking. The improved sightability will also allow surveys during less favorable snow and weather conditions. Although not required, having radiomarked wolverines should enhance tests of the SUPE.

The study area was increased from 4100 km^2 to 4500 km^2 to enable adequate sampling among 180 possible 25-km^2 SUs arranged in a 10 x 18 grid of sample units. We divided the area into 2 strata, high and low, based on the likelihood of those areas containing wolverine tracks as determined through prior aerial surveys (Becker, in press). We randomly selected for survey 41–50 (58%–70%) of 71 SUs in the high stratum and 26–33 (24%–30%) of 109 SUs in the low stratum.

We will divide SUs to be surveyed equally among 3 pilot/observer teams. The same SUs surveyed on the first day following a fresh snowfall will be surveyed on succeeding days until tracking conditions become unworkable. This is likely to occur after 4–5 days because wolverines often overlap their own trails or those of other wolverines. The assumption of this test is that any wolverine that does not move by day 1 or 2 of the survey will move by day 3 or 4, and, therefore, would make a track that could be followed. We will calculate and compare daily density estimates (Becker, in press) to assess precision of the first survey and determine if a correction factor must be applied. Having radiocollared wolverines in the study area should help in deciphering tracks among individual animals.

Job 2.3. Wolverine Harvest and Habitat Relationships

Of the 22 wolverines captured in this study, we know of only 1 (TF5) that is now active in the study area (Table 2). We know of 10 study animals that have died. Harvest by hunters or trappers accounted for the loss of 8 (36%) animals, 6 (27%) within and 2 (9%) outside the study area. We believe the latter 2 wolverines dispersed because 1 animal was caught 40-km to the west and the other was caught 144-km to the north (Golden 1996). One young female (TF2) probably died due to complications resulting from her radiocollar chafing her skin and causing an infection. The only study animal whose death was not caused directly or indirectly by humans was a young female (TF8) that was killed by a large predator, probably wolf.

We believe wolves are responsible for the death of TF8 because we observed them close to her on 2 occasions. We saw 1 wolf circling her on 31 May 1997, which was the first day we detected her radiosignal on mortality mode (S. Bowen, pers. commun.). The last observation of TF8 alive was 15 May 1997. We retrieved the carcass by helicopter on 2 June 1997. As the carcass was loaded onto the helicopter, 2 wolves remained within 300-m, barking and howling (W. Testa, pers. commun.). The necropsy revealed 5 puncture holes in the skin, 3 in the chest and 2 in the groin, which may have been made by canine teeth. Although the carcass was in an advanced stage of decomposition, it was intact and no part of it had been consumed. Its chest was crushed laterally on the ventral side, resulting in several broken ribs. These observations plus the behavior of the wolves and the timing of the death in late May suggest wolves attacked the wolverine, possibly in defense of a den site. Wolves have attacked wolverines in other areas but usually have not eaten the carcasses (Boles 1977).

Job 2.4. Wolverine Population Model

Survival of radiocollared yearling and adult wolverines in the Talkeetna Mountains averaged 0.71 annually and 0.85 over 6 months. Mean survival for the 6-month period of April–September was 0.94, but it was 0.75 for October–March when wolverines were most susceptible to harvest from trapping. Expected survival of a wolverine from the beginning of the study to 6 months was 1.00. Survival dropped to 0.33 at 1 year and then continued to decline gradually to 0.13 at 5.5 years (Fig. 1). Between 3 and 4.5 years, the survival rate was constant at 0.21 (Table 3). These estimates were lower than those predicted by Magoun (1985) for a hypothetical population of wolverines, based on her data from an essentially unharvested population in northwestern Alaska. For example, she estimated survival at 1.00 for years 1 and 2, 0.50 for year 3, then a gradual decline to 0.19 for year 13, which was the maximum known age of a wolverine. The confidence intervals around our estimates were large (Fig. 1 and Table 3), particularly for the 6-month and annual mean estimates that we truncated at 0.00 (lower) and 1.00 (upper). This variability reflects the low sample size of 22 wolverines and the large number of censored animals (Pollock et al. 1989). It precluded survival estimates by sex and age class and for shorter periods.

We believe we met most of the assumptions of the Kaplan-Meier procedure specified by Pollock et al. (1989). We were able to randomly sample animals of a particular sex and age class by capturing all but 2 animals through helicopter darting. We made no effort to select certain individuals, although we probably caught more males than females because males range more widely and may be more vulnerable. We met the assumption that survival times were independent for different animals, because wolverines are generally solitary and young are independent before the age of 1 year. Except for the study-related death of TF2, we believe it is unlikely that capturing the study animals or their wearing of a radiocollar influenced their survival. We were careful to censor animals randomly and not consider their fate in the decision. Wolverines were censored when we lost contact with them, even if they were later harvested and reported as killed, or if their death was probably capture-related. We censored 1 adult male when his radiocollar stopped transmitting after 1 month, added him back into the survival model when he was recaptured and radiocollared the following year, and finally marked him as dead when he was trapped about a year later while still radiocollared. We censored a yearling female because her death was capture-related. One female and 2 males killed by trappers were censored because we lost their radiosignals before they were trapped. In defining a time origin, we began our calculation of survival in April when the first study animals were captured, kits had been born, and the trapping season had ended. Because of the small sample size, we were unable to quantitatively assess whether or not we met the assumption that newly tagged animals had the same survival function as previously tagged animals.

RECOMMENDATIONS

This study should continue for at least another year. During the next report period, we will focus on completing the evaluation of the accuracy of the SUPE for wolverines and on comparing the efficacy of the TIPS and SUPE through simulation modeling. We will analyze movement data and relate home ranges and habitat use patterns to the availability of habitat and food resources. We also plan to develop a model to estimate wolverine sustainable yield.

ACKNOWLEDGEMENTS

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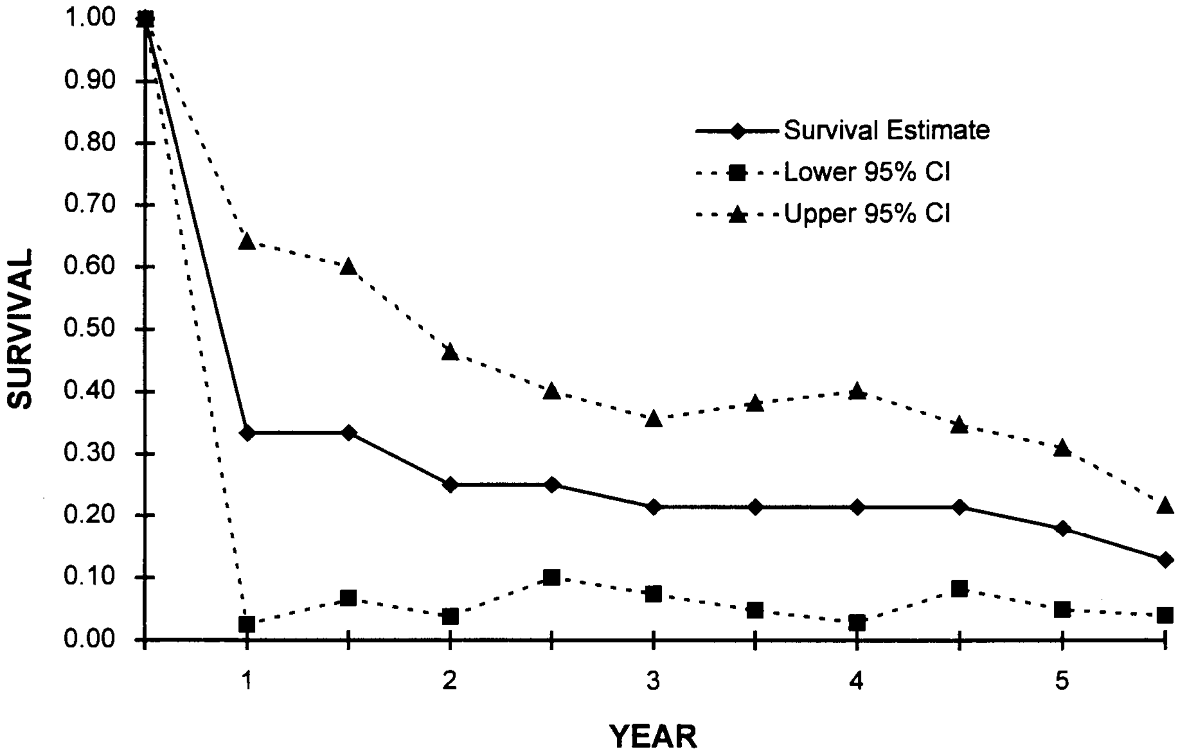

Figure 1 Kaplan-Meier survival function (modified for staggered entry of additional animals) for radiocollared wolverines in the Talkeetna Mountains, Alaska, April 1992–September 1997

Table 1 Ages and body measurements of wolverines captured in the eastern Talkeetna Mountains, April 1992 through March 1997

Animal nr	Sex	Date of Capture	Age[a] yrs	Weight kg	Body Length cm	Tail Length cm	Total Length cm	Head Circum. cm	Neck Circum. cm	Heart Girth cm
TF1	F	4/20/92	3	10.0	76.0	22.0	98.0	32.5	29.0	44.5[b]
TF2	F	4/21/92	1	9.5	76.0	20.0	96.0	31.0	28.0	41.0
TF3	F	4/3/93	1	10.0	84.0	22.0	106.0	35.0	31.5	42.5
TF4	F	3/6/94	1	10.0	80.0	10.4	90.4	34.4	30.3	40.0
TF5	F	3/7/94	1	11.5	78.5	18.5	97.0	34.0	32.5	46.5
TF6	F	3/27/94	1	11.6	81.2	19.5	100.7	33.5	31.0	42.5
TF7	F	3/14/96	2	11.0	82.0	21.5	103.5	33.5	30.0	39.0
TF8	F	3/1/97	1	9.5	82.5	11.5	94.0	31.5	28.0	35.0
TF9	F	3/1/97	3	12.0	84.0	22.0	106.0	32.0	31.0	41.0
Mean			1.6	10.6	80.5	18.6	99.1	33.0	30.1	41.3
SD			0.9	1.0	3.1	4.5	5.4	1.4	1.6	3.3
TM1	M	4/18/92	1	15.0	91.0	20.0	111.0	38.0	36.0	46.0
TM2	M	4/19/92	3	18.0	91.0	20.5	111.5	38.0	37.0	47.0
TM3	M	3/3/93	1	15.0	88.0	23.0	111.0	37.5	36.5	47.5
TM4	M	3/3/93	3	15.0	82.0	21.0	103.0	37.0	36.5	45.5
TM5	M	3/28/94	5	14.5	89.0	17.5	106.5	37.5	36.5	47.0
TM6	M	3/28/94	2	14.5	95.5	18.5	114.0	37.0	35.5	48.0
TM7	M	3/19/95	1	15.0	88.5	21.5	110.0	37.0	34.2	41.5
TM8	M	3/19/95	1	14.5	92.0	14.0	106.0	37.0	32.5	42.0
TM9	M	2/17/96	3	16.2	83.0	18.0	101.0	37.0	38.0	49.0
TM10	M	2/17/96	2	12.8	92.0	21.0	113.0	33.0	31.0	46.0
TM11	M	3/13/96	3	15.5	88.5	21.5	110.0	37.5	35.5	47.0
TM12	M	3/1/97	1	14.8	91.0	20.0	111.0	37.0	34.5	55.0
TM13	M	3/1/97	1	14.8	88.0	20.0	108.0	35.0	34.0	41.5
Mean			2.1	15.0	89.2	19.7	108.9	36.8	35.2	46.4
SD			1.3	1.2	3.6	2.3	3.8	1.4	1.9	3.6

[a] Age was determined from cementum annuli of premolars except for TF8, TF9, TM12, and TM13, whose ages were estimated based on tooth wear.

[b] The heart girth measurement for TF1 was taken from her second capture of 20 April 1993.

Table 2 Status of radiocollared wolverines captured in the eastern Talkeetna Mountains study area, 1992–1997

					Hunter/Trapper Take		Loss to	Current
Sex	N	Active Signal	Shed Collar	Lost Signal	Inside Area	Outside Area	Other Death	Status Unknown[a]
Females	9	1	1	1	3		2	1
Males	13	0	1	6	3	2		1
Total	22	1	2	7	6	2	2	2

[a] At the time this report was prepared, the radiotransmitters of these 2 animals were on mortality mode, indicating the wolverines either shed their collars or died.

Table 3 Kaplan-Meier survival estimates (modified for staggered entry of additional animals) for radiocollared wolverines in the Talkeetna Mountains, Alaska, April 1992–October 1997

Time Period	Dates	Nr At Risk	Nr Deaths	Nr Censored	Nr New Added	Survival	95% CI
0.5	Apr 1992–Sep 1992	4	0	1	0	1.00	1.00–1.00
1.0	Oct 1992–Mar 1993	3	2	0	3	0.33	0.03–0.64
1.5	Apr 1993–Sep 1993	4	0	1	1	0.33	0.07–0.60
2.0	Oct 1993–Mar 1994	4	1	0	5	0.25	0.04–0.46
2.5	Apr 1994–Sep 1994	8	0	1	0	0.25	0.10–0.40
3.0	Oct 1994–Mar 1995	7	1	3	2	0.21	0.07–0.35
3.5	Apr 1995–Sep 1995	5	0	1	0	0.21	0.05–0.38
4.0	Oct 1995–Mar 1996	4	0	0	4	0.21	0.03–0.40
4.5	Apr 1996–Sep 1996	8	0	2	0	0.21	0.08–0.35
5.0	Oct 1996–Mar 1997	6	1	2	4	0.18	0.05–0.31
5.5	Apr 1997–Sep 1997	7	2	3	0	0.13	0.04–0.22

JOB 3 — DISTRIBUTION, TREND, HABITAT USE, AND HARVEST POTENTIAL OF COASTAL RIVER OTTER POPULATIONS

BACKGROUND

Golden (1996) provided background for this project. Only Jobs 3.1–3.3 were active during this report period. We completed sampling latrine sites on the south side of Kachemak Bay to determine latrine-site use and scat deposition rates. We continued to monitor radiomarked otters and to collect scats for diet analysis. Job 3.4, river otter population model, will be addressed the next report period.

OBJECTIVES

3.1 To determine if latrine site use and fecal deposition rates are precise indicators of river otter abundance in coastal areas of Southcentral Alaska.

3.2 To determine which habitat features are most important in defining coastal river otter habitat.

3.3 To evaluate food habits of river otters relative to habitat types and geographic area.

3.4 To estimate sustainable harvest levels of river otter populations in coastal environments of Southcentral Alaska.

STUDY AREAS

The core study area in Kachemak Bay lies between Kasitsna Bay and Sadie Cove, with the center of activity in Tutka Bay. Habitat features in this part of Kachemak Bay are similar to those described by Bowyer et al. (1995) for western Prince William Sound. Although the latter has been commercially logged to a greater degree, several areas of Kachemak Bay have been developed for housing, which is generally within 100 m of the coastline.

We centered river otter investigations for Prince William Sound in Herring Bay at the north end of Knight Island and in Jackpot Bay on the mainland west of Chenega Island. See Bowyer et al. (1995) for a description of habitat features in the area.

METHODS

Job 3.1. Latrine Site Use and Fecal Deposition Rates by River Otters

We sampled up to 35 latrine sites in Kachemak Bay to assess the level of use of those sites by river otters and the rate at which they deposited scats. In summer 1995, we sampled latrine sites 3 times at approximately 3-week intervals (Golden 1996). We increased our sampling in 1996 to 4 3-week intervals and 5 3-day intervals between 1 June and 26 September. We sampled at 3-week intervals mainly to measure the distribution and rate of latrine site use, because we assumed this interval would allow adequate time for infrequently used sites to be visited by otters. We sampled at 3-day intervals mainly to measure daily scat deposition, because we assumed scats deposited during this short period would be less likely to be disturbed by rain or some other factor. On our initial survey each year, we removed all scats that had accumulated over winter without counting them. We removed scats from latrine sites during subsequent counts, except the last one of the summer. After the initial cleaning in 1995, we waited 3 weeks to count scats. In 1996 we waited 3 days after initial cleaning to count and remove all new scats deposited. We then followed a 3-week, 3-day sampling scheme throughout the summer.

