Carl von Ossietzky
Universität Oldenburg

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DIPLOMARBEIT

Patterns of habitat use of European White-fronted Geese (*Anser a. albifrons*) in the arctic breeding sites.

vorgelegt von:
Christian Ketzer

Betreuende Gutachterin:	Dr. Julia Stahl
Zweiter Gutachter:	PD Dr. Robert Biedermann

Oldenburg, d. 15.9.09

Carl von Ossietzky Universität Oldenburg

Fakultät V

Institut für Biologie und Umweltwissenschaften

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DIPLOMARBEIT - DIPLOMA THESIS

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> “A harbourless island with a dangerous coast, it was wisely avoided by any who had a more distant mission on those seas.”
>
> (from Aubyn B. R. Trevor-Battye, 1895: “Ice-bound on Kolguev”)

The field research for this thesis was possible within the framework of the annual Kolguev expedition of European White-fronted Goose Research Programme. The expedition was funded by Vogelschutz-Komitee e.V. and UNEP - ECORA. Radio equipment was provided by ALTERRA Wageningen. Further travel expenses were covered by University of Oldenburg AG Landschaftsökologie. ESRI Corporation provided ArcGIS 9.2.

VOGELSCHUTZ KOMITEE e.V.
UNEP
ALTERRA WAGENINGEN UR
CARL VON OSSIETZKY universität OLDENBURG

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1. Acknowledgements

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2. Introduction

2.1 Background of study

Kolguev is has a comparatively easy accessibility by aerial means of transportation and nowadays by ships from the Russian mainland coast, as well. But in the 20th century neither the island's avifauna has been explored systematically and regularly until the early 1990s nor any relationships of avian herbivores to the plants they are foraging on has been explored on Kolguev island. Kolguev is known to geographers since the 16th century (see chapter 3.1.2) and only a few efforts were undertaken to explore the island's ecosystem. From 2006 to 2008 the island's avifauna has been explored annually in the framework of a Russian-German joint research project with the emphasis on research on European White-fronted Geese *Anser a. albifrons* (to which I refer as EWfG in the following), Tundra Bean Geese *Anser fabalis* and Barnacle Geese *Branta leucopsis*.

Previous observations of foraging EWfG suggested a study on habitat use because of the observed difference between foraging sites chosen by the geese directly after spring migration to their breeding grounds on Kolguev and foraging sites of the subsequent brood rearing period in the summer life cycle of White-fronted Geese (A. V. KONDRATYEV, H. KRUCKENBERG pers. comm.). During arrival period in late May and early June and in the subsequent breeding period in late June and early July the geese show a scattered distribution among the whole island whereas later stages of brood rearing and moulting show a gradually movement of geese along the tundra bodies of water towards the lakes together with the young. This movement is resulting in aggregated patterns of goose distribution around the lakes and adjacent areas. Occurrence of predators is a possible explanation of habitat selection of the geese as well, but the survey design of the study focuses on availability of forage plants.

2.2 Research question

This study tries to explain to what extent habitat use of European White-fronted geese on Kolguev is influenced by spatio-temporal availability of forage plants and whether the selected exclosure and control approach is able to reflect a different consumption of different plants in different stages of the arctic summer life cycle of European White-fronted geese on Kolguev.

Furthermore, spatial patterns of habitat use are supposed to be figured out by analysing influence of lakes on habitat selection of geese. The spatial approach at the end of the season is also supposed to help to distinguish between habitat selection induced by availability of forage plants and predator- induced habitat selection.

3. Materials and methods

3.1 Study area

3.1.1 Geographic extent

The arctic Russian island Kolguev is situated in the South-eastern shelf region of the Barents Sea divided from the Russian mainland coast by the 75 km wide Pomorskij Strait, north-west of Kolokolkova Bay (Malozemelskaya Tundra). The geographic extent of Kolguev is N 69°30’ to N 68°41’ (North to South ~90 km) and E 48°14’ to E 50°18’ (East to West ~70 km). Without considering the lagoon and spit area in the Eastern part of Kolguev, the island is approximately 5000 km^2 large.

3.1.2 Short history of discovery

The island was discovered primarily by Sir Hugh Willoughby in 1553 during his attempt to find the North-East Passage for the British Empire. Although he failed to do so, he managed to reach the coast of Kolguev. TREVOR-BATTYE (1895) suggests that later writers assumed misleadingly that Willoughby reached the coast of Novaya Zemlya, but his sufficiently exact measurements of latitude suggest a successful landing on Kolguev rather than reaching Novaya Zemlya (TREVOR-BATTYE, 1895). During the following centuries several expeditions fixed exact coordinates of the island’s shoreline and the first scientific expedition under Savelyev and Ruprecht took place in 1841 (TREVOR-BATTYE, 1895). Several sources of Trevor-Battye suggest an early contact of the indigenous natives, the Nenets, to Russian traders in order to deal in natural goods such as Barnacle geese *Branta leucopsis*, other edible wildfowl, fox furs, reindeer products and seal fat to acquire products only available on the mainland (TREVOR-BATTYE, 1895).

Aubyn B. R. Trevor-Battye and his companion Thomas Hyland landed on Kolguev deliberately in 1894 for ornithological purpose which was often connected with intensive hunting in these times. Next to ornithological observations for the British

Ornithologists Union, Trevor-Battye delivered a detailed ethnographical description of the indigenous Nenets people while sharing their nomadic way of life. Nowadays the Nenets still live on Kolguev although they have lost numerous traditional habits due to forced assimilation in Soviet times. Assimilation processes, for instance, are expressed in usage of modern means of transportation such as snowmobiles instead of reindeer sleighs (A. V. KONDRATYEV and ALBERT ARDEEV pers. comm.).

3.1.3 Human influence on Kolguev

Carrying out a study on avian herbivores in the Russian Arctic might be connected with certain expectations concerning the assumed wilderness of this region. But it has to be said that the island is by no means a wilderness in terms of missing direct human influence.

