TOPIC 4. EVAPORATION

Evaporative heat loss occurs when the latent heat of vaporization resulting from a phase change from liquid water to gaseous water vapor is dissipated. This occurs in animals through respiration, evaporation of perspiration, and evaporation of surface water after the hair coat has become wet. Evaporative heat loss can be estimated with several methods. The mass transport method predicts evaporation as a function of vapor pressures. If the atmosphere has a lower vapor pressure than the surface of a plant or animal, water evaporates from the plant or animal until vapor pressure deficits at the surface and in the atmosphere are equal. It is relatively simple to calculate evaporation by this method, but it is not calculated very accurately, especially from aerodynamically rough surfaces in windy conditions when there is a lot of turbulence and hence atmospheric mixing. Then, the atmosphere never comes into equilibrium with the source of water even if the deficit is low. Several other approaches to calculating evaporative heat loss are described by Rosenberg (1974).

Evaporative heat loss is generally a minor fraction of total heat loss from animals at cold temperatures if their coats are dry. Respiratory exchange is low at least in some species, because the anatomy of the respiratory passages results in pre-warming and pre-cooling of the air that reaches the respiratory surface in the lungs, minimizing changes in vapor pressures of respired air. At high temperatures, evaporative heat loss is very important as a means of dissipating excess body heat by wild ruminants, and responses such as panting and sweating may be essential for survival. That is a good reason for evaluating them in considerable detail. Some animals use lakes and ponds as a means for keeping cool in the heat of summer. Moose, for example, spend considerable time in the water feeding while benefitting from the cooling effects of the water. Limited discussions of surface and respiratory evaporation follow in the next two UNITS.

LITERATURE CITED

Rosenberg, N. J. 1974. Microclimate: The Biological Environment. John Wiley & Sons, N. Y. 315 p.

UNIT 4.1: SURFACE EVAPORATION

Water vapor has mass, it occupies space, and therefore must have some place to be. The atmosphere has a capacity for holding water vapor that is dependent on atmospheric temperature. "Warm air can hold more moisture than cool air" is the usual phrase describing this relationship. The amounts held by the atmosphere at different temperatures were discussed in TOPIC 4 of CHAPTER 14. Heat transfer due to surface evaporation using a very simplified vapor pressure gradient approach is discussed here, with the full realization that it is not a good way to estimate something as dynamic as evaporative heat loss. It does serve to illustrate the basic idea, however, and indicates the similarities in the loss of heat energy by vapor pressure gradients to the the effects of temperature gradients on radiation, convection, and conduction losses.

The resistance approach to the transport of vapor may be considered an onlag of conduction from a surface to the air next to it. The transport of sensible heat proceeds at a rate directly proportional to the temperature gradient and inversely proportional to the resistance of the air to thermal conduction. Similarly, the transport of vapor is directly proportional to the vapor pressure gradient from the evaporating surface to the air and inversely proportional to resistance of the air to the diffusion of water molecules (Rosenberg 1974:167).

This is not unlike the mass transport method discussed by Rosenberg (1974:161) where the vapor pressure gradient is considered along with a "windiness" factor. The windiness of the atmosphere affects the thermal resistance; the two parameters are related. It is interesting that the mass transport method discussed by Rosenberg is attributed to research completeed by Dalton about 1800. The "Daltonian equation" is:

$$E = C\ (e_o - e_a)$$

where E is evaporation, C is an empirically determined constant involving some function of windiness, e_o is the vapor pressure at the surface, and e_a is the actual vapor pressure in the air at some point above the surface.

Modifications of this equation that have been proposed are described by Rosenberg (1974:162). The equation proposed by Penman (1948) requires measurement of vapor pressures at the surface and in the atmosphere and wind velocity 2 meters above the ground. The equation is:

$$E = 0.40\ (e_o - e_a)(1 + 0.17\ u_2)$$

where E = evaporation,
e_o = vapor pressure at the surface,
e_a = vapor pressure in the atmosphere, and
u_2 = wind velocity at two meters.

The use of this equation illustrates the contributions of vapor pressures (which are partial functions of temperature) and wind velocities to evaporation.