We also collected scats from randomly selected latrine sites in Herring and Jackpot Bays in Prince William Sound between 7 May and 10 June 1997 in association with scat sampling to estimate river otter density through DNA microsatellite analysis (Groves and Ben-David 1997). We will analyze latrine site use and scat deposition rates by river otters in this area the next report period.

Job 3.2. Habitat Selection and Movements of River Otters

We monitored the movements of 4 radiomarked otters by boat and airplane (Golden 1996). Locations were recorded on 1:63,360-scale maps. During the next report period, we will digitize and enter locations into an ArcView database for analysis.

We assessed the habitat of each latrine site in Kachemak Bay by measuring several features that Bowyer et al. (1995) found significant in their river otter habitat model for Prince William Sound. We added estimates of canopy cover and the presence of burrow sites to the site assessments (Table 1). During the next report period, we will analyze habitat availability and use after we assess the habitat characteristics of randomly selected sites.

Job 3.3. Food Habits of River Otters Among Habitat Types

We summarized the frequency of occurrence and size of food items identified in 90 scats from 38 latrine sites in 1995. In 1996 we collected and saved all scats deposited during the 3-day latrine-site sampling periods during summer 1996. Only scats estimated to be less than 1 week old were saved from the 3-week sampling periods. We will clean and analyze these scats for diet composition during the next report period.

RESULTS AND DISCUSSION

Job 3.1. Latrine Site Use and Fecal Deposition Rates by River Otters

Scat deposition rates (i.e., scats deposited/day) among the 3-week samples in 1995 were higher during late July and mid August than the rates during comparable periods in 1996 (Table 2). Although there was no observed trend in the scat deposition rate over time in 1995, there was a highly significant decline ($R^2 = 0.99$; $F_{1,2} = 450$; $P = 0.002$) in scats/day between sampling periods in 1996. Scat deposition rates among 3-day samples in 1996 declined gradually over the summer but not significantly ($R = 0.69$; $F_{1,3} = 6.72$; $P = 0.08$) (Table 2).

We conducted exploratory data analysis of 1996 scat deposition rates among latrine sites and sampling periods through median polish (Emerson and Hoaglin 1983). Latrine-site effects (i.e., differences from the grand median attributed to variation among latrine sites) were greatest in estimates from sites 5, 14, and 19 for the 3-week samples (Fig. 1) and sites 5 and 18 for the 3-day samples (Fig. 2). Sampling-period effects (i.e., differences from the grand median attributed to variation among sampling periods) differed markedly between the 3-week and 3-day intervals. The 3-week estimates reflected the strong decline in the scat deposition rate for this interval (Table 2), but the 3-day estimates showed no variation from the grand median (Fig. 3). The cause of this difference in temporal effect between the 3-week and 3-day sampling periods is not clear. It is possible that environmental factors, such as increasing rainfall or higher amplitude tides throughout the summer may have affected the retention of scats over the 3-week intervals more than the 3-day intervals. Additional tests of scat deposition rates are required to interpret the difference.

Job 3.3. Food Habits of River Otters

In our preliminary analysis of river otter diet, we identified 38 unique food items among 90 river otter scats sampled in Kachemak Bay in 1995 (Table 3). The unique food items found included some species identified only to family and 1 group of unidentified fish. Saffron cod, flatfish, rock sole, gunnels, and sculpins composed nearly 40% of the items identified among 38 latrine sites. Thirty of the food items were bony fishes. The remaining 8 items were snails, mussels, barnacles, clams, crabs, polycaete worms, chitons, and sea urchins.

Bowyer et al. (1994) found bony fish was also the most abundant prey in river otter scats (n = 337) in Prince William Sound, but they reported a much higher percentage of invertebrates in the diet than we found in Kachemak Bay. They did not include species that occurred ≤5 times on latrine sites in the entire data set (n = 357), which left 65 common species identified in the diet. In Kachemak Bay, 19 of the 38 unique food items were found at least 6 times among 38 latrine sites. These preliminary data indicate a substantially lower diversity of food for river otters in Kachemak Bay than in Prince William Sound.

River otters in Kachemak Bay generally preyed on fish no larger than a small rockfish (i.e., <30 cm) (S. Crockford, Pacific Identifications, pers. commun.). Kruuk (1995) also reported this size preference for otters in Scotland. Most of the invertebrates found in the scats were too small to be considered likely prey and were probably ingested secondarily to other prey.

RECOMMENDATIONS

We recommend continuing the Kachemak Bay phase of this project for another year to analyze scat contents, movements, food habits, and habitat data. We will examine the possibility of estimating river otter density in Kachemak Bay with the DNA microsatellite technique using scats collected in 1996. We will focus further fieldwork on river otters in Prince William Sound in cooperation with 2 University of Alaska Fairbanks studies.

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David, S. Andersen, L. Faro sampled latrine sites in Prince William Sound. A. Trites and D. Porter of the UBC Marine Mammal Lab and S. Crockford of Pacific Identifications cleaned scats and identified food items, respectively. G. and S. Christen provided housing in Kachemak Bay. J. DeCreft conducted radiotelemetry flights in Kachemak Bay and Prince William Sound.

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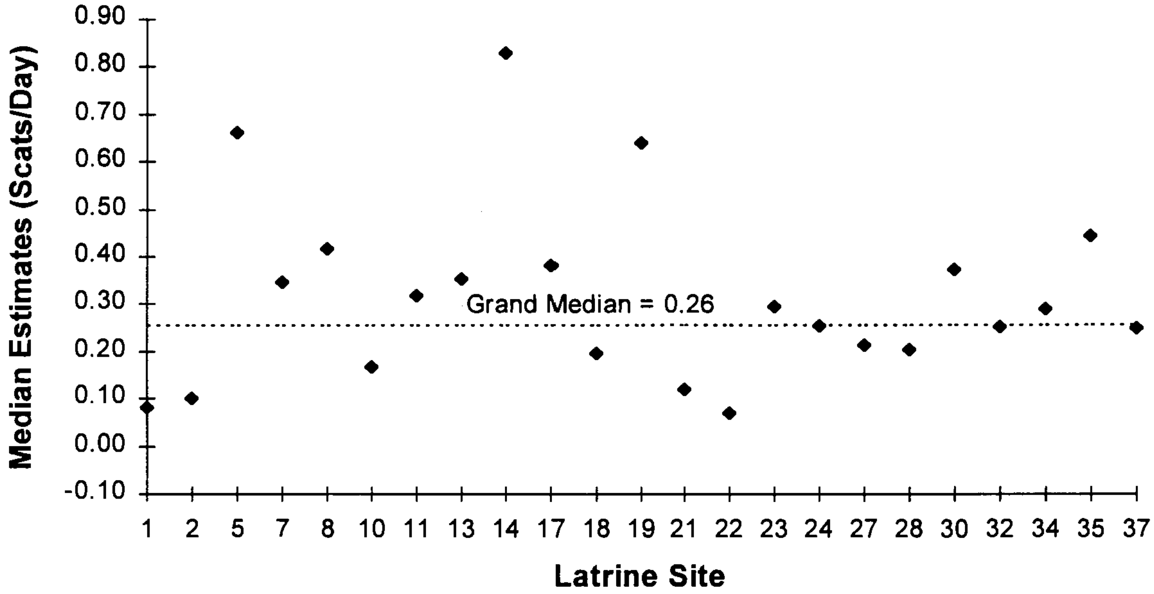

Figure 1 Latrine-site effect on median polish estimates (i.e., differences from the grand median attributed to variation among latrine sites) for river otter scat deposition rates among 23 select latrine sites sampled at 3-week intervals ($n = 4$) in Kachemak Bay, Alaska, summer 1996

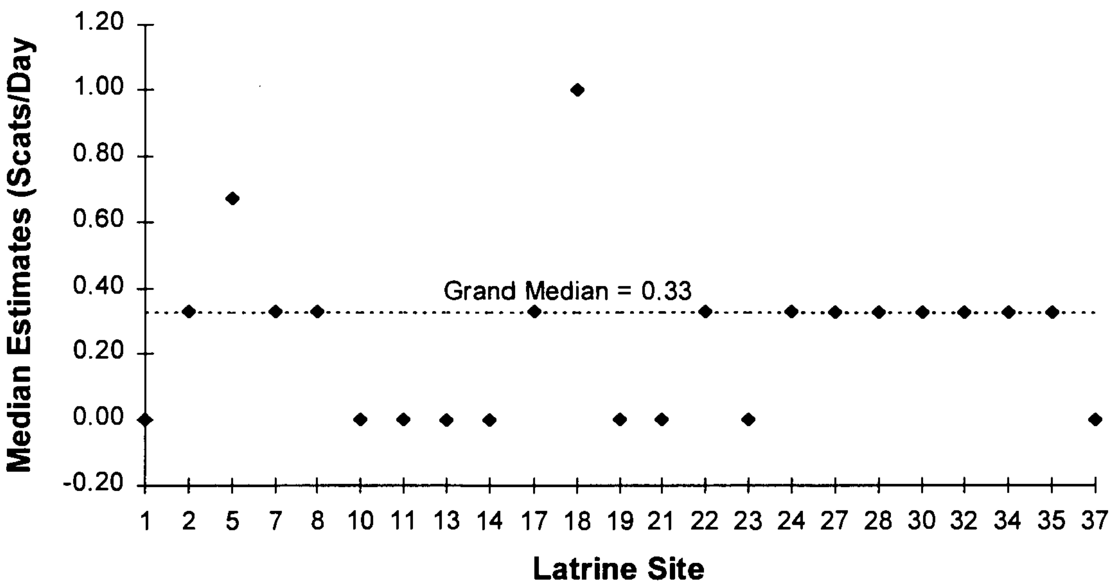

Figure 2 Latrine-site effect on median polish estimates (i.e., differences from the grand median attributed to variation among latrine sites) for river otter scat deposition rates among 23 select latrine sites sampled at 3-day intervals ($n = 5$) in Kachemak Bay, Alaska, summer 1996

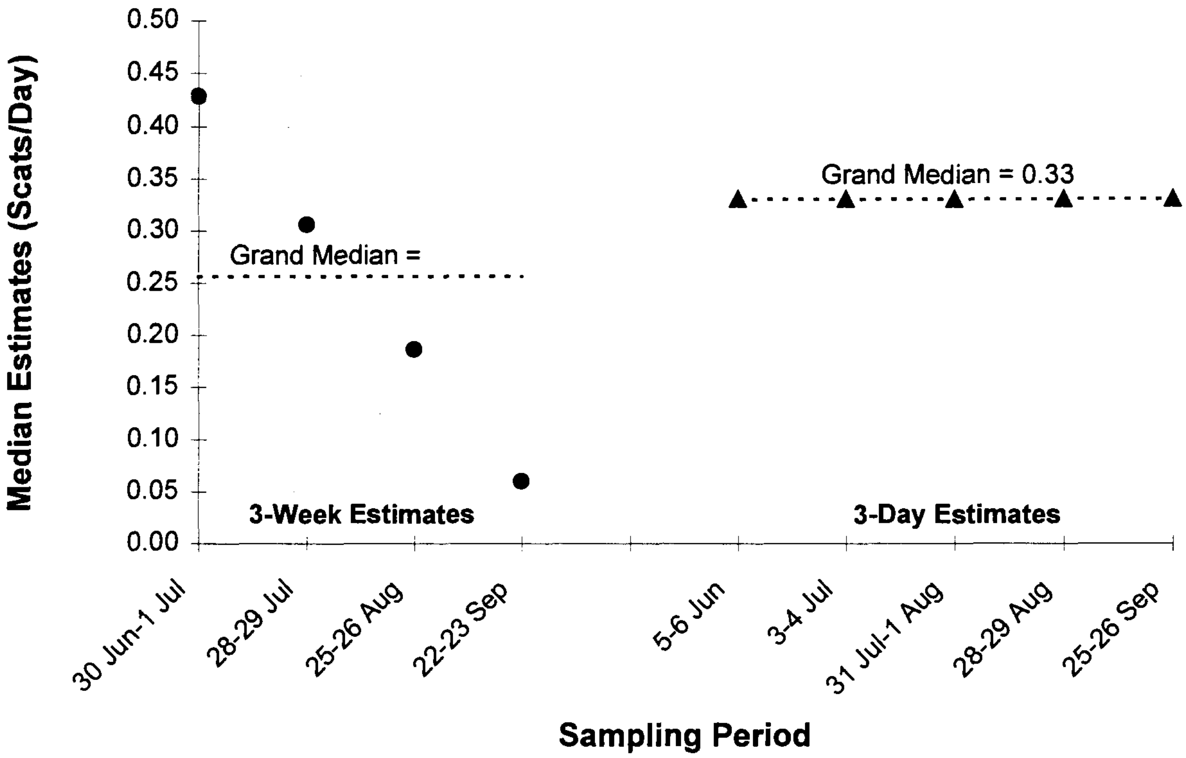

Figure 3 Sampling-period effect on median polish estimates (i.e., differences from the grand median attributed to variation among sampling periods) for river otter scat deposition rates among 23 select latrine sites sampled at 3-week (n = 4) and 3-day (n = 5) intervals in Kachemak Bay, Alaska, summer 1996

Table 1 Habitat characteristics assessed at river otter latrine sites and randomly selected sites along the coast in Kachemak Bay and Prince William Sound

Habitat Characteristic	Description	Assessment Level
Aspect	Dominant direction of the shoreline as established with a compass.	N, NE, E, SE, S, SW, W, NW
Exposure	Severity of wave action to which the site could be exposed.	Exposed, Moderate, Protected
Vegetated and Tidal Slopes	Vegetated slope is the portion of the site above mean high tide and tidal slope is the portion of the site below mean high tide.	Degree of slope measured to the nearest 5° interval
Intertidal Substrate	Sand (<0.5 cm diam.), gravel (0.5–10 cm diam.), small rocks (10–25 cm diam.), large rocks (25 cm–6 m diam.), bedrock (>6 m)	Five ranked categories to the nearest value: 0 = 0%, 1 = 25%, 3 = 75%, 4 = 100%
Vegetation — Canopy Cover	Proportion of overstory canopy cover provided by trees and understory canopy cover provided by shrubs	% Overstory, % Understory
Vegetation — Old-Growth	Proportion of old-growth trees (i.e., stems) composing the forest overstory	Five ranked categories to the nearest value: 0 = 0%, 1 = 25%, 3 = 75%, 4 = 100%
Burrow Sites	The number of potential burrow sites and evidence of past use	Five ranked categories: 0 = no sites; 1 = 1–3 sites, little or no use; 2 = 4+ sites, little or no use; 3 = 1–3 sites, signs of use; 4 = 4+ sites, signs of use

Table 2 Mean number of scats and mean number of scats/day deposited by river otters at select latrine sites (n = 23) during 3-week and 3-day intervals in Kachemak Bay, Alaska, 1995 and 1996

Sampling Dates	Mean Nr Scats	SD	Mean Nr Scats/Day	SD
3-Week Interval				
2–4 Jul 1995	9.52	7.65	0.55	0.44
24–25 Jul 1995	14.04	9.03	0.65	0.42
15–17 Aug 1995	8.91	9.28	0.40	0.42
30 Jun–1 Jul 1996	14.35	9.67	0.57	0.38
28–29 Jul 1996	9.96	8.24	0.40	0.32
25–26 Aug 1996	7.13	7.62	0.28	0.30
22–23 Sep 1996	2.78	3.57	0.11	0.14
3-Day Interval				
5–6 Jun 1996	1.43	2.19	0.49	0.73
3–4 Jul 1996	1.22	1.31	0.41	0.44
31 Jul–1 Aug 1996	0.96	1.36	0.34	0.50
28–29 Aug 1996	1.57	3.36	0.52	1.12
25–26 Sep 1996	0.96	1.64	0.33	0.56

Table 3 Frequency of occurrence of unique food items (n = 38) identified in river otter scats (n = 90) among latrine sites in Kachemak Bay, summer 1995