As they did in former times, a nomadic living part of the Nenets community is still herding numerous reindeer and hunting geese and other birds easier to pursue such as the ubiquitous Willow Grouses *Lagopus l. lagopus*. The vast majority of Nenets today lives in the small village of Bugrino with a basic infrastructure in the very south of Kolguev. The village is served by helicopter more or less regularly. Moreover, ecosystems of Kolguev are directly influenced by oil exploration and its facilities such as oil rigs, crew barracks and a cargo plane landing strip on the spit in the Eastern lagoon system of the island. Furthermore occasional shoots in the Northern part of Kolguev, consisting of members of Russian oil company LukOil, take place. Except of two meteorological stations, scattered, wooden huts providing protection to migrating Nenets reindeer herders, some abandoned oil rigs and wooden remains of geological surveys for oil exploration, Kolguev has no noteworthy infrastructure. Roads s. str. are completely absent and next to some of the abovementioned huts, the only witnesses of human activities on central Kolguev today are some paths visible in the short arctic summer. The latter are mainly caused by snowmobile and reindeer sleigh use in the late snow melt period and even during the summer.

I could not figure out, to what extent the influence of herded reindeer affects the island’s ecosystem, especially in relation to geese. But it remains doubtful, whether hitherto existing large scale classifications of human influence being absent on Kolguev as stated in DÖMPKE ET AL. (Eds. 1998) can be kept up facing the situation on a smaller scale. There is no area with a certain kind of protection status existing on Kolguev, thus the island is exposed to any future human attempts concerning land use. In terms of future protection it has to be considered that Kolguev appears to be in the focus of Russian oil industry. In the light of the particular interweavement of private industry interests and Russian politics it is to be expected that future decisions concerning the area of conflict of resource exploitation and nature conservation will not be made in favour of Kolguev's sensitive tundra ecosystem.

3.1.4 Climate

Kolguev is situated in the Arctic as it is north of Polar Circle (N 66°33') and north of 10°C July isotherm marked by the Russian mainland coast of Malozemelskaya Tundra.
The island has a mean annual temperature of -2.6°C. The coldest month is February (-12.9°C mean monthly temperature) while the warmest month is August at 7.7°C mean monthly temperature. Mean July temperature is 7.2°C. The growth period, defined by days of an 24h average exceeding 5°C, lasts on average 75 days. The last day of snowfall in 2008 was 15th June and after a two-week period of intensive snow melt, last snow patches melted at the end of June. Due to a low quality of our data logger measurements in the field resulting from an insufficient protection against wind chill and direct sunlight, I adjusted these temperature values by averaging over the data logger values and the manually noted daily values of a simple thermometer in the lee of a tent. The resulting data suggest a markedly higher average July temperature of 12°C and an August average of 7.7°C. The period of daily average temperatures above 5°C began at 16th June and did not end before leaving Kolguev at 18th August. The intensive snow melt period was resulting in long detours to cross rivers and made fieldwork occasionally difficult. The first night frost after June was on 2nd August. There is no freely available database explaining, whether the measured increased July temperature on Kolguev is a regular phenomenon during the last years potentially caused by arctic climate change. According to Nenets' information about comparisons of annual weather based on experience, 2008 was a year of high snow quantities and a late initiation of snow melt.

3.1.5 Fauna

Although there are strong facts supporting the important role of locally and temporarily different availability of food determining presence and absence patterns of grazing geese, it is important to give some remarks on species co-occurring with geese. It is necessary to understand the special relationship of these species as predators and disturbers. Certain forms of evasive behaviour in geese can be induced by predating species and result in patterns of habitat use which are mainly explored by a comparative analysis of food plants in this thesis.

Red foxes *Vulpes vulpes* and Arctic foxes *Alopex lagopus* predate adult geese as well as eggs and chicks. Buried eggs either serve as a reserve in times of food shortage or direct summer diet. Rodents, such as Lemmings *Lemmus spec.*, a common food source of foxes in high arctic ecosystems, are completely absent on Kolguev. A possible explanation for the species' absence might be the distance between Kolguev and the mainland tundra. Among the avian predators the widespread Glaucous Gull *Larus hyperboreus* is an important predator of goose chicks and eggs. Furthermore, predation of the widespread Arctic Skua *Stercorarius parasiticus* is an important factor limiting the number of individuals, too. Both gull species use to patrol around goose clutches and around leading adults during early stages of brood-rearing, waiting for the right moment to predate eggs or chicks. Next to the ubiquitous foxes, gulls seem to be the most serious thread on young geese and eggs. Among the birds of prey, Rough-legged Buzzards *Buteo lagopus*, Peregrine Falcons *Falco peregrinus* and less abundant Gyr Falcons *Falco rusticolus* are important factors to be named among the geese predators as well.

This thesis tries to shed light on locally and temporarily different availability of food plants as a driving factor inducing patterns of habitat use in EWfG. Moreover, predator pressure of the abovementioned fox species can be another important factor driving the brood-rearing geese families to the lakes. Only the pelagial of a lake provides efficient protection against hunting foxes by forming an insurmountable obstacle to them. During our observations we could observe numerous attempts of hunting foxes to catch brood-rearing geese thus escaping to the closest lake. Once the geese are on the pelagial, the foxes even tend to patrol along the lake shore for a while, figuring out whether there is another chance to catch a temporarily incautious goose leaving the expanse of water too early.

Reindeer *Rangifer tarandus* also tend to have a certain influence on the breeding grounds of the geese, too. Next to different forms of non-directional distribution, seasonal migration of wild reindeers induced by locally different food abundance keeps up a certain disturbance level for the geese. Reindeer migration influencing geese can be man-induced as well. The Nenets are herding a semi-domestic part of the reindeer population following large reindeer flocks all over the island. Facing these large numbers of reindeers it would be interesting to carry out studies of reindeer migration influencing geese in their high-arctic breeding sites.

3.1.6 Flora

Due to the phytogeographic zonation of the Arctic presented by YURTSEV (1994) Kolguev is situated in the Northern hypoarctic tundra subzone right below the arctic tundra subzone whose beginning is marked by the Northern part of the Barents Sea around Novaya Zemlya. In a floristic division of the Arctic, Kolguev belongs to the Kanin-Pechora province (YURTSEV, 1994). YURTSEV (1994) emphasizes on the strong influence of European boreal species even on Kolguev and an impoverished arctic and arctic-alpine plant complex. Low shrubs and dwarf shrubs together with arctic grasses, mosses and lichens of the graminoid tundra (WALKER ET AL., 2005, WALKER ET AL., 1995) are forming a closed vegetation cover. The study presented focuses on the relationship of geese to their forage plants thus some characteristic forage habitats are described in the following instead of giving a complete description of Kolguev’s fauna.