The next step in determining the amount of heat energy involved in evaporation. The amount of heat required to vaporize water--the heat of vaporization--is temperature-dependent. This is often overlooked in general science and elementary physics books where the heat of vaporization is given as a single value, 540 cal per gram, which applies only to 100 ^{o}C. Evaporation of water from an animal requires from 596 cal per gram of water evaporated at 0 ^{o}C to 574 cal per gram at 40 ^{o}C (Fairbridge 1967). The larger energy requirement for the heat of vaporization at lower temperatures is necessary because more energy is needed to break the chemical forces between cooler liquid water molecules that are vibrating more slowly than warmer ones that are vibrating faster. The heat required for evaporation can come from the organism or the environment.

The relationship between the heat of vaporization and air temperature may be expressed with a linear regression equation (Moen 1973: 99):

$$\text{HEVA} = 595.59 - 0.5376\ \text{ATTE}$$

where HEVA = heat of vaporization (calories), and
ATTE = atmospheric temperature (C).

The use of such an equation is certainly preferable to the use of a single value, or to the use of some other value for "average" temperatures. Completion of the graph in the WORKSHEET that follows provides a nomogram for quick estimates, and the equation is easily programmed into a series of calculations.

LITERATURE CITED

Fairbridge, R. W. (Ed.) 1967. The Encyclopedia of Atmospheric Sciences and Astrogeology. Reinhold Publ. Corp. N.Y. 1200 p.

Moen, A. N. 1973. Wildlife Ecology. W. H. Freeman and Sons. San Francisco. 458 p.

Penman, H. L. 1948. Natural evaporation from open water, bare soil, and grass. Proc. Roy. Soc. Lond. A. 193: 120-145.

Rosenberg, N. J. 1974. Microclimate: The Biological Environment. John Wiley & Sons, N.Y. 315 p.

REFERENCES, UNIT 4.1

SURFACE EVAPORATION

BOOKS

TYPE	PUBL	CITY	PAGE	ANIM	KEY WORDS-----------------	AUTHORS/EDITORS--	YEAR
aubo	jwis	nyny	315		microclimat; biolog envir	rosenberg,nj	1974

SERIALS

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				odvi			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				odhe			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ceel			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				alal			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
CJZOA	38--4	679	688	rata	eff wnd, moist, ht ls,newb	lentz,cp; hart,js	1960

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				anam			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				bibi			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovca			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				ovda			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				obmo			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
				oram			

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BVJOA	124--	83	88	doca	evap htloss, mech, newb cf	hales,jrs; findl/	1968
JASIA	74--2	247	258	doca	accum & evap moist, sweatg	allen,te; bennet/	1970

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
IJLAA	46--8	459	460	dosh	evaporation, colorat effec	singh,m; acharya,	1976
IJLAA	47--6	67	368	dosh	heat dissip, diff typ shee	singh,m; acharya,	1977
JAPYA	26--5	517	523	dosh	eff temp, wool lengt, evap	hofmeyr,hs; guid/	1969
RSPYA	30--3	327	338	dosh	thermorespir respon, shorn	hofman,wf; riegle	1977
RSPYA	30--3	339	348	dosh	respir ht loss regu, shorn	hofman,wf; riegle	1977

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JPHYA	284--	162p	163p	dogo	core temp, resp loss, exer	jessen,c; mercer,	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JDSCA	51-10	1689	1692	rumi	surf evap rates, effe temp	joshi,bc; mcdowe/	1968
SZSLA	31---	345	356	doru	evaporativ temp regulation	jenkinson,dm	1972
SZSLA	31---	357	369		evap heat loss, arid envir	bligh,j	1972