Food Items		Freq. of Occur. Among Latrine Sites	Percent Freq. of Occur.	Cumulative Percent Freq. of Occur.
Common Name	Species Name	n = 38		
Saffron Cod	Eleginus gracilis	27	8.8%	8.8%
Flatfish	Pleuronectiformes	23	7.5%	16.3%
Rock Sole	Lepidopsetta bilineata	23	7.5%	23.8%
Other Gunnels	Pholididae	23	7.5%	31.3%
Other Sculpins	Cottidae	22	7.2%	38.4%
Pollock	Theragra chalcogramma	19	6.2%	44.6%
Crescent Gunnel	Pholis laeta	15	4.9%	49.5%
Other Pricklebacks	Stichaeidae	13	4.2%	53.7%
Threespine Stickleback	Gasterosteus aculaeatus	12	3.9%	57.7%
Unidentified Fish	Pisces	12	3.9%	61.6%
Sand Lance	Ammodytes hexapterus	11	3.6%	65.1%
Other Greenlings	Hexagrammos spp	11	3.6%	68.7%
Salmon	Oncorhynchus spp	10	3.3%	72.0%
Starry Flounder	Platichthys stellatus	8	2.6%	74.6%
Gadids	Gadidae	8	2.6%	77.2%
Ronquill	Bathymasteridae	7	2.3%	79.5%
Snake Prickleback	Lumpenus sagitta	6	2.0%	81.4%
Snail	Unidentified	6	2.0%	83.4%
Mussel	Mytilus spp	6	2.0%	85.3%
Yellowfin Sole	Limanda aspera	5	1.6%	87.0%
Herring	Clupea harengus	5	1.6%	88.6%
Barnacle	Unidentified	5	1.6%	90.2%
Clam	Unidentified	5	1.6%	91.9%
Padded Sculpin	Artedius fenestralis	4	1.3%	93.2%
Rockfish	Sebastes spp	3	1.0%	94.1%
Irish Lord	Hemilepidotus spp	2	0.7%	94.8%
Staghorn Sculpin	Leptocottus armatus	2	0.7%	95.4%
Tomcod	Microgadus proximus	2	0.7%	96.1%
Pacific Cod	Gadus macrocephalus	2	0.7%	96.7%
Crab	Unidentified	2	0.7%	97.4%
Great Sculpin	Myoxocephalus polyacanthocephalus	1	0.3%	97.7%
Sand Fish	Trichodon trichodon	1	0.3%	98.0%
Whitespotted Greenling	Hexagrammos stellerіI	1	0.3%	98.4%
Smelt	Osmeridae	1	0.3%	98.7%
Eelpout	Zoarchidae	1	0.3%	99.0%
Polycaete Worm	Unidentified	1	0.3%	99.3%
Chiton	Unidentified	1	0.3%	99.7%
Sea Urchin	Unidentified	1	0.3%	100.0%

JOB 4 — APPLYING THE LYNX TRACKING HARVEST STRATEGY THROUGH RULE-BASED MODELING

Annual progress on this job is presented in the Appendix, *An Expert-System Model for Lynx Management in Alaska*, which was submitted for publication to the Mammal Trapping Symposium held in Edmonton, Alberta, 17–19 August 1997.

The objective for the next reporting period will be to distribute a runtime version, including documentation, of the model to potential users and to further refine the model based on their review.

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APPENDIX: JOB 4

AN EXPERT-SYSTEM MODEL FOR LYNX MANAGEMENT IN ALASKA

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Abstract: To provide more responsive management options during the 9–11-year lynx (*Lynx canadensis*) population cycle, Alaska adopted a tracking harvest strategy (THS) for lynx harvest management. This strategy applies to the road-connected areas of Southcentral and Interior Alaska. It modifies trapping season lengths as lynx and prey populations, mainly snowshoe hares (*Lepus americanus*), vary to ensure that sustainable harvest limits are not exceeded. This has become a more challenging task for individual wildlife biologists due to (1) greater urbanization, (2) increased access by trappers, (3) the growing antitrapping movement, and (4) the influence of federal subsistence regulations. A lack of reliable, quantitative population trend data continues. There is also the difficulty in deciding how to adjust trapping regulations with regard to pelt primeness, the potential for incidental catch and for orphaning kittens, and the possible changes in harvest pressure due to pelt prices. These conditions have placed area biologists in the position of relying on poor information and little guidance to make important management decisions. A clear decision-making protocol was needed that (1) was based on existing knowledge of lynx population trends, production, survival, sustainable harvest, and on new information and (2) standardized the decision-making process of the THS. To address this need, I developed an interactive model, called LynxTrak, that uses a rule-based expert-system approach to determine the most appropriate management action to take. This system employs rules that consist of if-then scenarios, culminating in a choice. I used the expert-system shell EXSYS Professional Editor Ver. 5.1.4-WIN16 (MultiLogic, Albuquerque, New Mexico) to build this model. LynxTrak uses a knowledge base that incorporates a wide network of quantitative and qualitative information regarding lynx across their range, including available literature, in-house databases, and the collective observations and experiences of field biologists and trappers. The model first calculates the potential of the lynx population in question from information provided by the user. Population potential is a function of lynx abundance, food availability, production, and survival. The estimated optimal yield of the population is based on its potential and estimated size and leads to the calculation of the target harvest index. Harvest pressure is a function of lynx harvest, trapping effort, and the amount of refugia. The reciprocal of the target harvest index divided by the harvest pressure results in a determination of the risk factor to the lynx population. The risk factor in conjunction with the current lynx season result in a new season recommendation as the final choice in the model. If managers reject the choice presented by the model, it is their responsibility to justify a different course of action. In this paper, I present the basis for the model's structure and mechanics along with a simulation of the model using data from a management area in Southcentral Alaska.

PROCEEDINGS OF THE MAMMAL TRAPPING SYMPOSIUM, Edmonton, Alberta, 17–19 August 1997, pp. 000–000

Background

Lynx (*Lynx canadensis*) populations in Alaska and much of Canada fluctuate greatly over a 9–11-year period, responding mainly to the abundance of snowshoe hares (*Lepus americanus*). Lynx population trends are closely correlated with those of snowshoe hares even when alternate prey is available (Nellis et al. 1972, Brand et al. 1976, Brand and Keith 1979). Lynx respond directly to changes in hare abundance, primarily through variation in recruitment of kittens (Nellis et al. 1972, Brand et al. 1976, Mowat et al. 1996*b*). This response by lynx follows the remarkably synchronous hare population cycles, which are more pronounced in northern latitudes (Akcakaya 1992). Managers of lynx harvest in these areas must be able to respond with appropriate harvest regulations to ensure sustainable harvest limits are not exceeded.

Caughley (1977:197) proposed the use of a tracking strategy as one method for managing the harvest of populations in a fluctuating environment. The tracking strategy provides for an increase in harvest while a population is growing and a reduction in harvest during a population decline. Brand and Keith (1979) supported this strategy for lynx. They suggested that trapping mortality was additive to natural mortality, based on their models of lynx populations in southern Alberta. Therefore, they recommended lynx harvest be curtailed for 3–4 years during the low phase of the cycle, starting with the second year after the peak in harvest, to ensure lynx recruitment would not be hindered once snowshoe hare populations increased (Brand and Keith 1979:846). Slough and Mowat (1996) and Poole (1994, 1997) reported high levels of natural mortality during the early years of snowshoe hare scarcity in Yukon and Northwest Territories, respectively. They concluded that harvest from trapping may at times compensate for natural mortality and, therefore, a tracking strategy need not severely restrict harvest during these periods.

In 1987 the Alaska Department of Fish and Game (ADF&G) and the Board of Game (BOG), which authorizes seasons and bag limits in Alaska, adopted a tracking harvest strategy (THS) to allow the dynamic management of lynx based on the ability of populations to support harvest. This was in response to concerns by lynx managers that high lynx-pelt prices would encourage excessive harvest during the declining phase of the lynx cycle. The strategy established 2 basic and 3 supplemental criteria for changing seasons in the road-connected areas of Interior and Southcentral Alaska that have high trapper use (Fig. 1). The 2 basic criteria are (1) percent kittens in the harvest and (2) evidence of increasing populations of both lynx and hares. The supplemental criteria are (1) period of pelt primeness, (2) potential negative effects of early seasons' orphaning kittens too young to survive, and (3) the possible effects of late seasons on higher harvests due to increased movement and greater vulnerability of lynx.

The THS was implemented in 1988 and resulted in season closures in some units when lynx populations seemed to be at low levels. The THS became difficult to use in subsequent years because of the need to issue emergency orders to change seasons outside the usual regulatory schedule established by the BOG. This problem was resolved in 1992 when the BOG authorized ADF&G to change season lengths within the broad seasons of 1 November–28 February in Interior game management units and 10 November–28 February in Southcentral units. ADF&G is not authorized to modify bag limits under this plan because that is a BOG allocation prerogative. There is a no-limit bag for lynx trapping throughout most of the state.

Another problem arose with implementation of the THS: the criteria did not provide sufficient or standardized guidelines for managers to make their decisions. Lynx management in Alaska has depended primarily on the abilities of individual area biologists to assess lynx population levels, to determine where lynx and hares are in their 9–11-year cycle, and select the most appropriate harvest regulations. These tasks have become more challenging due to (1) greater urbanization and its encroachment on lynx habitat, (2) increased access by trappers, (3) the growing antitrapping movement, and (4) the influence of federal subsistence regulations. It has also been difficult to adjust regulations with regard to pelt primeness, the potential for incidental catch and for orphaning kittens, and the possible changes in harvest pressure due to pelt prices. A lack of reliable, quantitative population trend data continues. These conditions had placed biologists in the position of relying on poor information and little guidance to make important management decisions. A decision-making protocol was needed, one based on existing knowledge of lynx population trends, production, survival, sustainable harvest, and new information.

To aid lynx managers achieve sustainable harvest objectives under the THS, I developed a rule-based model as a decision-making tool. The advantage of the rule-based model is that it provides a documented, logical structure to the decision-making process that is both intuitive and experiential (Ignizio 1991). Such models can process quantitative data but are most useful when coping with qualitative information to reach decisions (Starfield 1990). Rule-based models build on what is known using available literature, in-house databases, and the collective knowledge of experts (Starfield and Bleloch 1991). These types of models have become known as knowledge-based systems or expert systems (Ignizio 1991). Expert systems are now widely used to address many situations in natural resource management (Rykiel 1989, Starfield and Bleloch 1991, Starfield 1997), such as management of rangelands (Ritchie 1989) and lake systems (Starfield et al. 1989), prescribed burning (Reinhardt et al. 1989), and population modeling (Starfield 1990).

Expert systems are used with a computer program shell to incorporate the user's experience and available information into a decision tree, which is the foundation of the rule-based model (Ignizio 1991). Designers of a model first establish all potential decisions or choices that could reasonably be made regarding a particular situation. Next, questions using qualitative variables are formulated about the specific conditions or situations that may exist. Finally, a set of rules is devised as if-then scenarios that direct the user toward an informed, logical, and consistent decision. This modeling approach can provide the user with a protocol that, because it is fully documented, ensures accountability.

MODEL DEVELOPMENT

I used the expert-system shell EXSYS Professional Editor, Version 5.1.1-NT for Windows 95 (MultiLogic, Inc., Albuquerque, New Mexico). I selected this shell because of its versatility, ease of use, and full documentation potential. In addition, this shell is able to test all possible rules in the model through backward chaining (EXSYS 1992). This process ensures the most appropriate solution is derived because information is gathered from each applicable rule regardless of its order in the model. The model can be extended easily because new rules may be added at any time.

I built a 50-rule prototype to determine if a full-working model were feasible and useful. I used input from research and management staff at ADF&G during a review of the prototype to address the most important parameters involved in the lynx-hare cycle, harvest scenarios, and management options. After verifying the utility of the model with potential users, I incorporated material for the knowledge base of the model from pertinent literature, lynx researchers, managers, and trappers in Alaska and Canada, and from Alaskan lynx harvest data gathered through pelt sealing. I modified the model several times during development to include recent research findings and to reflect the input from managers after it had been used to help adjust trapping seasons. The current working version of the model, LynxTrak (ver. 1.0), contains 295 rules that use 30 qualifiers, 72 variables, and 13 choices. A runtime version of the model and documentation are available from the author. This version contains all necessary program software to run the model but will not allow editing.

To verify that the model was working properly and all rules were valid, I ran it through a validation subroutine that was part of the program shell. The subroutine checked the combinations of input to determine if the model:

(1) produced no conclusions

(2) failed to derive needed qualifiers or variables

(3) created loop errors

(4) assigned a value to a variable that was outside the limit for that variable

(5) assigned more values to a qualifier than the maximum number allowed for that qualifier (EXSYS 1992).

I conducted validation tests for each of the 7 current-season values: closed, 1 month, 1.5 months, 2 months, 2.5 months, 3 months, and the THS maximum. During testing I held these values constant along with those of other variables (e.g., the amount of lynx habitat available) with preassigned values. The validation procedure then randomly selected the values of the other qualifiers and variables to solve for a particular choice (e.g., new lynx season = 2 months). The program shell made a separate run after each set of values was selected. The output of the runs were tree diagrams that would display where an error in logic occurred and which rules were responsible for the error. A few errors were detected during several validation runs and all were corrected. To confirm the model was error-free, I subsequently ran 100 tests for each of the 7 current-season values. I found no errors among the rules during these 700 random tests. I chose not to validate the model using systematic tests because this procedure would have required testing all of the thousands of possible combinations of values.

In addition to the validation tests, I tested the sensitivity of the model to changes in values for each variable on the derivation of the final variable, *risk factor*. Values for 22 variables were initially set at moderate levels then each one was changed one-at-a-time while holding the values of the other variables constant. The influence of each variable was determined by the amount each of its values affected the *risk factor*.

MODEL STRUCTURE AND FUNCTION

The model incorporates qualitative and quantitative information the user provides through responses to questions posed by the qualifiers and a few variables. Those responses, which are mainly qualitative values (e.g., low, moderate, high), are converted to numerical values of variables that become the knowledge base of the model. The knowledge-base variables are then used in combination to calculate other numerical variables or nonnumerical string variables (which are qualitative and not needed for further calculations) and, finally, the choice of new trapping regulations. I kept the magnitude of the values low (typically 1, 2, or 3) to simplify calculations, but I weighted certain variables, such as *lynx abundance* and *hare abundance*, more heavily due to their relative importance. When the values of 2 or more variables were combined, I rescaled the result to a lower range of values.

I constructed LynxTrak around 4 modules: (1) population potential, (2) target harvest index, (3) harvest pressure, and (4) risk factor (Fig. 2). The model calculates the potential of the lynx population to increase, which is a function of lynx abundance, food availability, production, and survival. The estimated optimal yield of the population is based on its potential to increase and its estimated size, leading to the calculation of the target harvest index. Harvest pressure is a function of lynx harvest, trapping effort, and the amount of refugia. The relationship of the target harvest index to harvest pressure results in a determination of the risk factor to the lynx population. The risk factor and the current lynx season result in a new season recommendation as the final choice in the model. This process is presented in greater detail in the flow diagram in Appendix A. The qualifiers and variables used as parameters in LynxTrak are defined in Table 1.

As background information, the model first asks the user to identify the area of concern (e.g., game management unit) to establish whether or not it is within the tracking harvest strategy area. LynxTrak then asks for the current trapping season, which ranges in one-half-month steps from closed to the maximum allowable season under the THS. However, no open season is less than 1 month because of the impracticality of shorter seasons. If the season is closed, several variables will be given preset values (Appendix A) that will be stored in the knowledge base. If the season is open, the model will proceed to the population-potential module beginning with *lynx abundance*.

Population Potential

This module is composed of 4 components: (1) lynx abundance, (2) food availability, (3) production, and (4) survival (Appendix A).