Forage habitats used by the geese at the beginning of the summer season at the end of May could be identified by selecting *Carex spec.* (especially *Carex aquatilis*) dominated patches in wet areas of shallow depressions, under the influence of early snow melt. Forage habitats the geese are using in the later summer season in the nearest vicinity of lake shores and river valleys could be distinguished by choosing patches which showed high abundance of grasses. Those patches were dominated by mosses and arctic poacea. Forage habitats situated in greater distances to the lake shores consist of comparably dry areas in the hill slopes of the depressions most of the tundra lakes are situated in, or of patches at the upper slope. Next to an extensive cryptogam layer these habitats are generally dominated by arctic grasses, e.g. *Festuca spec.* and *Puccinellia spec.* and initial growth of crippled *Salix spec.* and *Betula spec.* at the upper slope while the transition zone of these habitats to the abovementioned humid forage habitats in the nearest vicinity of the lake shores is characterized by *Eriophorum spec.* and *Rubus chamaemorus* occurence.

3.1.7 Survey area

The field season on Kolguev in 2008 marked by the helicopter transfers from the administrative centre of Nenets Autonomous Okrug Naryan Mar to Kolguev and vice versa lasted from 28th May to 18th August. Our expedition established the base camp on N 69°10’05’’ and E 48°54’36’’ near a dune complex in a depression at the southern riverbank of Peschanka.

Due to demands of easy accessibility in times of rivers being covered by ice in spring and very high river water levels during the snow melt period I chose a survey area south of the base camp. The survey area was covering about 40 km^2 between the river Ambarnyi in the west, river Vangpenzya in the east and Peschanka in the north. At its southernmost border the survey area was bounded by the origin of river Senkina (2nd A3 size folded map in Appendix gives an overview on selected plots).

In terms of representativeness the area mentioned above might appear rather small compared to the size of the whole island. But only within a corridor of that size, a sufficient number of plot checks and observations per day was possible in a reasonable timeframe. Moreover, the size of the area selected guaranteed avoidance of pseudo-replication. For reasons of checking plots in regular and temporally comparable intervals one had to conduct as much plot checks as possible in a period as short as possible. Furthermore, the area contained a large number of lakes which were considered in the study. Most of the inland landscape types from the central Peschanka river up to the central hilly ridge of Kolguev was covered by the area selected.

3.2 Sampling design and conduct of sampling procedure

In order to create a reliable set of easy-to-apply methods providing data on habitat use and working under rather unpredictable conditions, I chose a multilevel sampling approach shown in Tab. 3-1 below.

Tab. 3 - 1: Sampling approach of 2008 field survey.

Priority	Sampling method	Data on…	Temporal aspect
1	Exclosure and control experimental set-up	Biomass consumption and growth Food quality (by C/N analysis) Grazing pressure	Time series
2	Radio tagging of brood-rearing EWfG	Enhanced visibility of grazer's direct influence during the season	Time series
3	End-of-the-season-survey	Spatially explicit impression on grazing pressure	Cumulative

For a chronological overview on sampling activities see Tab. 3-2 below.

Tab. 3 - 2: Steps in 2008 field survey. The annotation column refers to chapters explaining the particular survey step.

Time	Sampling parts			Annotations
May	Orientation^{*1}			^{*1} Chapter 3.1.2 ^{*2} Chapter 3.2.2 ^{*3} Chapter 3.2.3 ^{*4} Chapter 3.2.4 ^{*5} Chapter 3.2.5
June	Establishing car_aq plots^{*2}	Establishing puc_phr plots^{*2}	Neck collars^{*4}	
July	Plot checks^{*3}		Tracking attempts^{*4}	
August	Plot rebuilding	End-of-the-season survey^{*5}		

3.2.1 Field map creation and usage

It was necessary to invest some time of the pre-expedition efforts in creating a reliable field map based on satellite images to allow orientation in the field. The satellite image-based field map delivered an up-to-date impression of landscape elements for a proper plot site selection. Therefore, I created a field data set in ArcGIS 9.2 (ESRI

CORPORATION). It consists of free of charge available Landsat 7 ETM+ data (NASA LANDSAT PROGRAM, 2000) in a MrSID-compressed mosaic of GeoTIFF files. See <list of abbreviations> for remarks on data types mentioned before. I downloaded these images and processed data in ArcGIS 9.2. The Landsat scene serves as a basic 30 m x 30 m resolution layer for further editing both in field and during later data processing. More information about the Landsat program and sensor features, which cannot be given here for brevity, is given in ALBERTZ (2007). All GPS data gained in the field could directly be implemented in GIS by using the extension MxGPS for ArcMap (MXGEO CORPORATION, 2006). In addition to the digital version, printed excerpts of the satellite images with an visible UTM coordinate grid as an overlay provided a useful field map. This field map was showing the recent number, extent and position of lakes and other waterbodies better than the out-of-date soviet maps available in the internet and elsewhere. Despite their sometimes intentional infrastructural inaccuracy for strategic reasons, the soviet military maps deliver geographic information in insufficiently mapped, remote areas. These globally available small-scale maps posed an invaluable help in combination with the abovementioned satellite images. The book about soviet military mapping from FILATOV ET AL. (2005) gives a detailed description helping to understand and to use these charts.

3.2.2 Establishment of Exclosure & Control plots

In the following I will describe technical aspects of erecting exclosures and control prior to a subsequent description of measurements conducted in the plots. There are important implications resulting from the plot design itself which have to be considered already in the stage of erecting the constructions.

The experimental set-up of a single exclosure consisted of four 50 cm aluminium poles of 35 cm above ground height and tightened thin red ropes run in 15 and 35 cm above ground. The construction was completed by two diagonal lines at the upper end of the poles. This construction was forming a lightweight and easy-to-transport but effective fence against grazing geese. In addition to that, the exclosure construction was intended to form a sole manipulation of grazing pressure. Therefore one had to avoid possible shadowing which can be caused by inappropriately thick poles and the material forming the lateral and dorsal barrier of the fence construction. The lateral ropes were intended to keep out geese grazing around the construction. The dorsal ropes forming the ‘roof’ of the exclosure should have a protective function for the plot, concerning eventual bird landing attempts from above. The poles were stabilized by fixing them on the ground with an additional rope connected to tent pegs in each of the four outer corners of the plot.