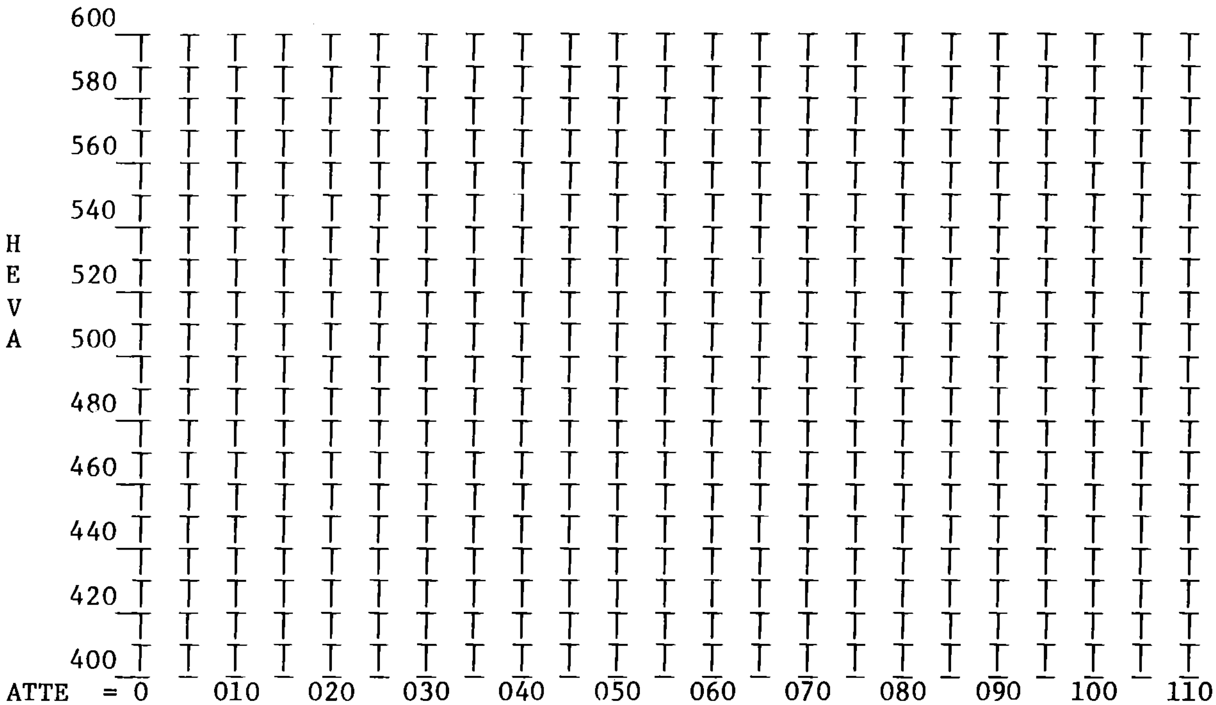
Heat of vaporization

The relationship between the heat of vaporization and air temperature may be expressed with a linear regression equation from Moen (1973:99). The equation is:

$$HEVA = 595.59 - 0.5376\ ATTE$$

where HEVA = heat of vaporization (calories), and
ATTE = atmospheric temperature (°C).

Calculate HEVA for the maximum and minimum temperatures given on the graph and convert the values of HEVA with straight line.



UNIT 4.2: RESPIRATORY EVAPORATION

Evaporation from the respiratory tract must follow the basic physical principles with regard to vapor pressure gradients discussed earlier, but the dynamics of external respiration make the exchange of heat by respiratory means much more complex. Air movement is forced as a result of movements of the diaphragm. Turbulence is expected as air moves through the respiratory tract since there are folds or convolutions in the respiratory tract that extend the distance tranversed by the air before entering or leaving the nasal cavity and lungs. This results in warming of the inhaled air and cooling of the exhaled air, which is an energy convection mechanism of particular significance to northern species such as caribou.

The calculation of respiratory evaporation on theoretical bases is impossible due to the complexities associated with this process *in vivo*. Estimates of respiratory evaporative heat loss are given in CHAPTER 16, UNIT 1.6, recognizing at least the potential contribution of evaporation to the total heat loss and, at most, the magnitude of the loss under certain conditions.

Note that the references on the next page deal primarily with domestic ruminants. Evaporation is most important to the animal at high temperatures, so research on respiratory evaporation has been directed primarily toward the hotter climates.