Lynx Abundance

This component begins with questions about the regularity and timing of the lynx cycle. Depending upon how much is known about the cycle, a value will be assigned to the variable *lynx trend*. It is assumed that a decline in trend during the early years after the harvest peak is followed by an increasing trend several years after the peak. The trend value will be positive if the trend is increasing, negative if it is decreasing, and 0 if it is stable. The model then asks about the relative abundance of lynx tracks to derive the variable *lynx track count*. The assumptions are that some method for counting tracks is being used and that the counts relate to actual changes in animal abundance (Golden 1994). The final question in this component concerns observations by trappers about lynx abundance levels to derive the variable *lynx quest*. These observations are usually obtained through ADF&G's annual trapper questionnaire, which is sent to a large number of trappers each year, or from inquiries by local biologists. Trappers are asked if they believe lynx were scarce, common, or abundant in their trapping area during the most recent season compared with the previous season. The subsequent numerical values assigned to knowledge-base variables *lynx trend*, *lynx track count*, and *lynx quest* are summed to derive *lynx abundance parameters*, which is then converted to its relative value as the final output *lynx abundance*. I set the scale of *lynx abundance* at a range of 2–10 rather than 1–5 because of the importance of this parameter to the model.

Food Availability

The input and knowledge-base parameters comprising *lynx abundance* are equivalent for *hare abundance*. Measurements of the relative abundance can be made through pellet counts (Krebs et al. 1986, Slough and Mowat 1996) or track counts (Poole 1994, Golden 1994). Additional questions are asked in this component about the abundance of alternate prey for lynx and the abundance of other predators, such as coyotes, that may compete with lynx for food. These factors may be significant particularly when hare populations are low (Nellis et al. 1972, Keith 1974, Brand et al. 1976, Keith et al. 1977). The numerical values for *hare abundance* and *alternate prey* added together minus *competition* will derive *food availability parameters*, which is then converted to *food availability*. While the range of values for *hare abundance* was set at 2–10 as with *lynx abundance*, I assigned values of 1–5 for *food availability* because both variables interact separately with other variables further along in the model, and a higher range of values for *food availability* would have given it too much influence.

Reproductive Potential

This module considers the ability of the lynx population to produce kittens. An estimate of the reproductive potential is possible after it has been determined carcasses were collected during the previous trapping season and female reproductive tracts were analyzed for the presence of placental scars. If ages of the lynx are known from tooth annuli (Crowe 1972), then *pregnant adult* and *pregnant yearling* values can be added to the knowledge base. If age is not known, except for the classifications adult and kitten, then the value *pregnant female* can be determined. Placental scar counts using the criteria reported by Mowat et al. (1996*a*) will provide a value for *placental scars*. Value ranges for pregnancy rates and placental scar counts of lynx were estimated from literature sources (Brand et al. 1976, Brand and Keith 1979, O'Connor 1984, Quinn and Thompson 1987, Mowat et al. 1996*a*, Slough and Mowat 1996) (Table 1). The sum of variables *pregnant adult* and *pregnant yearling* with *placental scars* or *pregnant female* with *placental scars* will derive *reproductive potential.* If carcasses were not collected or if there were no females among the carcasses, *reproductive potential* would be assigned a value of zero and the model would advance to the component *production.*

Production

This component calculates *production* from *reproductive potential* and the percentage of kittens in the harvest. Percent kittens may be estimated from their proportion among carcasses or from pelts (Quinn and Gardner 1984, Stephenson and Karczmarczyk 1989, Slough 1996). The sum of *reproductive potential* and *kittens* results in *production parameters*, which converts to the final output *production* with values of 1–5. If *reproductive potential* equals zero, *production* is equivalent to *kittens*. If *reproductive potential* and *kittens* are both zero, or if the trapping season is closed, *production* is given the value *hare abundance* divided by 2.

Survival

Because lynx survival is closely tied to the abundance of snowshoe hares (Nellis et al. 1972, Brand et al. 1976, Brand and Keith 1979, Poole 1994, Mowat et al. 1996*b*, Slough and Mowat 1996), I linked the variables *kitten survival* and *adult survival* with the knowledge-base variables *hare abundance* and *food availability*, respectively. Although this provides only a rough index of survival, it is based on the assumption that lynx survival is correlated with the dynamics of hare abundance. The sum of *kitten survival* and *adult survival* derives *survival parameters*, which converts to the final output *survival* with values of 1–5.

The module for *population potential* is completed by summing *survival* with the knowledge-base variables *lynx abundance*, *food availability*, and *production.* The output variable, *population potential parameters*, is derived from this summation, and it converts to the final output variable, *population potential*, which is a nonnumeric string variable. The 7 possible values for *population potential* range from very low to very high.

Target Harvest

This module is composed of 3 components: (1) estimated density, (2) population estimate, and (3) estimated optimal yield (Appendix A). An example of the relationships of these variables is shown for Game Management Unit 13 in Appendix B.

Estimated Density

An estimate of lynx density (nr/100 km^2) for an area is derived from the maximum density possible for a population, modified by *population potential*, the quality of the habitat, and the amount of refugia from trapping (Appendix B). *Population potential*, with 7 possible values of very low–very high, and the general quality of the existing lynx habitat, designated poor, fair, or good, determine the ranges of *maximum density* values possible. The *maximum density* range is 0.5–10 lynx/100 km^2 for poor habitat, 1–17.5 lynx/100 km^2 for fair habitat, and 2–25 lynx/100 km^2 for good habitat. These values were approximated for habitat in the THS area of Alaska, based on densities of 3.1–10 lynx/100 km^2 in southern Alberta (Brand et al. 1976), 1–20+ lynx/100 km^2 on the Kenai Peninsula, Alaska (Bailey et al. 1986), 1.2–3.9 lynx/100 km^2 in Interior Alaska south of Fairbanks (Stephenson and Karczmarczyk 1989), 2.2–30 lynx/100 km^2 in Northwest Territories (Poole 1994), 4.8–6 lynx/100 km^2 in eastern Interior Alaska (Perham 1995), and 2.7–44.9 lynx/100 km^2 in Yukon Territory (Slough and Mowat 1996). Refugia from trapping may be essential to maintaining healthy lynx populations, particularly during the low phase of their cycle and during recovery (Slough and Mowat 1996, Poole 1997). Slough and Mowat (1996) estimated the minimum effective size for a refugium in high-quality habitat in Yukon Territory is 500 km^2 during years when lynx home ranges are stable. The percentage of lynx habitat as refugia in an area is converted to a *refugia index* (e.g., ≤20% and >80% refugia convert to indices of 1 and 5, respectively). The *refugia index* is then converted to a new value, ranging from 0.6 to 1.0, which is multiplied by *maximum density,* corrected for *population potential* and *habitat quality*, to derive the *estimated density* of the population (Appendix B).

Population Estimate

The amount of *lynx habitat* multiplied by the *estimated density* derives the *population estimate* (Appendix B). *Low* and *high population estimates* are calculated by multiplying the *estimated density* by 0.8 and 1.2, respectively.

Estimated Optimal Yield

To determine the *estimated optimal yield, production* is multiplied by *survival* to derive an estimated population *surplus* (Appendix B). There are 7 values of *surplus* ranging from 1% to 20%. The value of 20% was chosen as the maximum level of harvest, following the recommendation by Knick (1990:36) that bobcat harvest rates not exceed 20% of the fall population. *Surplus* multiplied by the *population estimate* derives *estimated optimal yield. Low* and *high estimated optimal yields* are calculated by multiplying *estimated optimal yield* by 0.8 and 1.2, respectively.

The final output in this module is *target harvest index. Estimated optimal yield* is divided by the *high harvest* recorded for the area, which is used as a measure of the highest *estimated optimal yield.* The result multiplied by 100 derives the *target harvest parameters*, which is converted to the *target harvest index* with values of 1–7.

Harvest Pressure

This module is composed of 2 components: (1) lynx harvest and (2) trapping (Appendix A).

Lynx Harvest

This component begins by comparing the most recent lynx harvest with the historic high harvest. The current *season harvest* is divided by the *high harvest* and multiplied by 100 to derive the *harvest parameters*, which is converted to the *harvest index*. The next step is to assess harvest density by dividing *season harvest* by *lynx habitat* to derive the *harvest density index parameters*, which is converted to the *harvest density index*. The level of overharvest, or *overtarget index*, is determined from the relationship between *season harvest* and the *last target* for harvest that was established. This component is completed by summing *harvest index*, *harvest density index*, and *overtarget index* to derive the *lynx harvest parameters*, which converts to *lynx harvest* with values of 2–10 because of its relative importance.

Trapping

This component assesses trapping activity and effort within the area. The relative number of *trappers* multiplied by the *season length* in days derives *trapper day parameters*, which converts to an index of *trapper days*. *Trapper days* is then added to *trapper catch* (or catch per trapper), *trapper type* (long-term or recreational), *pelt price* (season average), *incidental take* (potential take through other trapping), and *trapping access* (opportunity based on trail and weather conditions). The sum of these variables derives *trapping parameters*, which converts to the final output variable *trapping* with values of 1–7.

Harvest pressure parameters is derived from *lynx harvest* plus *trapping* minus *refugia index*. It is converted to *harvest pressure* with values of 1–7.

Risk Factor

This is the last module in the model. Its function is to determine the extent, if any, the preferred level of harvest will be exceeded. The level of risk possible relates directly to the growth potential of the lynx population.

Target harvest index is divided by *harvest pressure*, and the reciprocal derives *risk factor parameters*. This numerical variable is converted to the string-variable *risk factor*. There are 7 *risk factor* values ranging from very low to very high.

Choices: New Trapping Regulations

LynxTrak recommends new trapping regulations based on a matrix of possible choices (Table 2). The level of risk is matched with the current trapping season. The resulting choice may recommend modifying the current season or maintaining it; there may commonly be more than 1 option given in a choice. The preference for those options is shown as confidence values ranging from 0 to 10. After a run is completed, the input variables may be changed and the model can be run again. It is advisable for managers to conduct several runs of the model while varying the input slightly to increase their own confidence in the results, particularly if their confidence in the input is not high.

Sensitivity Analysis

During the sensitivity analysis when all values were held at moderate levels, the final variable, *risk factor*, was moderately high (Appendix C). This confirmed that LynxTrak was slightly conservative, an attribute built into its design. Changing the individual values relating to snowshoe hare abundance resulted in the widest range in *risk factor* levels. This was expected because *hare abundance* is directly related to the calculation of *survival* in the model. *Lynx trend*, *lynx count*, *reproductive potential*, *habitat quality*, and *refugia* also had values that had more influence on *risk factor* than other variables because of their relative importance in the model. Other than those few exceptions, the model was designed to minimize the influence of any particular variable and to allow the combination of variables to direct the model's outcome.

Simulation

LynxTrak has been applied to Southcentral game management units on 3 occasions to assist with annual adjustments to trapping seasons. The practical application of the model aided the decision-making process while contributing to model development. This simulation illustrates how the model works using input pertinent to Game Management Unit 13, which is a large area in the northeastern portion of Southcentral Alaska and is part of the THS area. It is surrounded by large mountains and contains approximately 13,425 km^2 of lynx habitat mostly in the lower elevations. The area receives high levels of use by hunters and trappers because of its proximity to Anchorage. However, the level of trapping has been sporadic and is highest near the few roads in the unit. This trapping pattern has often resulted in a large amount of refugia for lynx. The results of the simulation, showing input and output, is presented in Appendix D.

The output began with recommended choices and confidence levels for the new trapping seasons and associated confidence levels. The preferred recommendation was to increase the season to 3 months from the current season of 2 months. The next option was to increase to 2.5 months, and the least preferred option was to maintain the current season. The rationale for recommending a 1-month increase was that the *target harvest index* was at a very high level (7 of 7) and the *harvest pressure* was at a moderate level (4 of 7), which led to a low *risk factor*. The *target harvest index* was high because the input to the model indicated *lynx abundance* and *hare abundance* were near their peak levels and *production* was high. These parameters led to a *population potential* that was very high. Although *lynx harvest* was relatively high (8 of 10), *trapping* was moderately low (3 of 7), which led to moderate *harvest pressure* overall.

The manager should follow the recommended choice of extending the trapping season to 3 months unless there is a compelling reason to do otherwise. As mentioned in the opening text of the model (Appendix D), if such a reason exists, it is up to the manager to justify deviating from the expert system's recommendation.

Conclusions and Management Implications

LynxTrak seems to give reasonable results based on its practical application. It addresses most of the criteria of the tracking harvest strategy but does not account for the effects of pelt primeness or season timing on trapper effectiveness. It also does not consider the potential for orphaning kittens, which is greater during early winter because of the take of adult females with dependent young (Slough and Mowat 1996). Managers must still consider these parameters aside from the model. Subsequent versions of LynxTrak may include them if they can be practically incorporated.

The parameters used in the model reflect the type and quality of information available to managers. Because there is often a lack of empirical data in furbearer management, the model was designed to allow managers to evaluate many parameters on a qualitative scale that can be converted to a quantitative scale. Other parameters are strictly quantitative measures. The preferred approach is for the manager to gather quantitative information on a parameter first and then convert it to a qualitative value for its use in the model. The ability of the model to incorporate both qualitative and quantitative information gives managers the opportunity to use the model even when only minimal data are available. To get the best results from the model and to feel confident in those results, the lynx-harvest manager should strive to gather data on (1) the amount of lynx habitat and refugia available in an area, (2) lynx and hare population trends through field surveys, (3) reproductive activity from lynx carcasses, and (4) activities and success of trappers in an area.

Two of the most important features of an expert system are the critical review and rigor required to build it and its dynamic ability to incorporate change. The parameters used in the model were indicators and, as such, may be modified. Each qualifier and variable in LynxTrak was evaluated in terms of its usefulness in helping assess current population status and harvest to reach the appropriate choice of a new lynx season. Many qualifiers and variables were rejected during model development because they were not considered essential criteria. Others were added to the model after it had been used to help set new seasons. New rules can easily be added to the model and they should continue to be evaluated. It is advisable to limit detail to the essential elements because the possibility of making the model too complex is as great a risk as omitting important variables (Starfield et al. 1989). LynxTrak will remain a work in progress, changing as new data and new management challenges arise.

LynxTrak was designed to work as a decision support system for the tracking harvest strategy in Alaska. It is a practical tool that should be used in concert with empirical population models such as those discussed for lynx by Stephenson and Karczmarczyk (1989) and for bobcats by Knick (1990). Such quantitative models can measure the relationships of vital population statistics and estimate population growth potential and sustainable yield (Eberhardt and Siniff 1977). However, Dixon and Swift (1981:1549) pointed out the difficulty that strictly quantitative models have in accounting for social and economic variables, which strongly influence management decisions. Rule-based models incorporate these variables effectively because they allow the manager, through an expert system, to use available quantitative and qualitative knowledge and to cope with a lack of information (Starfield 1990:601). The efficacy of LynxTrak must be tested in its application over time, but it should result in more appropriate and accountable decisions by lynx harvest managers in Alaska.