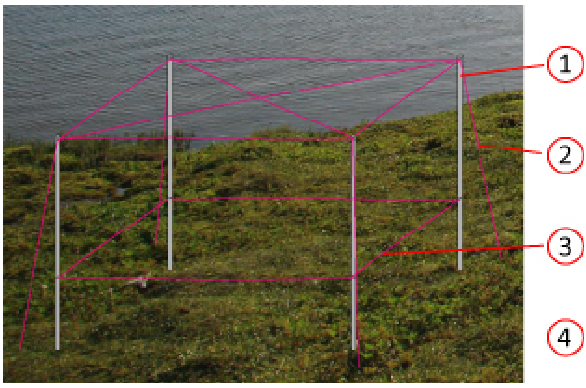


Fig. 3 - 1: Exclosure plot

Fig. 3 - 2: Control plot

1: Aluminium pole, 2: Stabilizing line, 3: Fence line, 4: Shashlik-piles furnished with tape, indicating the control plot. Piles and flags are drawn to a larger scale to enhance visibility.

The exclosures and associated control plots were both covering an area of 1 m^2. They were erected as soon as the snow in the particular site had melted and plant cover could be identified. For remarks on snow cover conditions throughout the field season see chapter 3.1.4 above. When erecting the fences I considered possible edge effects that might result from the geese’s avoidance of nearest exclosure surroundings caused by the ‘unfamiliar object’ itself. In contrast to that, attracting aspects of the construction resulting in intensified grazing in the direct vicinity of the plot are also conceivable. Therefore, control plots were established in an adequate distance to the exclosures by considering homogeneity of the selected habitat. The control plots consisted of little wooden 20 cm barbecue sticks whose upper ends had been furnished with flashy little tapes on each edge of the plot in order to facilitate recovery.

The selected plot sites (n=32) were situated in areas of early snow melting dominated by early available *Carex spec.* and river valleys or lake depressions in areas of late snow melting whose shores have both stands of *Carex spec.* and *Puccinellia spec*. The survey focused on a limited selection of species (*Carex aquatilis*, *Carex subspathacea*, *Puccinellia phryganodes*) in order to simplify the sampling procedure and reduce material for further laboratory analysis (See chapter 3.3) to be brought back to Germany by plane. There was no official permission available to export plants out of the Russian Federation. Therefore all material collected had to be in a size to ease undiscovered transport. All selected plant species were suspected to be fed by EWfG as it was known from former expeditions to Kolguev (A.W. KONDRATYEV and H. KRUCKENBERG pers. comm.) and existing works on foraging White-fronted Geese (<citation>). To guarantee recovery, I marked both exclosure and control plots by fixing the coordinates with a handheld GPS (GPS 12 Personal Navigator, Garmin Inc.).

Tab. A1 in the Appendix gives an overview on the characteristics and coordinates of each established plot. For an additional spatial overview see map (2nd A 3 size folded map) in the Appendix.

3.2.3 Measurements in Exclosure and Control plots

As it is already described in the two introductory tables concerning the time schedule of the survey (see Tab. 3-1 & Tab. 3-2 above), the main component of field survey was the exclosure and control approach. It was intended to analyse spatio-temporal differences of biomass consumption expressed in differences of canopy height and plant dry matter weight. It delivered data on biomass quality expressed in C/N ratio and spatio-temporal differences of grazing pressure which can be measured by counting the geese’s dropping. The exclosure plot is serving as a manipulative element excluding the geese’s influence and simulating undisturbed plant growth under “normal”, abiotic conditions. The marked control plot serves as comparable area under “complete” conditions of grazing herbivores influencing plants during the summer season.

I conducted repeated measurements in the plots adhering to more or less regular intervals. See chapter 5.1.1 for remarks on the possibility of keeping intervals regular. The survey began with a first check directly after establishing the plots and ended right before leaving Kolguev. Depending on the time of plot establishment, I could check the plots three to five times during the season. The repeated measurements in the plots were intentionally limited to five checks or less per season to minimize disturbing actions in the grazed areas and thus influencing the results of grazing pressure measurement by one's own presence. Each check consisted of the following procedures illustrated in Tab. 3-3 below:

Tab. 3 - 3: Plot check procedures.

Order No.	Procedure	No. of repetitions	Ex.	Cl.	Surr.	Annotations
1	Tiller density measurement	10	✓	✓		25 cm^2 plastic frame thrown over the shoulder
2	Tiller height measurement	5				Estimation & generalization by using a metal ruler
3	10 Tiller sample *Carex aquatilis*	1	✓	✓		Cutting of above-ground plant material by scissors
	and					
3	*Carex*-turf taking	1	✓	✓		400 cm^2 turf
	or					
3	10 Tiller sample *Puccinellia phryganodes*	1	✓	✓		Cutting of above-ground plant material by scissors
4	Dropping count	1	✓	✓		Randomly selected, covering a 4 m^2 area by using a rope (1.13 m)
5	Dropping count	5			✓	
6	Sorting Turf-components	1	✓	✓		Separation of *Carex* material in the camp for later analysis

While taking the tiller samples for later assessment of available biomass one had to consider that incoming geese in spring also feed on the stem bases of *Carex aquatilis*. That is because fresh green above-ground plant parts with low fibre content are still scarce directly after snow melting in late May and early June. During this period the relatively long-billed EWfG also use the submerged parts of the first delicate shoots breaking through the melting snow or even through thin ice covers of stagnant water in boggy patches formed by late frosts in the first half of June. Therefore I took 400 cm^2 (20 x 20 cm) turfs out of the exclosures and control plots to be sorted by *Carex* and Non-*Carex*-compartments in the base camp. Tab. 3-3 above clarifies the particular *Carex* plot check procedure. Single *Carex* plants could then be divided in leaves, stem bases, roots and flowers back home in the laboratory as it will be described in chapter 3.3.1 below.

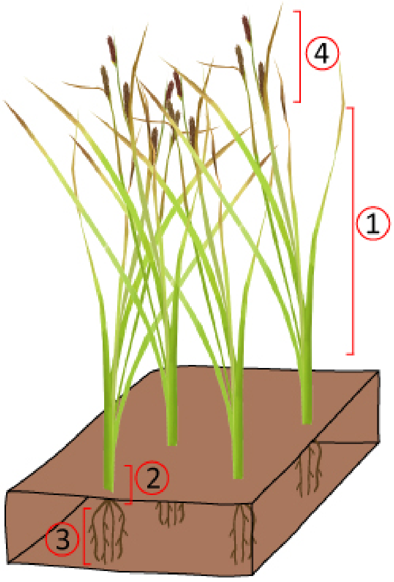


Fig. 3 - 3: Illustrated Carex aquatilis turf with plant parts taken for diet analyis.