REFERENCES, UNIT 4.2

RESPIRATORY EVAPORATION

SERIALS

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

odvi

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

odhe

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ceel

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

alal

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

rata

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

anam

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

bibi

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovca

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

ovda

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

obmo

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

oram

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
BVJOA	124--	83	88	doca	evap ht los mech newb calf	hales,jrs; findl/	1968

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
JAPYA	40--4	514	520	dogo	thrmosnstv sites, hypothal	jessen,c	1976
JPHYA	284--	162p	163p	dogo	core temp, resp loss, exer	jessen,c; mercer,	1978

CODEN	VO-NU	BEPA	ENPA	ANIM	KEY WORDS-----------------	AUTHORS----------	YEAR
IJLAA	47--6	367	368	dosh	heat dissip, diff typ shee	singh,m; acharya,	1977
JAPYA	26--5	517	523	dosh	eff temp, wool lengt, evap	hofmeyr,hs; guid/	1969
RSPYA	30--3	327	338	dosh	thermorespir respon, shorn	hofman,wf; riegle	1977
RSPYA	30--3	339	348	dosh	respir ht loss regu, shorn	hofman,wf; riegle	1977

CLOSING COMMENTS

Thermal characteristics and basic heat transfer processes have been discussed in CHAPTER 15. The discussions and calculations have been an extension of those in CHAPTER 14, and these two chapters provide the background for evaluations of thermal energy balances and animal responses in the next two chapters.

The next chapter (CHAPTER 16) includes evaluations of thermal energy balances of animals in specific situations. These evaluations help one understand the roles of physiological and behavioral adjustments by free-ranging animals in their natural habitats.

Aaron N. Moen
November 18, 1981

GLOSSARY OF SYMBOLS USED - CHAPTER FIFTEEN

ABCO = Absorption coefficient
ABTB = Absolute temperature of the bottom sensor
ABTT = Absolute temperature of the top sensor
AITE = Air temperature
AREA = Area
ATTE = Atmospheric temperature

CCAI = Conductivity coefficient of air
CCMB = Calories per square centimeter per day
COCO = Convective coefficient

DCYC = Diameter of the cylinder in centimeters
DLTA = Delta T = temperature difference
DPTH = Depth of conducting material

ERTL = Effective radiant temperature of the leaf
EVAP = Evaporation

HEVA = Heat of vaporization

IART = Instrument air temperature
IREM = Coefficient of infrared emissivity

KCMH = Kilocalories per centimeters per hour
KCOA = Conductivity coefficient of the air
KCOI = Conductivity coefficient of the insulation
KMTH = Kilocalories per square centimers per day

LFPC = Lengths of flat plats

QCVE = Quantity of convective heat loss
QFCV = Quantity of forced convection
QHCO = Quantity of heat conducted
QNCV = Quantity of natural convection
QRED = Quantity of radiant energy downward
QREE = Quantity of radiant energy emitted
QREN = Quantity of radiant energy of net flux
QRET = Quantity of radiant energy of total flux
QREU = Quantity of radiant energy upward
QRSK = Quantity of radiant energy from the sky

RATB = Radiant energy of the bottom surface
RATK = Radiant temperature in k
RATT = Radiant energy of the top surface
RECO = Reflection coefficient
RTEK = Radiant temperature of the earth's surface
RTSK = Radiant temperature of the clear sky in k

SACD = Surface area involved in conductivity
SACV = Surface area of the convector
SAFC = Surface area involved in forced convection
SANC = Surface area invovlved in natural convection
SBCO = Stephan-Boltsmann constant
SQME = Square meters
SUTE = Surface temeperature

TCCO = Thermal conductivity coefficient
TIME = Time
TREF = Total radiant energy flux

WIVE = Wind velocity in centimeters per second

GLOSSARY OF CODENS - CHAPTER FIFTEEN

SERIALS are identified by five-character, generally mnemonic codes called CODEN, listed in 1980 BIOSIS, LIST OF SERIALS (BioSciences Information Service, 2100 Arch Street, Philadelphia, PA 19103).

The headings for the lists of SERIALS are:

CODEN VO-NU BEPA ENPA ANIM KEY WORDS----------------- AUTHORS---------- YEAR

The volume and issue numbers (VO-NU) are given after the CODEN entry, followed by beginning page (BEPA), ending page (ENPA), species discussed (ANIM), KEY WORDS from the title, AUTHORS [truncated if necessary, slash (/) indicates additional authors], and year.