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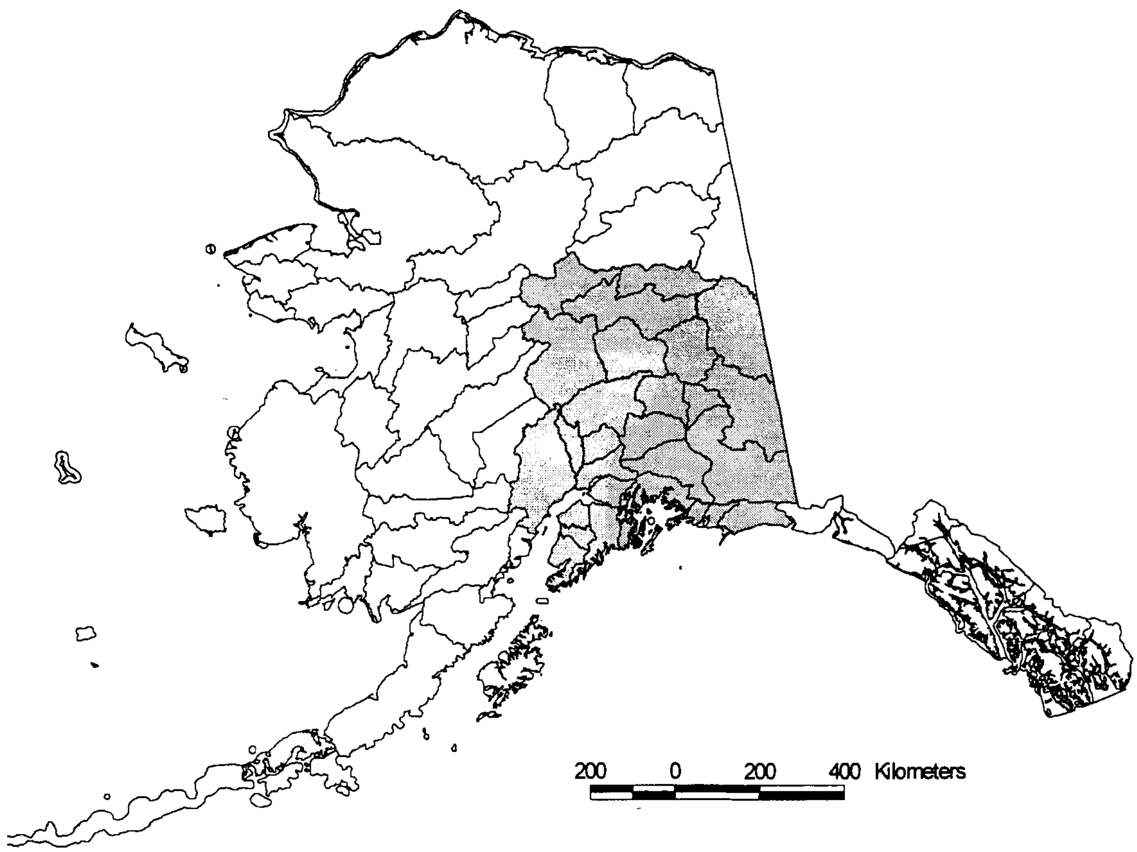


Figure 1 Tracking harvest strategy area (shaded) and game management units (lines) in Alaska.

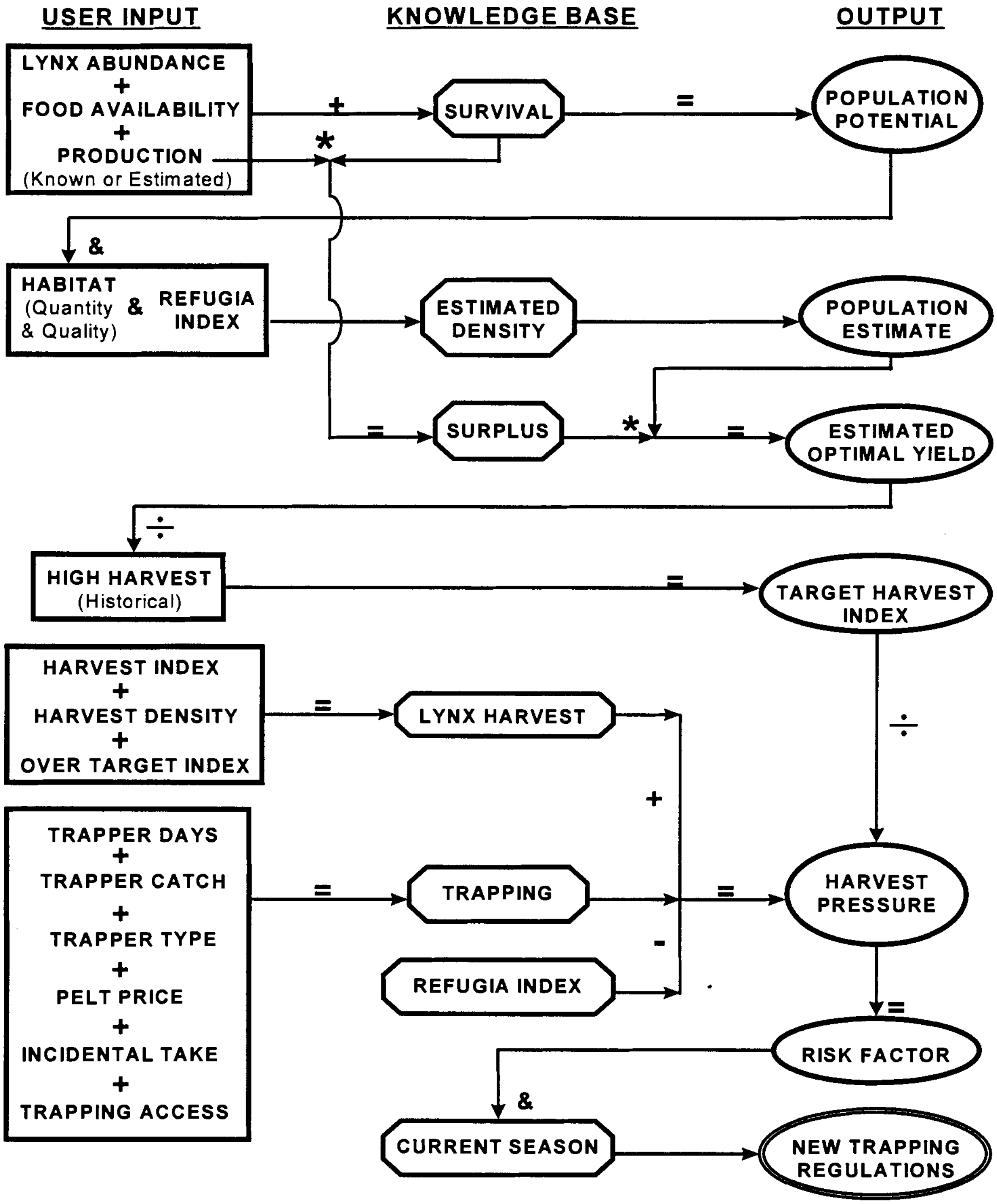


Figure 2 Summary flow diagram of LynxTrak depicted as user input, knowledge base, and output. The user input (rectangles) is the response given to qualifiers (or occasionally variables) which LynxTrak asks as questions. The responses are then used to calculate numerical variables that become the knowledge base (octagons). The output (ovals) consists of the knowledge-base variables used in combination to calculate other numerical variables and, finally, the choice of new trapping regulations.

Table 1 Descriptions and the ranges of values (lowest to highest) of the parameters used in LynxTrak. The parameters are qualitative and quantitative factors represented by qualifiers (q), numeric variables (v), and nonnumeric string variables (sv).

Parameter	Description	Range of Values
Area (q)	Area of concern	Units present in THS area
Season (q)	Current lynx trapping season	Closed–THS maximum
Lynx Cycle (q)	Lynx population cycle	Regular or Irregular
Lynx Peak (q)	Last lynx population peak	1–10+ yr, Unknown
Lynx Change (q)	Recent lynx population trend	Decreasing, Stable, Increasing
Track Count (q)	Lynx track counts	Low–High
Lynx Trapper (q)	Trapper observations on lynx	Scarce–abundant
Hare Cycle (q)	Hare population cycles	Regular or Irregular
Hare Peak (q)	Last hare population peak	1–10+ yr, Unknown
Hare Change (q)	Recent hare population trend	Decrease–Increase
Hare Count (q)	Hare track or pellet counts	Low–High
Hare Trapper (q)	Trapper observations on hares	Scarce–abundant
Prey Abund (q)	Abundance of other prey for lynx	Low–High
Competition (q)	Abundance of competing predators	Low–High
Carcass (q)	Lynx carcasses collected	Yes or No
Carc Fem (q)	Collection of female carcasses	Yes or No
Lynx Age (q)	Ages of carcasses	Known or Unknown
Preg Adt (q)	Percentage of pregnant adults	≤50% – >75%, Unknown
Preg Yrlg (q)	Percentage of pregnant yearlings	≤33% – >66%, Unknown
Preg Fem (q)	Percentage of pregnant females	≤40% – ≥70%
Mean RPS (q)	Mean number of recent placental scars	≤2.5 – >4.0
% Kittens (q)	Percentage of kittens in harvest	≤10% – ≥25%, Unknown
Hab Qual (q)	General quality of lynx habitat	Poor, Fair, Good
Refugia (q)	Percent of lynx habitat untrapped	≤20% – >80%
Trappers (q)	Relative number of lynx trappers	Low–High
Catch/Trapper (q)	Relative number lynx caught per trapper	Low–High
Trapper Type (q)	Typical (>60%) trapper	Long-Term or Recreational
Pelt Price (q)	Average lynx pelt price	≤$50 – >$300
Incidental Take (q)	Potential for incidental lynx take	Low–High
Trap Access (q)	Access to trapping areas	Poor, Fair, Good
Lynx Trend (v)	Trend in lynx relative abundance	-2–3
Lynx Count (v)	Lynx track counts	1–5

Table 1 Continued

Parameter	Description	Range of Values
Lynx Quest (v)	Trapper observations on lynx	1–3
Lynx Abundance (v)	Relative level of lynx abundance	2–10
Hare Trend (v)	Trend in hare relative abundance	-2–3
Hare Count (v)	Hare track or pellet counts	1–5
Hare Quest (v)	Trapper observations on hares	1–3
Hare Abundance (v)	Relative level of hare abundance	2–10
Alternate Prey (v)	Abundance of other prey for lynx	1–3
Competition (v)	Abundance of competing predators	0–2
Food Avail. (v)	Overall availability of food	1–5
Pregnant Adult (v)	Percentage of pregnant adults	0–3
Preg. Yearling (v)	Percentage of pregnant yearlings	0–3
Preg. Females (v)	Percentage of pregnant females	2–6
Placental Scars (v)	Relative number recent placental scars	1–3
Kittens (v)	Percentage of kittens in harvest	0–5
Production (v)	Expected level of lynx production	1–5
Kitten Survival (v)	Potential for kitten survival	1–5
Adult Survival (v)	Potential for adult survival	1–5
Survival (v)	Potential for survival of all lynx	1–5
Potential (sv)	Expected growth potential	Very Low–Very High
Maximum Density (v)	Maximum population density expected	0.5–25
Refugia Index (v)	Relative amount of untrapped habitat	1–5
Est. Density (v)	Expected number of lynx/100 km^2	Calculated
Habitat (v)	Amount of lynx habitat (km^2)	User Provides
Population Est. (v)	Number of lynx expected in the area	Calculated
Surplus (v)	Expected % lynx available to take	0.01–0.20
Est. Opt. Yield (v)	Optimal number of lynx available to take	Calculated
High Harvest (v)	Highest harvest for the area	User Provides
Target Harvest (v)	Relative level of harvest desired	1–7
Season Harvest (v)	Lynx harvest for most recent season	User Provides
Harvest Index (v)	Relative level of lynx harvest	1–5
Harvest Density (v)	Relative harvest/100 km^2	1–7
Last Target (v)	Preferred level of last harvest	User Provides
Overtarget (v)	Relative level of overharvest	1–5
Lynx Harvest (v)	Relative lynx harvest in the area	2–10
Trappers (v)	Relative number of lynx trapper	1–3

Table 1 Continued

Parameter	Description	Range of Values
Season Length (v)	Number of days in the current season	0–120
Trapper Days (v)	Relative number of trapper days	1–3
Trapper Catch (v)	Relative number of lynx caught/trapper	1–3
Trapper Type (v)	Index of trapper type in area	1–3
Pelt Price (v)	Index of average pelt price	1–5
Incidental Take (v)	Index of potential incidental take	1–3
Trapping Access (v)	Index of access quality	1–3
Trapping (v)	Index of overall trapping effort	1–7
Harvest Pressure (v)	Relative level of harvest pressure	1–7
Risk Factor (sv)	Relative risk of exceeding target	Very Low–Very High

Table 2 New season choices (measured in months) based on risk factor levels versus the current season for a given area. Arrows indicate an increase (↑) or a decrease (↓) to the current season. Values in parentheses indicate degree of confidence in the choice (0 = none, 10 = absolute).

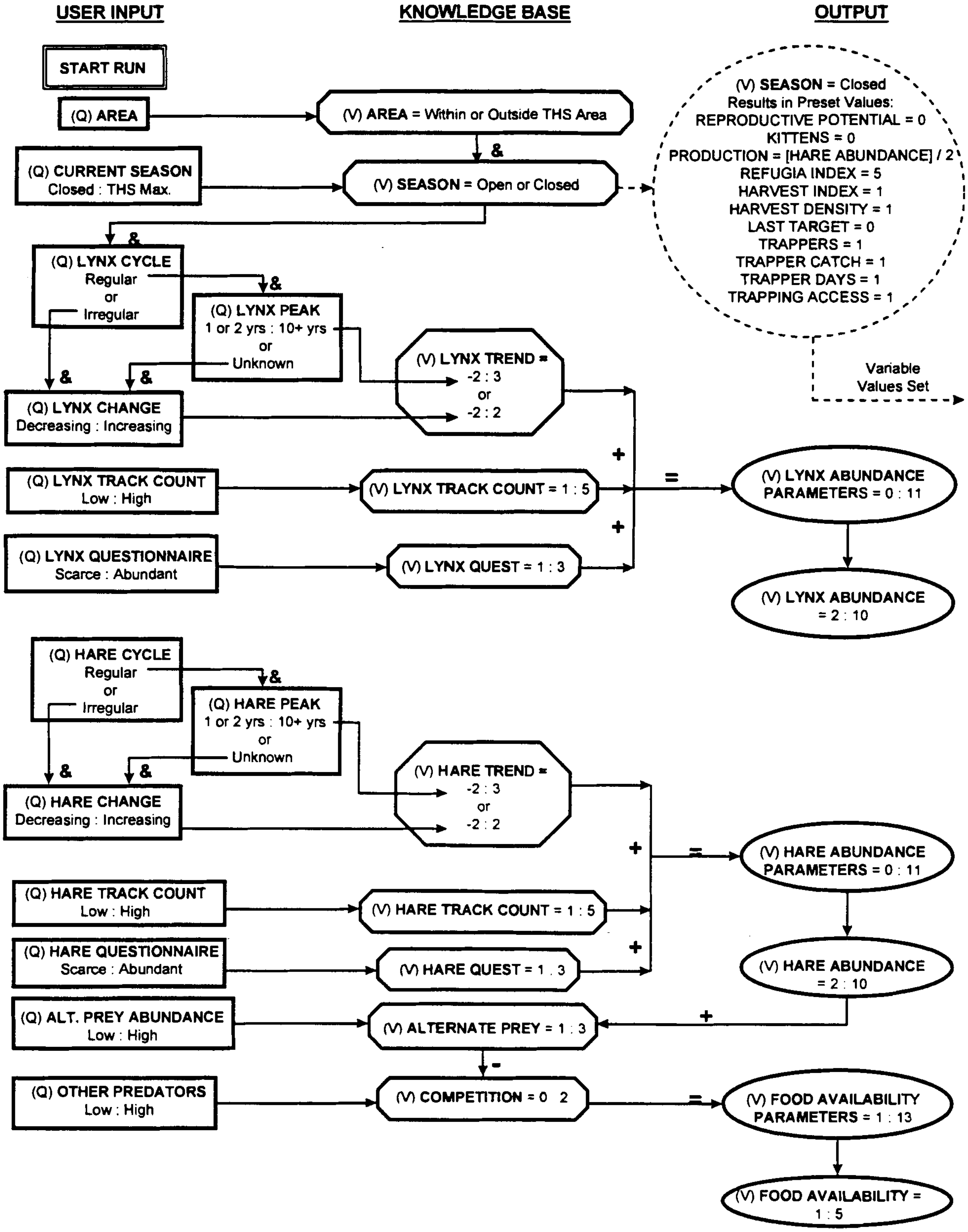
Current	Risk Factor[a]						
Season	Very Low	Low	Mod. Low	Moderate	Mod. High	High	Very High
THS Max.[b]	Maintain(9)	Maintain(9)	Maintain(8) ↓ to 3(6)	↓ to 3(8) Maintain(6)	↓ to 2.5(8) ↓ to 3(6)	↓ to 2(8) ↓ to 2.5(6)	↓ to 1.5(8) ↓ to 2(6)
3 Mo.	↑ to THS Max.(9)	↑ to THS Max.(8) Maintain(4)	Maintain(8) ↑ to THS Max.(6) ↓ to 2.5(4)	↓ to 2.5(8) Maintain(6)	↓ to 2(8) ↓ to 2.5(6)	↓ to 1.5(8) ↓ to 2(6)	↓ to 1.5(8) ↓ to 1(6)
2.5 Mo.	↑ to THS Max.(9)	↑ to THS Max.(8) ↑ to 3(6) Maintain(4)	↑ to 3(8) Maintain(6)	↓ to 2(8) Maintain(6)	↓ to 1.5(8) ↓ to 2(6)	↓ to 1.5(8) ↓ to 1(6)	↓ to 1(9)
2 Mo.	↑ to 3(9)	↑ to 3(8) ↑ to 2.5(6) Maintain(4)	↑ to 2.5(8) Maintain(6)	Maintain(8) ↓ to 1.5(6)	↓ to 1.5(8) ↓ to 1(6) Maintain(4)	↓ to 1(8) ↓ to 1.5(6)	↓ to 1(8) Close(6)
1.5 Mo.	↑ to 2.5(9)	↑ to 2.5(8) ↑ to 2(6) Maintain(4)	↑ to 2(8) Maintain(6)	Maintain(8) ↓ to 1(6)	↓ to 1(8) Maintain(6)	↓ to 1(8) Close(4)	Close(8) ↓ to 1(6)
1 Mo.	↑ to 2(9)	↑ to 2.0(8) ↑ to 1.5(6)	↑ to 1.5(8) Maintain(6)	Maintain(9)	Maintain(8) Close(6)	Close(8) Maintain(4)	Close(9)
Closed	Open to 1(9)	Open to 1(8) Maintain(4)	Open to 1(8) Maintain(6)	Maintain(8) Open 1(4)	Maintain(9)	Maintain(9)	Maintain(9)

[a] Risk factor level is the likelihood of exceeding sustainable yield. It represents the relationship between target harvest and harvest pressure for a particular area.