1: Leaves, 2: Stem bases, 3: Roots, 4: Flowers.

The illustration shows flowering Carex in July. In earlier stages of the season semi-submerged stem base-parts and roots are dominating the plant composition of a turf. The turf body is drawn to a smaller scale and the number of plants is lower than in reality to save space.

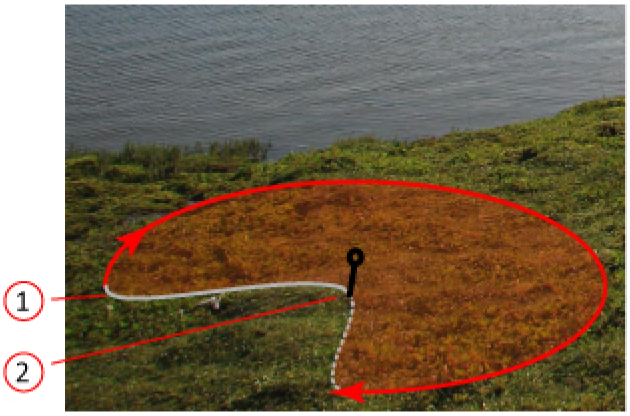


Fig. 3 - 4: Illustrated dropping count. The illustration shows a dropping count as it is mentioned in Tab. 3 -3.

1: 1,13 m line, 2: Tent peg. The tent peg serving as a central fixation for the line and is surrounded while counting the droppings. It is drawn to a larger scale to enhance visibility.

The size of turfs taken guaranteed a sufficient number of individual plants per turf (n ≥ 10), avoiding a total devastation of the plot throughout the season. I could not sort the collected plant material in situ for the abovementioned reason of keeping the disturbance level as low as possible by a maximum reduction of the duration of stay in the plot site itself.

All samples were stored in paper bags fixed on a line in the camp’s equipment tent to protect them from humidity. This comparably dry and airy kind of storage guaranteed a fast drying of the samples to an acceptable moisture level and minimized further decomposition caused by microbial activities and facilitated by humidity.

3.2.4 A direct approach to habitat use: Radio tagging

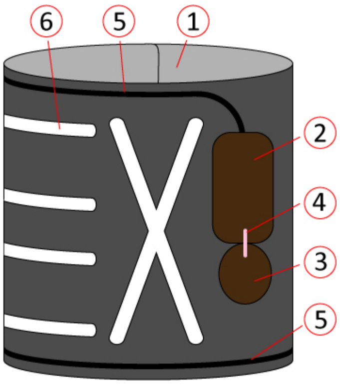
We chose an additional radio tagging approach following the plot establishment stage of the project trying to figure out distinct patterns of habitat use by following brood-rearing EWfG. Our idea was to identify geese in the exact habitat used during brood rearing. The radio tagging approach was intended to track whole families of EWfG at the time of individuals accumulating near the tundra lakes instead of merely observing the effects by measuring biomass consumption with the help of the abovementioned comparison of grazed control and ungrazed exclosure plots. One expected advantage was to make repeated tracking possible and thus creating a time series of goose groups grazing in a distinct habitat. Chapter 5.x refers to numerous problems of the selected method.

The radio units on the neck collars applied to the female EWfG had already been used by personnel of ALTERRA Wageningen to track individual movements of Eurasian Widgeons *Anas penelope* in the Dutch polder regions for damage assessment caused by intensive duck grazing on polder land (Gerard Müskens pers. comm.).

The radio neck collars of ALTERRA used in 2008 field season contained a small and lightweight VHF radio transmitter emitting a permanent signal traceable by handheld VHF receivers (ICOM ‘Communications Receiver’ IC-R10) for a three month period. The transmitter is bonded to the exterior of a black standard neck collar bearing an unique engraved code, which is normally used in ringing EWfG. The radio unit is sealed with liquid rubber to protect it from humidity and dirt. The radio’s antenna is fixed alongside the upper and lower edge of the PVC neck collar body sealed by cured liquid rubber as well. The illustration below shows a schematic neck collar furnished with a transmitter.

Fig. 3 - 5: Illustration of neck collar with transmitter.

1: Flexible PVC ring body, 2: VHF radio unit, 3: Battery, 4: Soldering point, 5: Antenna loop, 6: 3-capital ring code, here XUU.



I used ten transmitters of frequencies between 151.998 and 153.9705 MHz. To save battery power, the radio unit was soldered to the battery just before applying the neck collars to a female EWfG. Only one radio unit could easily be started by removing a taped magnet from the outer body releasing an integrated magnet switch instead of soldering. We chose nests of female White-fronted geese to be caught during the late incubation period right before hatching when the young was already audible and the eggshell partially fractured. The sample size of collars attached was n=10, restricted by the number of expensive radio neck collars. The longer the incubation period has proceeded, the more likely female EWfG will return to the nests. They are attracted by the calling young immediately after a first banishment caused by our direct presence at the nest while positioning and arming the trap.

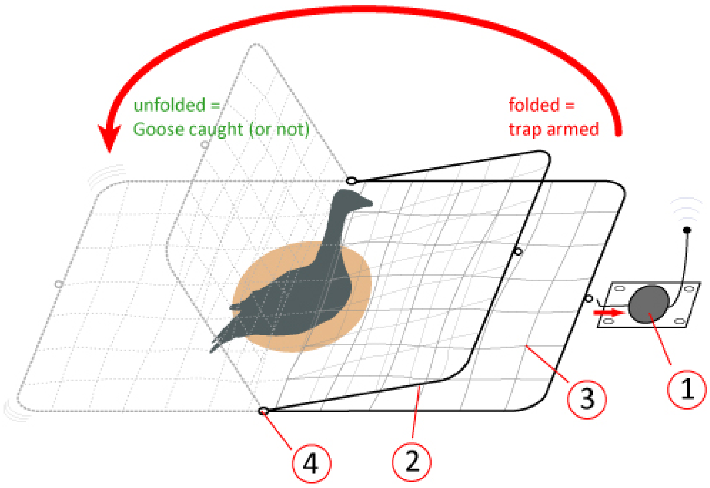
The trap described in the following had been used successfully on former expeditions both as manually, line-triggered and as remote-triggered versions (A. V. KONDRATYEV pers. comm.). The trap type basically follows the “luchok” trap design (PRIKLONSKIJ, 1960). The metal parts of the trap are to be camouflaged as properly as possible not to cause the goose’s distrust when it is returning to the nest. The modern version of this trap type has a servo-motor driven, remote-controlled trigger mechanism. The trigger mechanism contains a little hook releasing the clamped spring driven bails. The illustration below shows a schematic setting of a nest surrounded by a trap at the moment of unfolding bails directly after release mechanism being triggered by the remote control.