AGMYA Agricultural Meteorology
AJZOA Australian Journal of Zoology
AMSCA American Scientist
ANYAA Annals of the New York Academy of Sciences

BIOJA Biophysical Journal
BISNA Bioscience
BVJOA British Veterinary Journal

CBCPA Comparative Biochemistry and Physiology
CBPAB Comparative Biochemistry and Physiology A Comparative Physiology
CJZOA Canadian Journal of Zoology

ECOLA Ecology

IJBMA International Journal of Biometeorology
IJLAA Indian Journal of Animal Sciences
IREZA International Review of General and Experimental Zoology

JANSA Journal of Animal Science
JAPYA Journal of Applied Physiology
JASIA Journal of Agricultural Science
JDSCA Journal of Dairy Science
JOMAA Journal of Mammalogy
JPHYA Journal of Physiology
JRMGA Journal of Range Management
JTBIA Journal of Theoretical Biology
JWMAA Journal of Wildlife Management

NAWTA North American Wildlife and Natural Resources Conference, Transactions of the,
NJZOA Norwegian Journal of Zoology

OJVRA Onderstepoort Journal of Veterinary Science and Animal Industry

PHMBA	Physics in Medicine and Biology
PHZOA	Physiological Zoology
PRLBA	Proceedings of the Royal Society of London B Biological Sciences
RSPYA	Respiration Physiology
SCAMA	Scientific American
SCIEA	Science
SZSLA	Symposia of the Zoological Society of London
TRJOA	Textile Research Journal
ZOLZA	Zoologicheskii Zhurnal

LIST OF PUBLISHERS - CHAPTER FIFTEEN

The headings for the lists of BOOKS are:

TYPE PUBL CITY PAGE ANIM KEY WORDS---------------- AUTHORS/EDITORS-- YEAR

All essential information for finding each book in the library is given on just one line. The TYPE of book could have either AUTHORS (aubo) or EDITORS (edbo). Publishers (PUBL) and CITY of publication are given with four-letter mnemonic symbols defined below. The PAGE column gives the number of pages in the book; ANIM refers to the species discussed in the book (given as a four-letter abbreviation of genus and species), and KEY WORDS listed are from the title. The AUTHORS/EDITORS and YEAR of publication are given in the last two columns.

acpr	Academic Press	New York	nyny
else	Elsevier	New York	nyny
gaul	George Allen and Unwin Limited	London	loen
haro	Harper and Row	New York	nyny
jwis	John Wiley and Sons, Inc.	New York	nyny
mhbc	McGraw-Hill Book Co., Inc.	New York	nyny
pepr	Pergamon Press	Oxford, England	oxen
spve	Springer-Verlaug Inc.	New York	nyny
whfr	W. H. Freeman Co.	San Francisco, CA	sfca

GLOSSARY OF ANIMAL CODE NAMES

Wild ruminants are referred to in this CHAPTER by a 4-character abbreviation from the family, genus and genus-species. These are listed below under Abbreviation.

Scientific names of North American wild ruminants are those used in BIG GAME OF NORTH AMERICA, edited by J.C. Schmidt and D. L. Gilbert (1979: Stackpole Books, Harrisburg, PA 17105, 494 p.), and may be different from the scientific names given in the original literature.

The abbreviations used for North American wild ruminants are listed below.

CLASS: MAMMALIA

ORDER: ARTIODACTYLA	Abbreviation
FAMILY: CERVIDAE	cerv
GENUS: *Odocoileus* (deer)	od--
SPECIES: *O. virginianus* (white-tailed deer)	odvi
O. hemionus (mule deer)	odhe
GENUS: *Cervus* (Wapiti, elk)	ce--
SPECIES: *C. elaphus*	ceel
GENUS: *Alces* (moose)	
SPECIES: *A. alces*	alal
GENUS: *Rangifer* (caribou)	
SPECIES: *R. tarandus*	rata
FAMILY: ANTILOCAPRIDAE	
GENUS: *Antilocapra*	
SPECIES: *A. americana* (pronghorn)	anam
FAMILY: BOVIDAE	bovi
GENUS: *Bison* (bison)	bi--
SPECIES: *B. bison*	bibi
GENUS: *Ovis* (sheep)	ov--
SPECIES: *O. canadensis* (bighorn sheep)	ovca
O. dalli (Dall's sheep)	ovda
GENUS: *Ovibos*	
SPECIES: *O. moschatus* (muskox)	obmo
GENUS: *Oreamnos*	
SPECIES: *O. americanus* (mountain goat)	oram

The abbreviations used for European wild ruminants are listed below.