[b] The maximum season allowed under the tracking harvest strategy (THS); 1 November–28 February in Interior Alaska and 10 November–28 February in Southcentral Alaska.

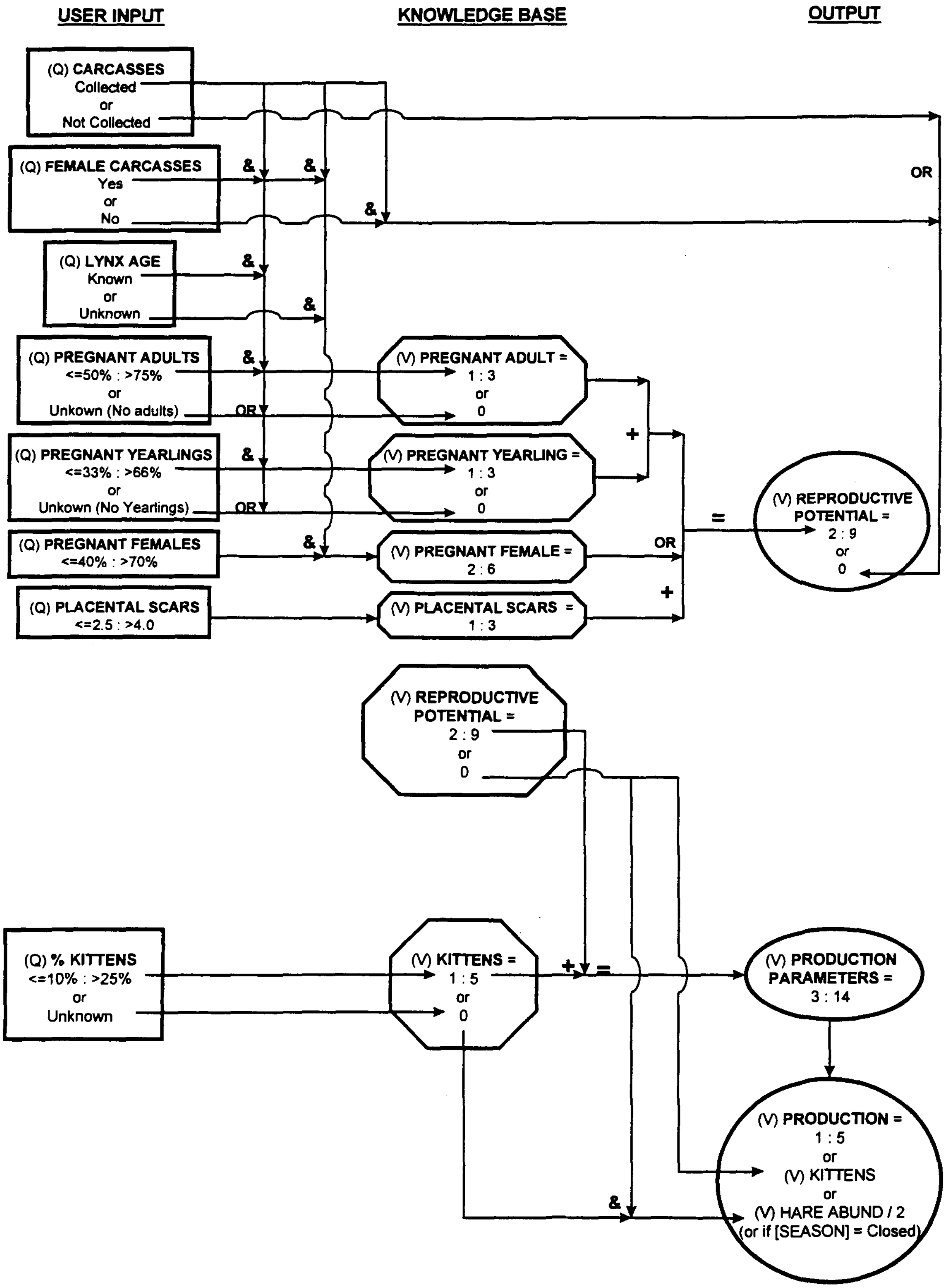
Appendix A Detailed flow diagram of LynxTrak that depicts the complete process of the model (summarized in Figure 2). The ranges of values for qualifiers and variables under user input (rectangles) relate to the ranges of values for the variables shown under the knowledge base (octagons). The ranges of values for the variables under output (ovals) represent results calculated from the knowledge base (e.g., Lynx Abundance Parameters = 0–11) and indices of those results (e.g., Lynx Abundance = 2–10), which are used in further calculations. Qualifiers are denoted by (q), numeric variables by (v), and nonnumeric string variables (e.g., *risk factor*) by (sv).

APPENDIX A

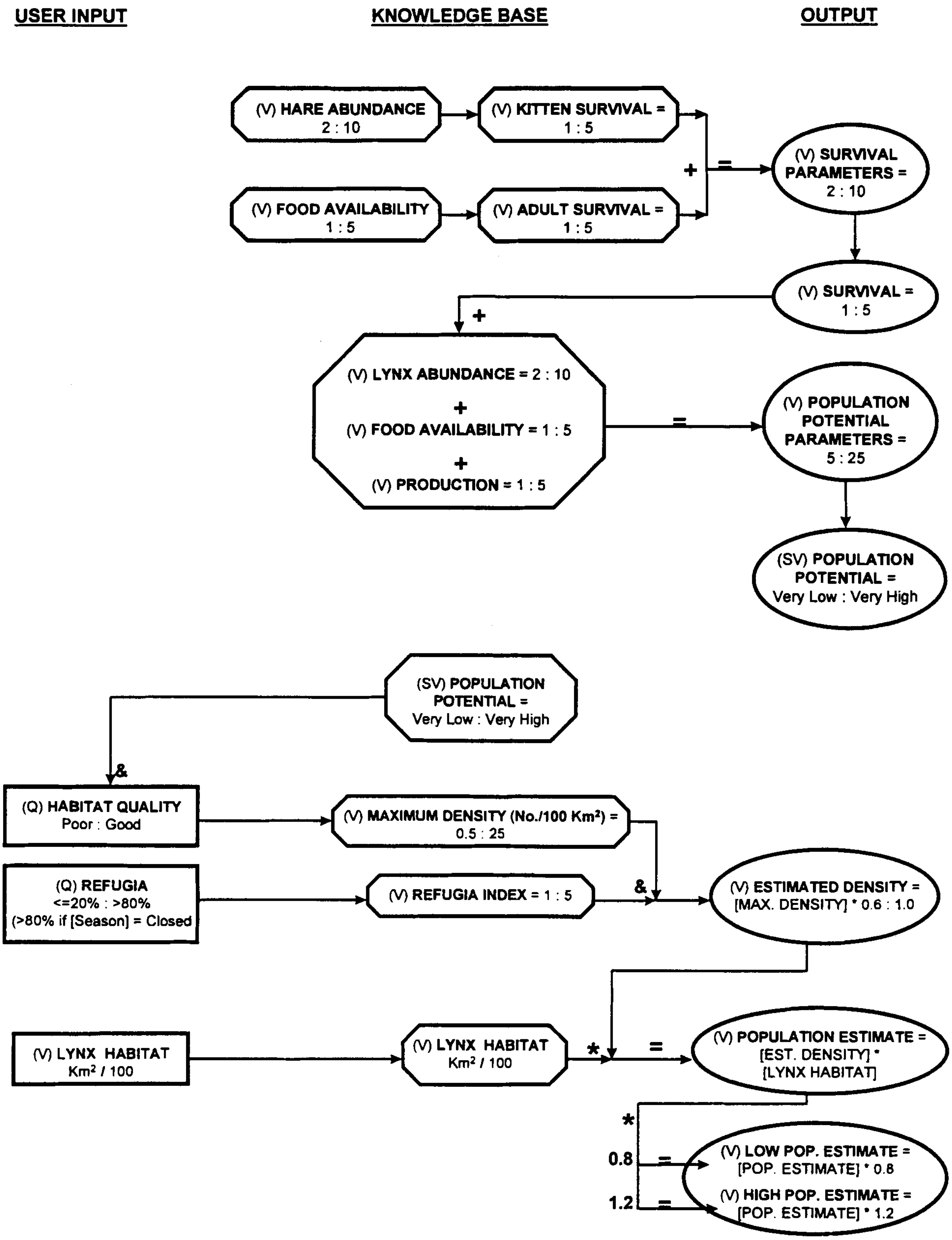


USER INPUT
KNOWLEDGE BASE
OUTPUT
START RUN
(Q) AREA
(V) AREA = Within or Outside THS Area
&
(Q) CURRENT SEASON
Closed : THS Max.
(V) SEASON = Open or Closed
(V) SEASON = Closed
Results in Preset Values:
REPRODUCTIVE POTENTIAL = 0
KITTENS = 0
PRODUCTION = [HARE ABUNDANCE] / 2
REFUGIA INDEX = 5
HARVEST INDEX = 1
HARVEST DENSITY = 1
LAST TARGET = 0
TRAPPERS = 1
TRAPPER CATCH = 1
TRAPPER DAYS = 1
TRAPPING ACCESS = 1
Variable
Values Set
(Q) LYNX CYCLE
Regular
or
Irregular
(Q) LYNX PEAK
1 or 2 yrs : 10+ yrs
or
Unknown
(V) LYNX TREND =
-2 : 3
or
-2 : 2
(Q) LYNX CHANGE
Decreasing : Increasing
(Q) LYNX TRACK COUNT
Low : High
(V) LYNX TRACK COUNT = 1 : 5
(V) LYNX ABUNDANCE
PARAMETERS = 0 : 11
(Q) LYNX QUESTIONNAIRE
Scarce : Abundant
(V) LYNX QUEST = 1 : 3
(V) LYNX ABUNDANCE
= 2 : 10
(Q) HARE CYCLE
Regular
or
Irregular
(Q) HARE PEAK
1 or 2 yrs : 10+ yrs
or
Unknown
(V) HARE TREND =
-2 : 3
or
-2 : 2
(Q) HARE CHANGE
Decreasing : Increasing
(V) HARE ABUNDANCE
PARAMETERS = 0 : 11
(Q) HARE TRACK COUNT
Low : High
(V) HARE TRACK COUNT = 1 : 5
(Q) HARE QUESTIONNAIRE
Scarce : Abundant
(V) HARE QUEST = 1 : 3
(V) HARE ABUNDANCE
= 2 : 10
(Q) ALT. PREY ABUNDANCE
Low : High
(V) ALTERNATE PREY = 1 : 3
(Q) OTHER PREDATORS
Low : High
(V) COMPETITION = 0 : 2
(V) FOOD AVAILABILITY
PARAMETERS = 1 : 13
(V) FOOD AVAILABILITY =
1 : 5