Fig. 3 - 6: Illustration of trap.

1: Remote controlled trigger unit,

2: Movable metal bail, 3: Nylon net,

4: Spring mechanism.



The unfolding trap bails pull a net over the goose in a split second which should therefore be unable to escape. Once the goose is successfully fixed, the neck collar can be attached by snapping the PVC ring around its neck and assuring it against opening by gluing. After re-releasing the goose and removing the trap construction, the goose is supposed to come back to the nest and can subsequently be tracked while it is leading the growing young.

3.2.5 End-of-the-season-survey

As a spatial approach to figure out patterns of habitat use we decided to conduct an “End-of-the-season-survey”. It was supposed to deliver spatial data about habitat use in a very short period near the end of the summer season in order to assess the assumed peak of grazing pressure prior to departure of the geese to their wintering grounds. All procedures of the survey are described in Tab. 3-4 below.

Tab. 3 - 4: Steps in final survey.

Order No.	Procedure	No. of repetitions	Remarks
1	Lake selection	-	Criteria: area, position
2	Selection of forage habitat	-	
3	Dropping counts in each habitat	5	
4	Distance measurements	5	Once per count

I chose n=49 lakes of various sizes in a 40 km^2 area in order to count droppings in different forage habitats of different distances to the lakes. The dropping counts were again supposed to deliver data on grazing pressure in relation to the parameters size of forage habitat, lake size and distance to the lake. Each lake was visited once within a four-day period from 10th to 13th August right before leaving the island. This short period gave me the possibility to compare different lakes in a final stage of grazing before departure of the geese to the Central European wintering grounds. Five randomized dropping counts were conducted in different forage habitats near the lake shores (For a detailed description of the dropping counts see chapter 3.2.2). Additionally, the overall-distance of counts to the lakes was measured in each habitat. The lake size could be estimated by creating a shapefile consisting of lake polygons on the basic satellite image layer whose usage in map creation is described in chapter 3.2.1 above. The size of forage habitats could be estimated by creating “buffers” around lake polygons. I measured all distances using a LASER-based distance measuring device (Leupold RX 1 6x23 mm) common among hunters to estimate shot distances. A map in the Appendix (2nd A 3 size folded map) is giving an overview on lakes chosen for the survey.

3.3 Laboratory analysis

After returning to Germany further measurements were conducted in the laboratory to gain data on quantity and quality of biomass available to grazing geese. The analysis could not take place directly on Kolguev due to our limited analytical facilities in the base camp. Therefore it was done in Germany. Prior to the detailed description of laboratory analysis the table below gives an overview about analytical steps.

Tab. 3 - 5: Steps in laboratory analysis.

Order No.	Measure	Part of Analysis	Sample type		Sample No. [1]			Plant parts
			Puc.	*Car.*	1st	Intm	last	
1	Oven-drying	Biomass	✓	✓	✓	✓	✓	Whole plants
2	Weighing			-				
3	Sorting							L, SB, R, F [2]
4	Oven-drying		-	✓				Leaves, stem bases
5	Weighing							
6	Grinding	C/N analysis	✓	✓	✓	-	✓	Leaves, stem bases
7	Weighing in							Homogenized material
8	Oven-drying							
9	C/N Analysis							

[1] Indicates sample selected for analysis taken out of all samples collected during the season.
Intm = All samples between 1st and last.

[2] L = leaves, SB = stem bases, R = roots, F = flowers.

3.3.1 Above-ground plant biomass

I oven-dried all *Puccinellia* and *Carex* samples at 65°C for 24 hours (UT 6760, Heraeus and Memmert 600 ovens) to create comparable biomass samples of an equally low water content for weighing as well as to stop all ongoing biotic activities as it is suggested by ALLEN (ED. 1989). I weighed the dried *Puccinellia* samples on a 0.1 mg precision balance (CP 225 D, Sartorius) as soon as possible. Material which could not be weighed immediately after leaving the oven was stored in an exsiccator until weighing. Exsiccator storage prevents dried plants from absorbing air humidity which is facilitated by the chilling process and during further storage under conditions of normal compartment air. In contrast to the *Puccinellia* samples I had to divide dried *Carex* plants into leaves, stem bases, roots and flowers in the laboratory for the abovementioned reasons of leaving the plot sites as fast as possible (See chapter 3.2.2). Root and flower material could be disposed because the focus of the survey lies on plant parts serving as a food source for geese. Considering the comparably long time of plant parts being exposed to relatively humid laboratory atmosphere during the sorting process, sorted *Carex* parts were dried at 65°C again (Memmert 600) and stored in an exsiccator before the final weighing of leaves and stem bases.

3.3.2 Nutrient content: C/N analysis

I grinded a sufficient amount of dried *Carex* (leaves and stem bases) and *Puccinellia* (whole plants) in a pebble mill (Pulverisette 7, Fritsch) after gaining plant weight data in order to homogenise the material of both sample plants containing all plant parts except roots (See chapter 3.3.1 above). Afterwards I oven-dried the grinded material again for about 5 hours in opened snap-cap vials at 105°C to guarantee total absence of water in the samples (ALLEN, ED. 1989). I weighed out 2 to 3 mg of plant powder (0.1 mg precision balance CP 225 D, Sartorius) in tin capsules (Tin capsules for solids, Säntis Analytical) and exsiccator-stored the tin caps until C/N analysis. For the abovementioned reasons of humidity absorption (see chapter 3.3.1 above) I exsiccator-stored the closed snap-cap vials containing the grinded plant material which could not be weighed out immediately after leaving the oven. The amount of plant powder weighed in the tin capsules was noted for further consideration during the actual analysis of total C and N content per sample by an elemental analyzer (CHNS 1112 Analyzer Flash EA, Thermo Electron Corporation).

The underlying analysis principally follows the description given in ALLEN (ED. 1989). In the analyzer the sample together with the tin capsule is combusted at 900 to 1000°C in pure oxygen. The combustion gases are divided in a separation column and subsequently identified by a heat conductivity detector. The obtained values of % C and N per sample provided the basis for further calculations on C/N ratio (ALLEN, ED. 1989) and the abovementioned data on total C and N content are used in the statistical data analysis which is described in chapter 3.4.2 below.