CLASS: MAMMALIA	
ORDER: ARTIODACTYLA	Abbreviation
FAMILY: CERVIDAE	cerv
GENUS: *Capreolus* (roe deer)	ca--
SPECIES: *C. capreolus*	caca
GENUS: *Dama* (fallow deer)	da--
SPECIES: *D. dama*	dada
GENUS: *Cervus* (Wapiti, elk)	ce--
SPECIES: *C. elaphus* (red deer)	ceel
GENUS: *Alces* (moose)	
SPECIES: *A. alces*	alal
GENUS: *Rangifer* (caribou)	
SPECIES: *R. tarandus*	rata
FAMILY: BOVIDAE	
GENUS: *Bison* (bison)	
SPECIES: *B. bonasus*	bibo
GENUS: *Capra* (ibex, wild goat)	cp--
SPECIES: *C. aegagrus* (Persian ibex)	cpae
C. siberica (Siberian ibex)	cpsi

OTHERS

Abbreviations for a few other species and groups of species may appear in the reference lists. These are listed below.

Axis axis (axis deer)	axax
Elaphurus davidianus (Pere David's deer)	elda
Cervus nippon (Sika deer)	ceni
Hydropotes inermis (Chinese water deer)	hyin
Muntiacus muntjac (Indian muntjac)	mumu
Moschus moschiferus (musk deer)	momo
Ovis nivicola (snow sheep)	ovni
Ovis musimon (moufflon)	ovmu
Ovis linnaeus (Iranian sheep)	ovli
Rupicapra rupicapra (chamois)	ruru
big game	biga
domestic sheep	dosh
domestic cattle	doca
domestic goat	dogo
domestic ruminant	doru
herbivore	hrbv
mammals	mamm
three or more species of wild ruminants	many
ruminants	rumi
ungulates	ungu
vertebrates	vert
wildlife	wldl
wild ruminant	wiru

JULIAN DAY: MONTH AND DAY EQUIVALENTS*

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	001	032	060	091	121	152	182	213	244	274	305	335	1
2	002	033	061	092	122	153	183	214	245	275	306	336	2
3	003	034	062	093	123	154	184	215	246	276	307	337	3
4	004	035	063	094	124	155	185	216	247	277	308	338	4
5	005	036	064	095	125	156	186	217	248	278	309	339	5
6	006	037	065	096	126	157	187	218	249	279	310	340	6
7	007	038	066	097	127	158	188	219	250	280	311	341	7
8	008	039	067	098	128	159	189	220	251	281	312	342	8
9	009	040	068	099	129	160	190	221	252	282	313	343	9
10	010	041	069	100	130	161	191	222	253	283	314	344	10
11	011	042	070	101	131	162	192	223	254	284	315	345	11
12	012	043	071	102	132	163	193	224	255	285	316	346	12
13	013	044	072	103	133	164	194	225	256	286	317	347	13
14	014	045	073	104	134	165	195	226	257	287	318	348	14
15	015	046	074	105	135	166	196	227	258	288	319	349	15
16	016	047	075	106	136	167	197	228	259	289	320	350	16
17	017	048	076	107	137	168	198	229	260	290	321	351	17
18	018	049	077	108	138	169	199	230	261	291	322	352	18
19	019	050	078	109	139	170	200	231	262	292	323	353	19
20	020	051	079	110	140	171	201	232	263	293	324	354	20
21	021	052	080	111	141	172	202	233	264	294	325	355	21
22	022	053	081	112	142	173	203	234	265	295	326	356	22
23	023	054	082	113	143	174	204	235	266	296	327	357	23
24	024	055	083	114	144	175	205	236	267	297	328	358	24
25	025	056	084	115	145	176	206	237	268	298	329	359	25
26	026	057	085	116	146	177	207	238	269	299	330	360	26
27	027	058	086	117	147	178	208	239	270	300	331	361	27
28	028	059	087	118	148	179	209	240	271	301	332	362	28
29	029	[060]	088	119	149	180	210	241	272	302	333	363	29
30	030		089	120	150	181	211	242	273	303	334	364	30
31	031		090		151		212	243		304		365	31

* For leap year, February 29 = JDAY 60. Add 1 to all subsequent JDAYs.

LIST OF WORKSHEETS - CHAPTER FIFTEEN