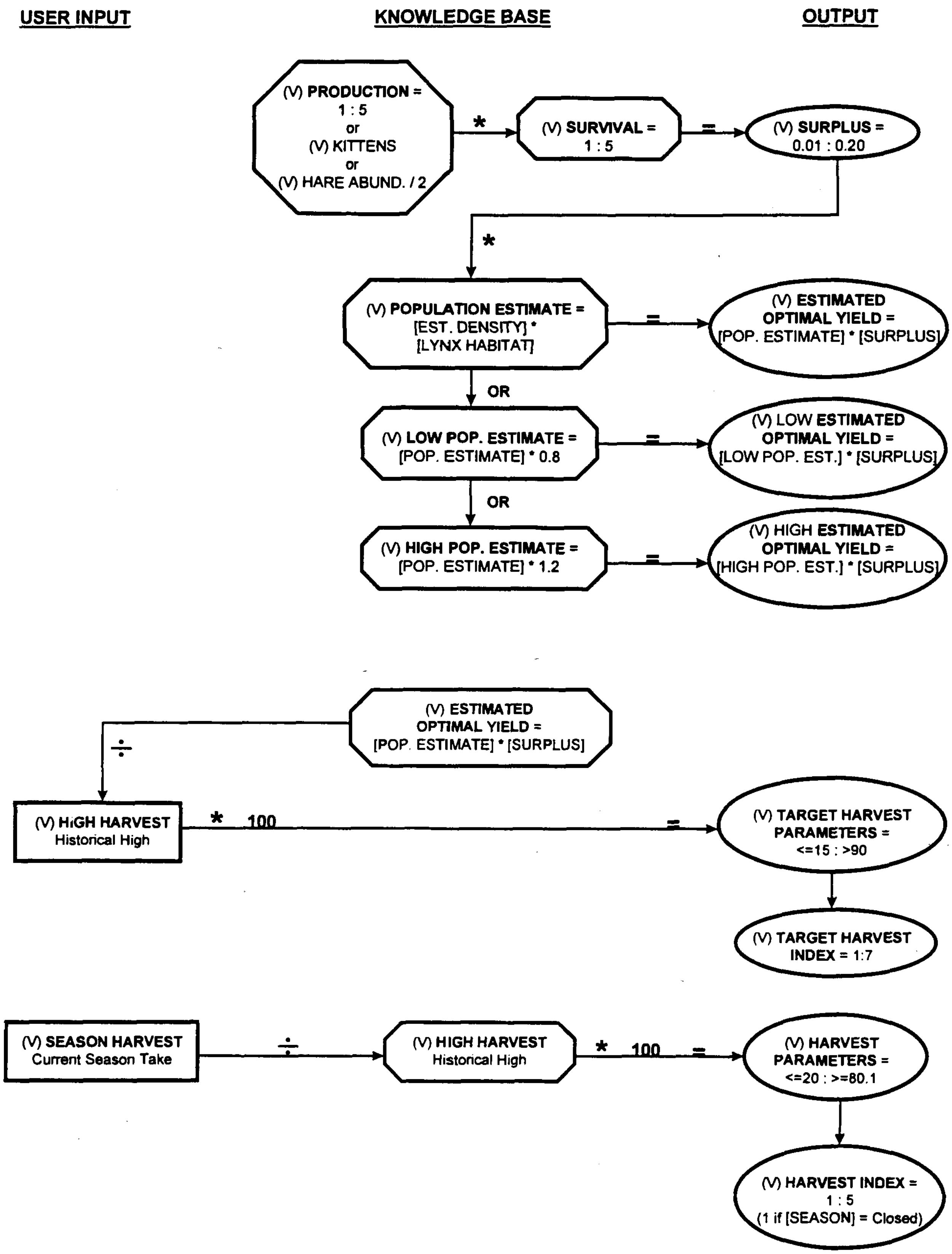
APPENDIX A Continued



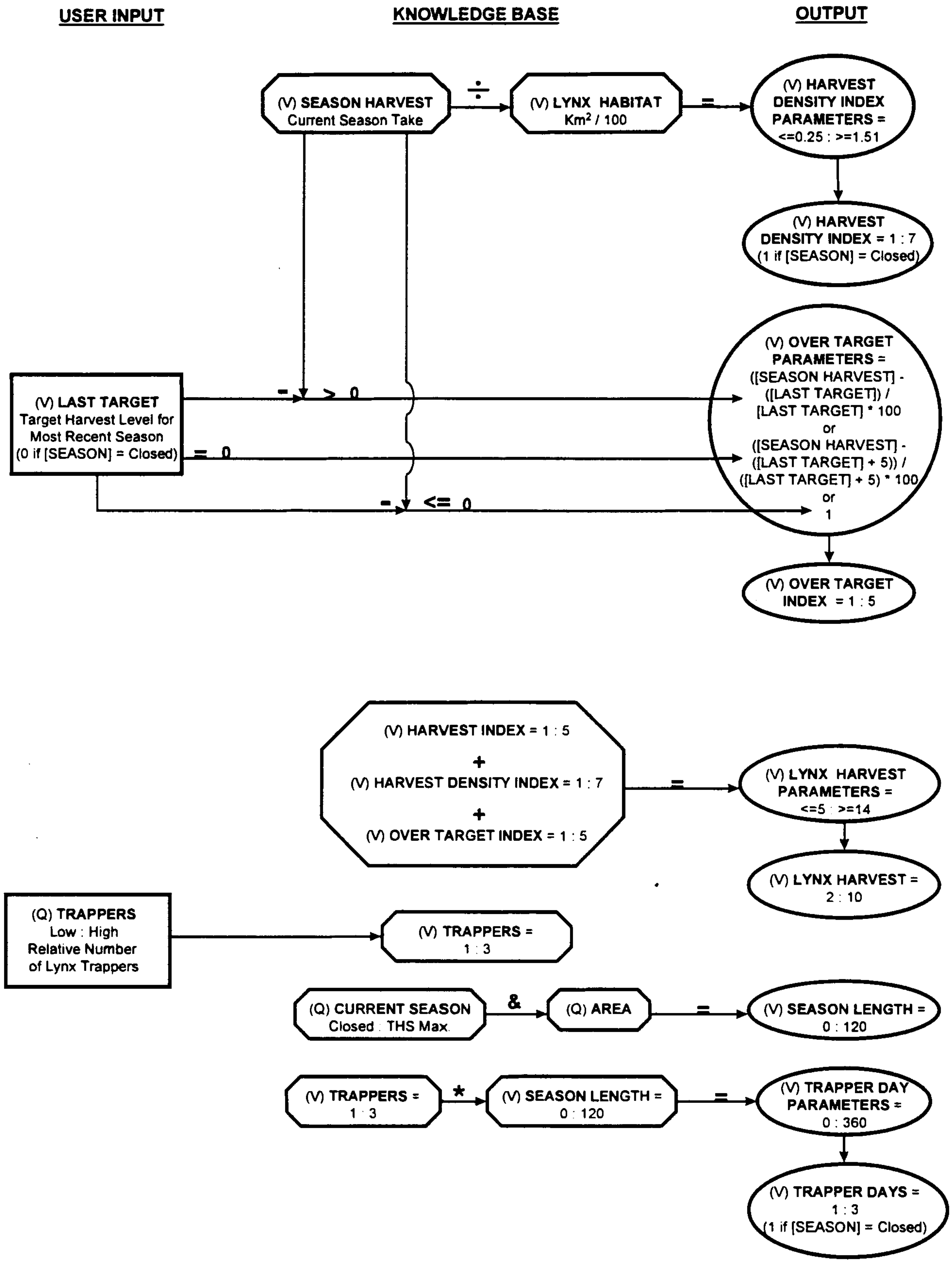
APPENDIX A Continued



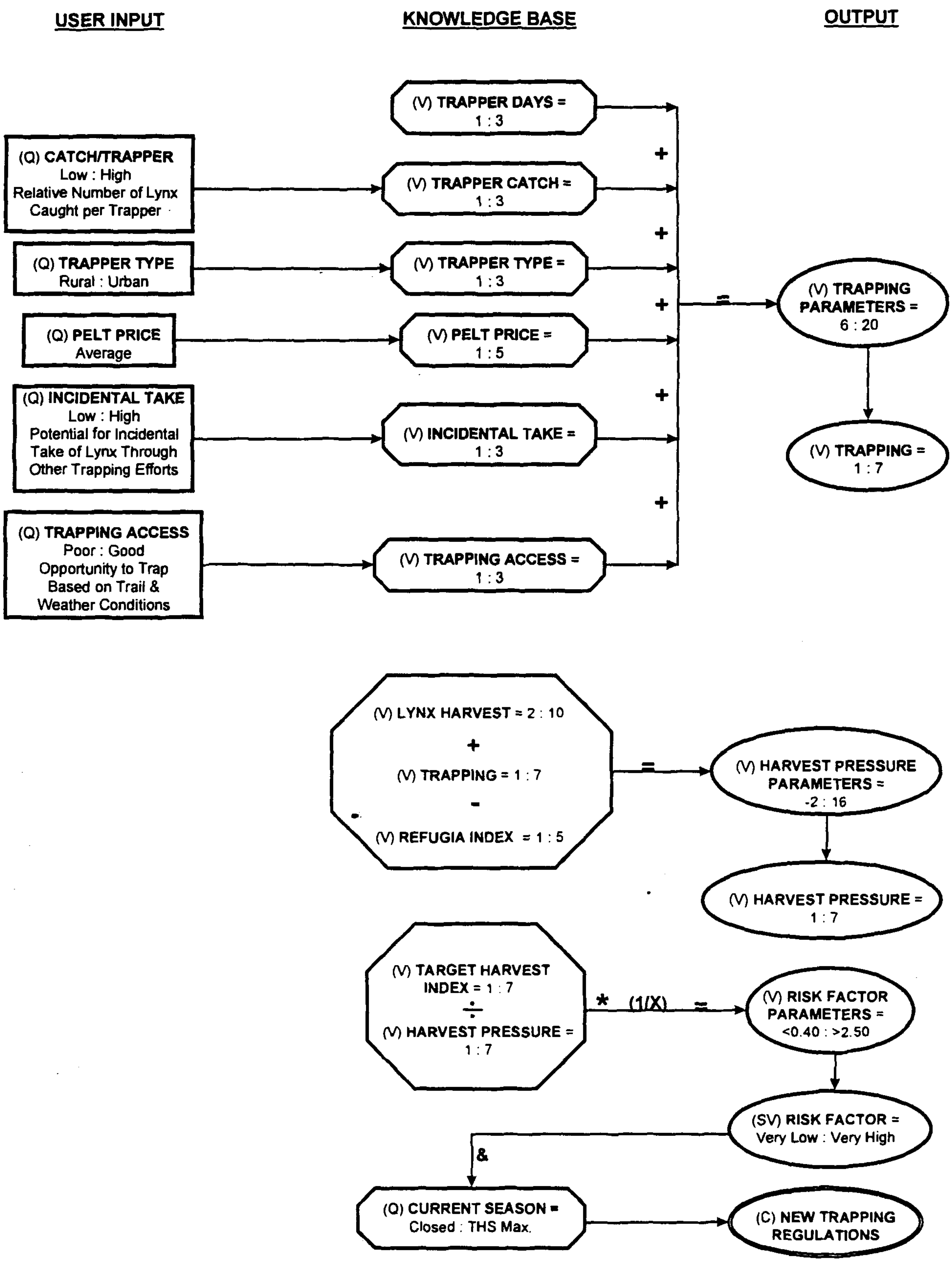
APPENDIX A Continued



APPENDIX A Continued



APPENDIX A Continued



Appendix B Examples of estimated optimal yields for lynx populations with different levels (limited to extreme and mid-range values) of refugia, population potential, estimated density and size, and surplus rates in habitats of poor, fair, and good quality in a 13,425-km^2 area (Game Management Unit 13) in Southcentral Alaska.

Habitat Quality	Percent Refugia[a]	Population Potential[b]	Estimated Density (Nr/100 km^2)	Estimated Population Size	Estimated Optimal Yield Per Surplus Rate[c] 0.01	0.08	0.20
Poor	≤20%	Very Low	0.3	40	0	3	8
		Moderate	2.1	282	3	23	56
		Very High	6	806	8	64	161
	41–60%	Very Low	0.4	54	1	4	11
		Moderate	2.8	376	4	30	75
		Very High	8	1074	11	86	215
	≥81%	Very Low	0.5	67	1	5	13
		Moderate	3.5	470	5	38	94
		Very High	10	1343	13	107	269
Fair	≤20%	Very Low	0.6	81	1	6	16
		Moderate	3.6	483	5	39	97
		Very High	10.5	1410	14	113	282
	41–60%	Very Low	0.8	107	1	9	21
		Moderate	4.8	644	6	52	129
		Very High	14	1880	19	150	376
	≥81%	Very Low	1.0	134	1	11	27
		Moderate	6.0	806	8	64	161
		Very High	17.50	2349	23	188	470
Good	≤20%	Very Low	1.2	161	2	13	32
		Moderate	6	806	8	64	161
		Very High	15	2014	20	161	403
	41–60%	Very Low	1.6	215	2	17	43
		Moderate	8	1074	11	86	215
		Very High	20	2685	27	215	537
	≥81%	Very Low	2.0	269	3	21	54
		Moderate	10	1343	13	107	269
		Very High	25.0	3356	34	269	671

[a] Percent refugia values are: ≤20%, 21–40%, 41–60%, 61–80%, and ≥81%.

[b] Population potential values are: very low, low, moderately low, moderate, moderately high, and high.

[c] Surplus rate values are: 0.01, 0.03, 0.05, 0.08, 0.11, 0.15, and 0.20.

Appendix C Sensitivity of LynxTrak to changes in the values of each variable on the final variable, risk factor, which determines new season choices (see Table 2). The effect on risk factor levels of changing each value individually was tested while holding the values of the other variables constant at moderate values (indicated in bold type). The model was designed to be slightly conservative, which is why a test of all moderate values resulted in a moderately-high risk factor.

		Risk Factor						
Qualifier	Value	Very Low	Low	Mod-Low	Mod.	Mod-High	High	Very High
Current Season	1					X		
	1.5					X		
	2					X		
	2.5					X		
	3					X		
Lynx Trend	-2					X		
	-1					X		
	0					X		
	1					X		
	2				X			
	3				X			
Lynx Count	1					X		
	2					X		
	3					X		
	4					X		
	5				X			
Lynx Questionnaire	1					X		
	2					X		
	3					X		
Hare Trend	-2							X
	-1							X
	0					X		
	1					X		
	2			X				

APPENDIX C Continued

		Risk Factor						
Qualifier	Value	Very Low	Low	Mod-Low	Mod.	Mod-High	High	Very High
	3			X				
Hare Count	1							X
	2							X
	3					X		
	4					X		
	5			X				
Hare Questionnaire	1							X
	2					X		
	3					X		
Alternate Prey	1					X		
	2					X		
	3					X		
Competition	0					X		
	1					X		
	2					X		
Pregnant Adults	1					X		
	2					X		
	3				X			
Pregnant Yearlings	1					X		
	2					X		
	3				X			
Placental Scars	1					X		
	2					X		
	3				X			
% Kittens	1					X		
	2					X		
	3					X		

APPENDIX C Continued

		Risk Factor						
Qualifier	Value	Very Low	Low	Mod-Low	Mod.	Mod-High	High	Very High
	4				X			
	5				X			
Habitat Quality	1					X		
	2					X		
	3				X			
Refugia	1						X	
	2						X	
	3					X		
	4					X		
	5				X			
Last Target	50						X	
	100					X		
	150					X		
Trappers	1					X		
	2					X		
	3					X		
Trapper Catch	1					X		
	2					X		
	3					X		
Trapper Type	1					X		
	2					X		
	3					X		
Pelt Price	1					X		
	2					X		
	3					X		
	4					X		
	5					X		

APPENDIX C Continued

		Risk Factor						
Qualifier	Value	Very Low	Low	Mod-Low	Mod.	Mod-High	High	Very High
Incidental Take	1					X		
	2					X		
	3					X		
Trapping Access	1					X		
	2					X		
	3					X		

Appendix D. Results of a simulation of LynxTrak to determine the most appropriate new trapping season for Game Management Unit 13. The first frame shows the starting text that appears when the model is asked to run. The following 5 frames represent 1 continuous window and show the preferred choices (with the levels of confidence for each choice), the qualifiers, and the variables used.

APPENDIX D

Starting text:

Welcome to "LynxTrak". This is an interactive model designed to help you as a wildlife manager adjust lynx harvest regulations under the lynx tracking harvest strategy. Lynx populations in Alaska fluctuate greatly over a 9-11-year period in response to the abundance of snowshoe hares. The tracking harvest strategy was adopted in 1988 to provide more responsive management options during the lynx cycle. "LynxTrak" is a decision-making tool that uses a "rule-based expert-system" approach to determine the most appropriate management action to take. The "experts" are ADF&G biologists, biologists from other agencies, trappers, and literature sources. The collective research findings, harvest data, population trend counts, and experiences and observations of the experts were used in building this management model. The "rules" used in the model consist of "IF" scenarios followed by "THEN" responses. The rules culminate in a "CHOICE" the experts believe is the best action to take. "LynxTrak" was designed to help managers make informed, logical, and consistent decisions using the guidance of other experts in considering all pertinent factors. It is NOT a substitute for the decision-making process. "LynxTrak" should increase accountability for lynx management decisions, because if you as manager reject the choice made by the model's "experts", it is your responsibility to justify your different course of action. No model is perfect, and there may be certain factors left out of this one that you now consider important. You may want to seek additional advice before taking any final action.