3.4 Data analysis

All unprocessed data on vegetation structure and goose grazing pressure gained directly in the field and data on plant weight and C and N content gained later on in the lab was arranged in Excel files for further analysis in R (R DEVELOPMENT CORE TEAM 2008). All Excel files can on the Data CD in Appendix.

3.4.1 T-test

I used paired t-tests to analyse differences of either paired exclosure and control plots or plots of the same nature but in two different sampling stages of the summer season (e.g. C/N ratio values at the beginning and the end of the summer season). All t-tests were processed in R using the function `t.test`. I considered paired plots by using `t.test(x,y,paired=T)`. The R test script can be found in Appendix (Data CD).

3.4.2 One-way ANOVA

A one-way ANOVA was used to analyse differences between more than two levels of the factors biomass, sward height and grazing pressure in the course of the summer season. One-way ANOVA was processed in R using the `aov()` function. The ANOVA script used in R can be found in Appendix (Data CD). One-way ANOVA requires heteroscedasticity, which was tested by conducting Fligner-Killeen test of homogeneity of variances using the `fligner.test()` function in R as suggested by CRAWLEY (2009) prior to ANOVA calculations.

3.4.3 Kruskal-Wallis test

Kruskal-Wallis test was used in data sets which did not meet the requirements concerning homogeneity of variances to conduct an ANOVA (see remarks on heteroscedasticity above). Kruskal-Wallis was thus used to conduct an “alternative” one-way analysis of variance by using the function `kruskal.test()` in R when there were occurring any significant differences in variances across the compared samples.

3.4.4 Post-hoc tests

I used Tukey’s HSD test (honest significant differences) as post-hoc test following one-way ANOVA to compare values of different sampling stages. In the abovementioned case of choosing Kruskal-Wallis test instead of ANOVA I used the function `pairwise.wilcox.test()` in R to conduct a post-hoc test based on Mann-Whitney U-test.

3.4.5 Lake and forage habitat patch size calculation

Sizes of lakes were calculated with ArcGIS “calculate geometry”-functions. Sizes of vegetation patches serving as forage habitats were calculated using the “Multi Ring Buffer” -function in ArcGIS. The selected buffer width complied with measured distances of surrounding vegetation units to the lake shores. Each buffer resulted in a new forage habitat patch polygon whose size could again be determined using area calculation functions in ArcGIS.

4. Results

4.1 Seasonal differences in forage plant availability

In order to save time and space, the analysed forage plant species *Carex aquatilis* and *Puccinellia phryganodes* are named reduced to genus.

4.1.1 Seasonal differences in plant biomass

Data obtained on plant weight of 20-tiller samples in the lab and 25 cm^2 tiller density measurements in the field were used to calculate biomass as following:

$$Biomass\left[g\cdot m^{-2}\right]=\left(\frac{tillerweight\ [g]}{20}\right)\left(tillerdensity\ \left[tiller\cdot 25\ cm^{-2}\right]\cdot 400\right)$$

Biomass weight per m^2 is calculated by multiplying weights of single plant tillers by the number of tillers. The weight of a single tiller is calculated dividing a 20-tiller sample by 20. Number of tillers is achieved by multiplying tiller density of a 25 cm^2 area by 400.

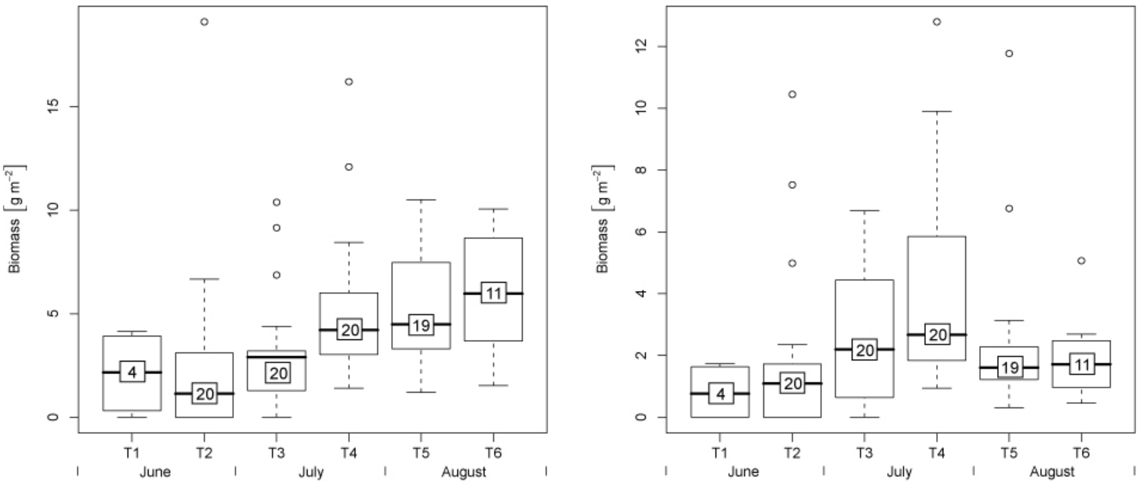


Fig. 4 - 1: Development of *Puccinellia* leaf biomass in ungrazed (left box) and grazed plots (right box) in the course of the summer season (T= sampling stage).

The ANOVA results for *Puccinellia* leaf biomass (Tab. 4-1) suggest a nearly significant difference between leaf biomass samplings of *Puccinellia* in controls (p = 0.0522) but a significant difference of *Puccinellia* biomass samplings in exclosures ($p < 0.05$). Despite great variances *Puccinellia* biomass in exclosures shows a slight increase in medians in the course of the season whereas grazed areas show increasing *Puccinellia* biomass to the mid-season and a further decline of biomass to the last sampling. Post-hoc test did not produce significant differences between single sampling steps of *Puccinellia* biomass, neither in exclosures nor in controls (p > 0.05). Absolute median biomass values of grazed and ungrazed plots do not differ greatly but they are slightly higher in ungrazed plots.