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Results

INCREASE SEASON TO 3 MONTHS	8
INCREASE SEASON TO 2.5 MONTHS	6
MAINTAIN CURRENT SEASON	4
The area(s) of concern, shown as Game Management Units and Subunits, is/are 13	
The current lynx trapping season is 2 MONTHS	
Lynx population cycles in this area have been FAIRLY REGULAR AND PREDICTABLE	
The number of years ago the lynx population last peaked in the area was 8	
Lynx track counts during the most recent winter relative to past counts in the area were MODERATELY HIGH	
The relative abundance of lynx in the area based on the trapper observations is COMMON	
Hare population cycles in this area have been FAIRLY REGULAR AND PREDICTABLE	
The number of years ago the hare population last peaked in the area was 9	
The abundance of hare tracks and/or pellets relative to past counts in the area are MODERATELY HIGH	
The relative abundance of hares in the area based on trapper observations is ABUNDANT	
The abundance of prey for lynx other than hares in the area relative to past levels is MODERATE	
The abundance of predators that may compete with lynx in the area relative to past levels is LOW	
Carcasses of lynx caught by trappers in the area during the most recent season were COLLECTED AND ANALYZED	
Did carcasses purchased from trappers in the area include females? YES	
The ages of lynx carcasses purchased from trappers in the area were KNOWN FOR ALL LYNX	
The percentage of pregnant adults (i.e., female lynx greater than 2 years old with recent placental scars) in the carcass sample was >75%	
The percentage of pregnant yearlings (i.e., female lynx between 1 and 2 years old with recent	

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APPENDIX D Continued

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Results

The percentage of pregnant yearlings (i.e., female lynx between 1 and 2 years old with recent placental scars) in the sample of carcasses was 33.1–66%

The mean number of recent placental scars among yearling and adult female lynx in the carcass sample was >4.0

The percentage of kittens in the lynx harvest, based on tooth analysis or pelt lengths of < 35", is 20.1–25%

The general quality of the lynx habitat, based on forest age, cover, composition, and ability to produce hares, is FAIR

The approximate percentage of lynx habitat in the area that was not trapped is 41–60%

The relative number of lynx trappers in the area this season compared with past seasons is MODERATE

The relative number of lynx caught per trapper this season compared with past seasons is MODERATE

Most trappers (i.e., more than 60%) who harvest lynx in the area are LONG-TERM OR RURAL-BASED TRAPPERS

The average lynx pelt price is $51–$100

The potential for incidental take of lynx through other trapping efforts is MODERATE

Access to trapping areas, primarily due to snow conditions, was FAIR

AREA: The area of concern, shown as Game Management Units or Subunits = PART OF THE TRACKING HARVEST STRATEGY AREA

SEASON: The trapping season is open or closed = OPEN

LYNX TREND: The trend in the relative abundance of lynx (Range = -2 : 3) = 2

LYNX TRACK COUNT: The relative abundance of lynx tracks (Range = 1 : 5) = 4

LYNX QUESTIONNAIRE: The relative abundance of lynx based on trapper observations (Range = 1 : 3) = 2

LYNX ABUNDANCE: Relative level of lynx abundance (Range = 2 : 10) = 8

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Results

HARE TREND: The trend in the relative abundance of hares (Range = -2 : 3) = 2

HARE TRACK COUNT: The relative abundance of the hare tracks or pellets (Range = 1 : 5) = 4

HARE QUESTIONNAIRE: The relative abundance of hares based on trapper observations (Range = 1 : 3) = 3

HARE ABUNDANCE: Relative level of hare abundance (Range = 2 : 10) = 10

ALTERNATE PREY: The relative abundance of prey for lynx other than hares (Range = 1 : 3) = 2

COMPETITION: The relative abundance of other predators that may compete with lynx (Range = 1 : 3) = 0

FOOD AVAILABILITY: The overall availability of food resources for lynx (Range = 1 : 5) = 5

PREGNANT ADULT: Percentage of pregnant adult lynx based on the presence of placental scars (Range = 0 : 3) = 3

PREGNANT YEARLING: Percentage of pregnant yearling lynx based on the presence of placental scars (Range = 0 : 3) = 2

PREGNANT FEMALE: Percentage of pregnant female lynx based on the presence of placental scars (Range = 0 : 6) = 0

PLACENTAL SCARS: The relative number of recent placental scars found in carcasses of all female lynx (Range = 0 : 3) = 3

REPRODUCTIVE POTENTIAL: The potential of the lynx population to produce kittens, based on pregnancy rates and placental scar counts = 8

PERCENT KITTENS: The percentage of kittens in the lynx harvest (Range = 0 : 5) = 4

PRODUCTION: Expected level of production in the lynx population (Range = 1 : 5) = 5

KITTEN SURVIVAL: The relative potential for kitten survival (Range = 1 : 5) = 5

ADULT SURVIVAL: The relative potential for adult lynx survival (Range = 1 : 5) = 5

SURVIVAL: Relative potential for survival of kittens, yearlings, and adult lynx (Range = 1 : 5) = 5

POPULATION POTENTIAL: Expected growth potential of the lynx population (Range = Very Low : Very High) = VERY HIGH

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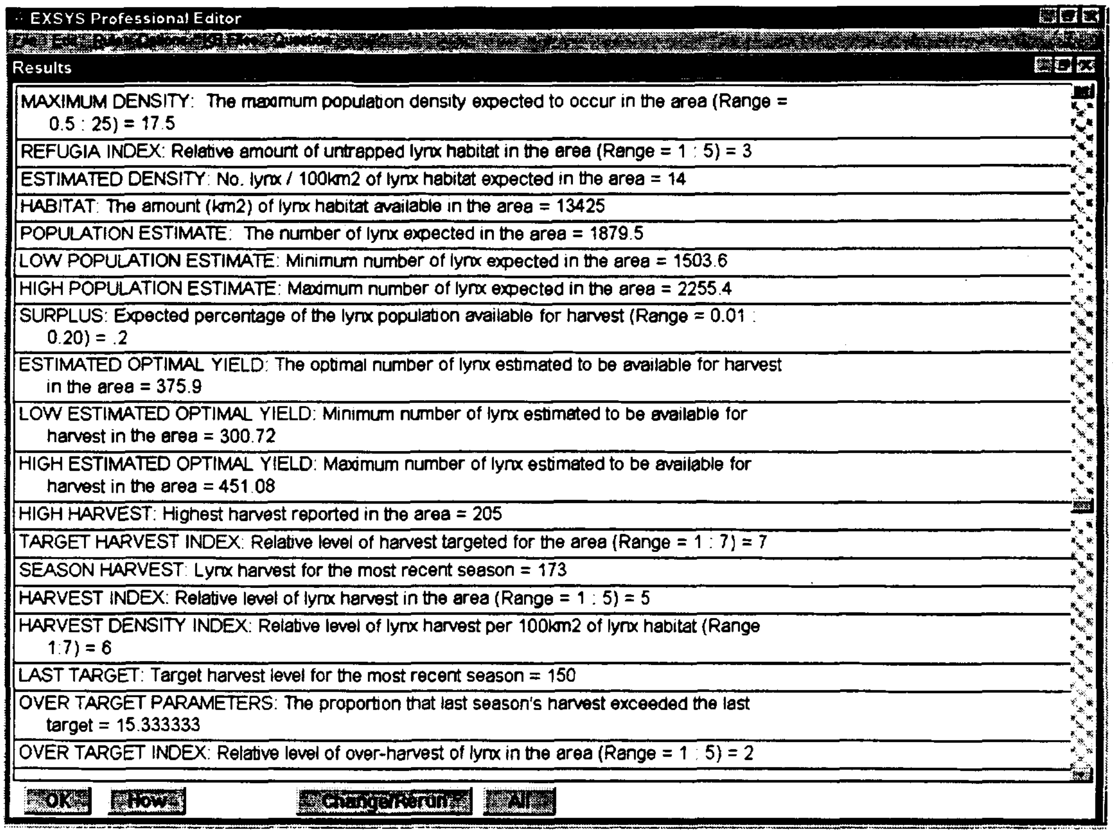
APPENDIX D Continued



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Results

MAXIMUM DENSITY: The maximum population density expected to occur in the area (Range = 0.5 : 25) = 17.5
REFUGIA INDEX: Relative amount of untrapped lynx habitat in the area (Range = 1 : 5) = 3
ESTIMATED DENSITY: No. lynx / 100km2 of lynx habitat expected in the area = 14
HABITAT: The amount (km2) of lynx habitat available in the area = 13425
POPULATION ESTIMATE: The number of lynx expected in the area = 1879.5
LOW POPULATION ESTIMATE: Minimum number of lynx expected in the area = 1503.6
HIGH POPULATION ESTIMATE: Maximum number of lynx expected in the area = 2255.4
SURPLUS: Expected percentage of the lynx population available for harvest (Range = 0.01 : 0.20) = .2
ESTIMATED OPTIMAL YIELD: The optimal number of lynx estimated to be available for harvest in the area = 375.9
LOW ESTIMATED OPTIMAL YIELD: Minimum number of lynx estimated to be available for harvest in the area = 300.72
HIGH ESTIMATED OPTIMAL YIELD: Maximum number of lynx estimated to be available for harvest in the area = 451.08
HIGH HARVEST: Highest harvest reported in the area = 205
TARGET HARVEST INDEX: Relative level of harvest targeted for the area (Range = 1 : 7) = 7
SEASON HARVEST: Lynx harvest for the most recent season = 173
HARVEST INDEX: Relative level of lynx harvest in the area (Range = 1 : 5) = 5
HARVEST DENSITY INDEX: Relative level of lynx harvest per 100km2 of lynx habitat (Range 1:7) = 6
LAST TARGET: Target harvest level for the most recent season = 150
OVER TARGET PARAMETERS: The proportion that last season's harvest exceeded the last target = 15.333333
OVER TARGET INDEX: Relative level of over-harvest of lynx in the area (Range = 1 : 5) = 2

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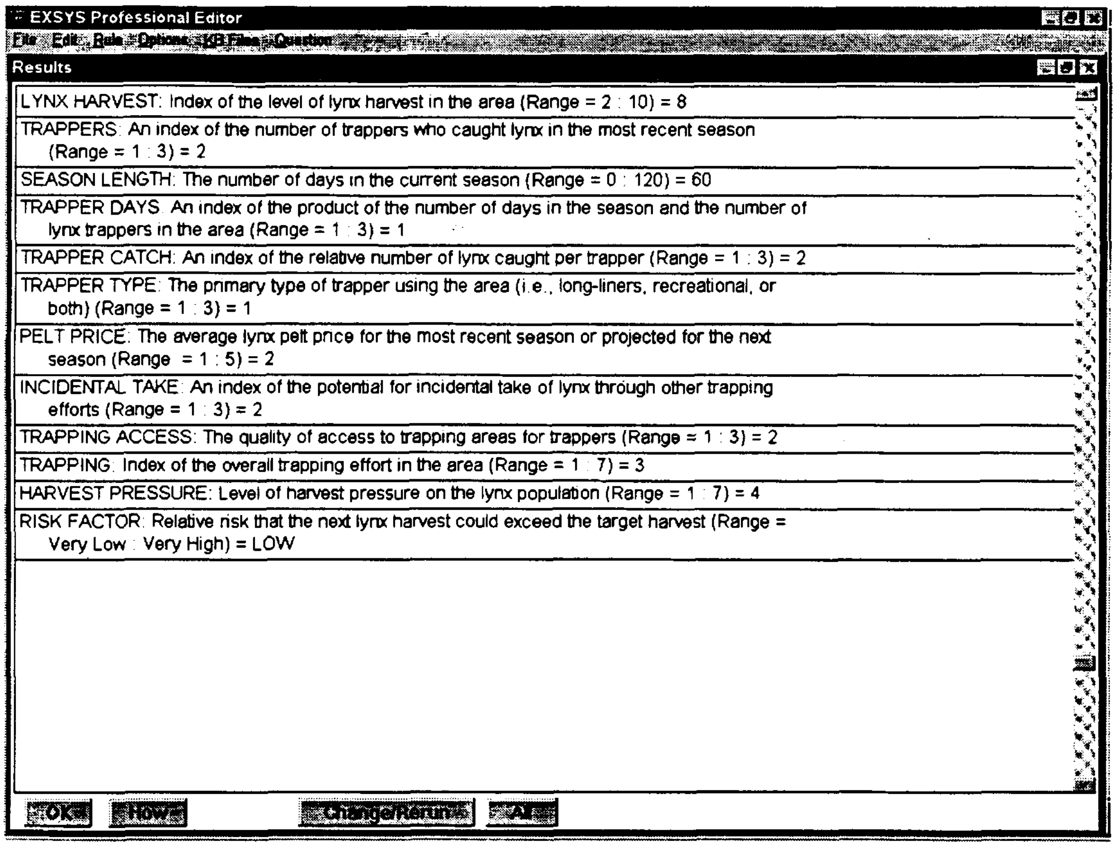

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Results

LYNX HARVEST: Index of the level of lynx harvest in the area (Range = 2 : 10) = 8
TRAPPERS: An index of the number of trappers who caught lynx in the most recent season (Range = 1 : 3) = 2
SEASON LENGTH: The number of days in the current season (Range = 0 : 120) = 60
TRAPPER DAYS: An index of the product of the number of days in the season and the number of lynx trappers in the area (Range = 1 : 3) = 1
TRAPPER CATCH: An index of the relative number of lynx caught per trapper (Range = 1 : 3) = 2
TRAPPER TYPE: The primary type of trapper using the area (i.e., long-liners, recreational, or both) (Range = 1 : 3) = 1
PELT PRICE: The average lynx pelt price for the most recent season or projected for the next season (Range = 1 : 5) = 2
INCIDENTAL TAKE: An index of the potential for incidental take of lynx through other trapping efforts (Range = 1 : 3) = 2
TRAPPING ACCESS: The quality of access to trapping areas for trappers (Range = 1 : 3) = 2
TRAPPING: Index of the overall trapping effort in the area (Range = 1 : 7) = 3
HARVEST PRESSURE: Level of harvest pressure on the lynx population (Range = 1 : 7) = 4
RISK FACTOR: Relative risk that the next lynx harvest could exceed the target harvest (Range = Very Low : Very High) = LOW

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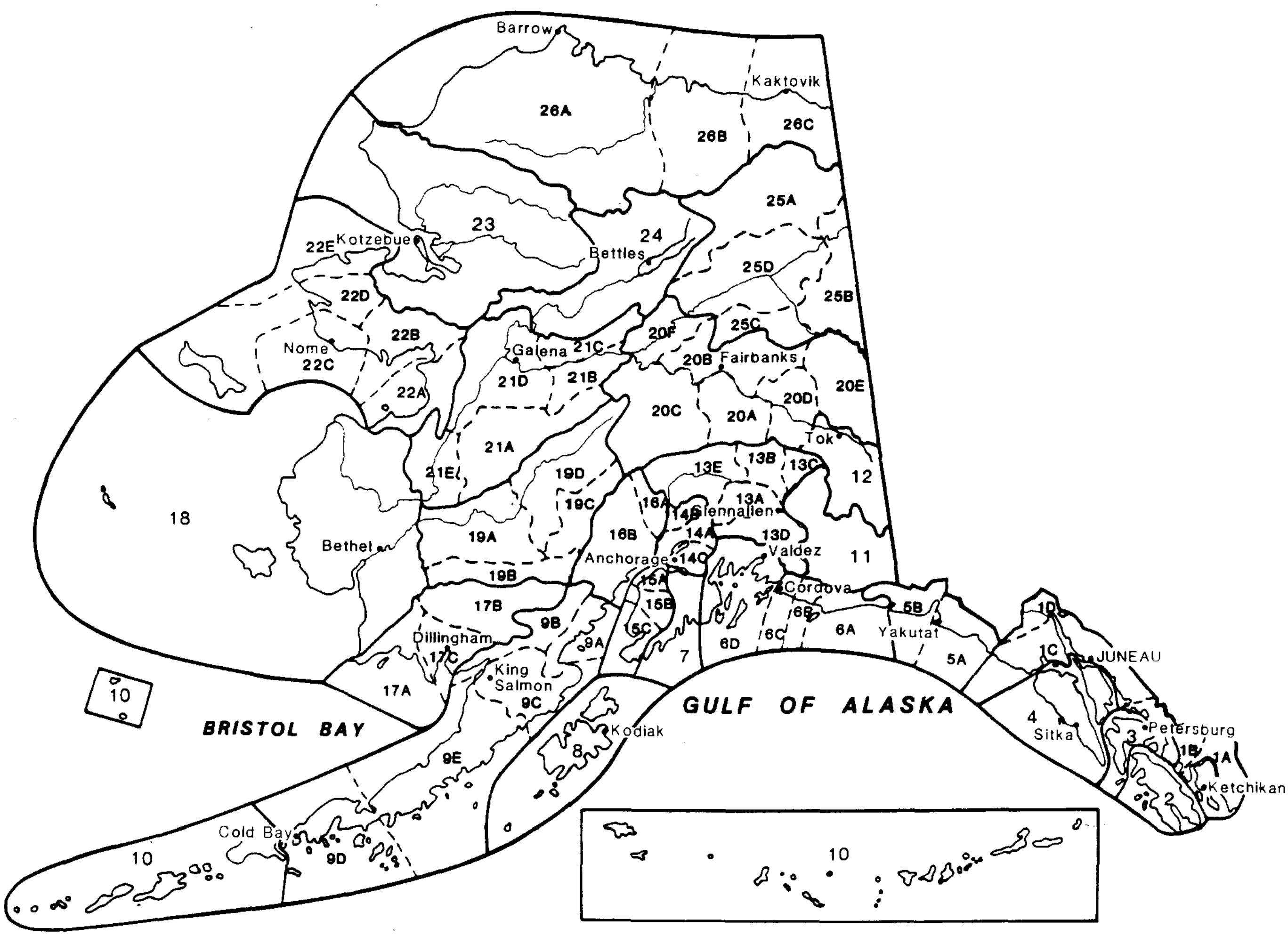
Alaska's Game Management Units



The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program allots funds back to states through a formula based on each state's geographic area and number of paid hunting license holders. Alaska receives a maximum 5% of revenues collected each year. The Alaska Department of Fish and Game uses federal aid funds to help restore, conserve, and manage wild birds and mammals to benefit the public. These funds are also used to educate hunters to develop the skills, knowledge, and attitudes for responsible hunting. Seventy-five percent of the funds for this report are from Federal Aid.

Tom Schumacher