Tab. 4 - 1: Results of ANOVA for *Puccinellia* biomass

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Puccinellia biomass - exclosures	169.3000	5, 88	33.8600	2.8968	0.0181
Error	1028.5800		s^2=25.5080		
Puccinellia biomass - controls	76.8600	5, 88	15.3700	2.2928	0.0522
Error	589.9800		s^2= 6.7000		

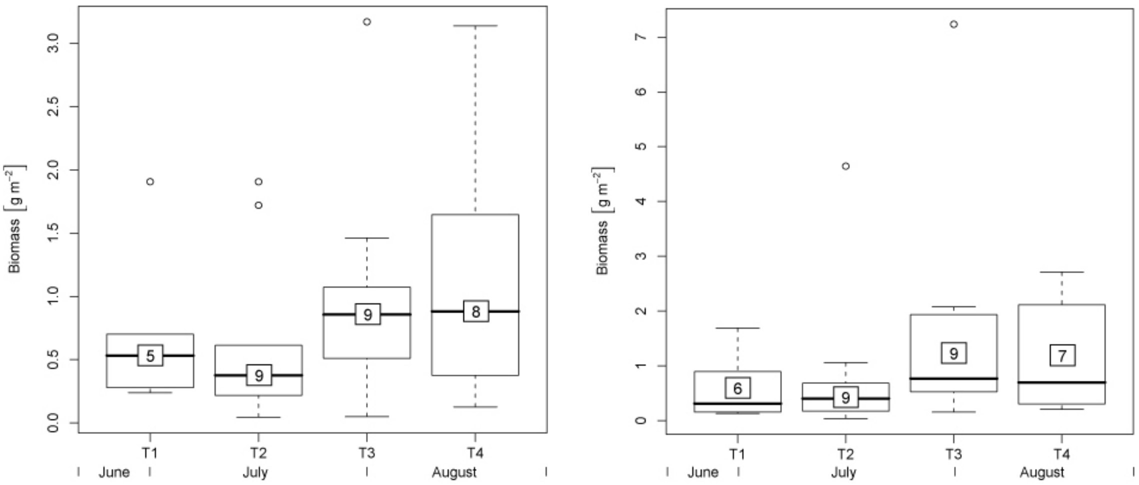


Fig. 4 - 2: Development of *Carex* stembase biomass in ungrazed (left box) and grazed plots (right box) in the course of the summer season (T= Sampling stage).

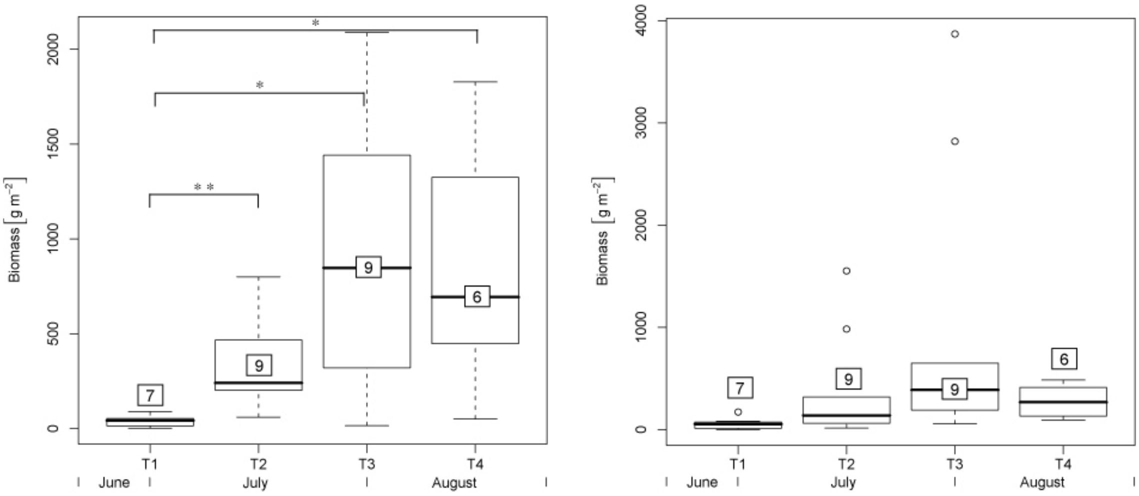


Fig. 4 - 3: Development of *Carex* leaf biomass in ungrazed (left box) and grazed plots (right plot) in the course of the summer season. “Star bars” are indicating significances of differences: **p*<0.05, **<0.01.

Differences between samplings of *Carex* stembase biomass in exclosures and controls remain non-significant throughout the season (ANOVA: *p*> 0.05). So do differences between samplings of *Carex* leaf biomass in controls. But there is a significant difference between samplings of *Carex* leaf biomass in exclosures (*p*< 0.01), indicating a constant increase of biomass in the course of the season (Fig. 4-3). Post-hoc tests on differences between single samplings only show significant differences between single *Carex* leaf biomass samplings in exclosure plots.

There is an increasing trend recognizable in development of *Carex* leaf biomass in exclosures and controls. The abovementioned *Carex* leaf biomass values in exclosures and *Carex* leaf biomass values in control plots are increasing in the course of the season, whereas Carex stembase biomass does not show a clear development.

Tab. 4 - 2: Results of ANOVA for *Carex* biomass.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Carex stembase biomass - exclosures	1.1837	3, 27	0.3946	0.5261	0.6681
Error	20.2505		s^2= 0.7500		
Carex stembase biomass - controls	4.5070	3, 27	1.5020	0.6265	0.6041
Error	64.7410		s^2= 2.3980		
Carex leaf biomass - controls	3811663	3, 27	1270554	1.9457	0.1460
Error	17630943		s^2= 652998		

Tab. 4 - 3: Results of Kruskal-Wallis test for factor biomass

Source	χ^2	*Df*	*p*
Carex leaf biomass - exclosures	14.6462	3	0.0021

A comparison of plant biomass between exclosures and control plots of *Carex* and *Puccinellia* at each of the four (in *Carex* plots) and six (in *Puccinellia* plots) different sampling stages of the summer season by using t-tests did not show significant differences between *Carex* stembase biomass in exclosure and control plots (Tab. 4-4 below). There is however an increasing difference between grazed and ungrazed plots from the first to the third sampling that is followed by a decrease of differences back to the initial value at the last sampling. Differences of *Carex* leaf biomass between exclosures and controls are decreasing from the first to the third sample and are furthermore significant ($p < 0.05$) at the fourth sampling. There are no significant *Puccinellia* plant biomass differences from the first to the fourth sampling whereas the last two samplings show significant differences between grazed and ungrazed plots ($p < 0.01$).

Tab. 4 - 4: Significances of biomass differences between exclosure and control plots per time step.

Compared plots: Excl. & Ctrls.	*t*	*Df*	*p*	Compared plots: Excl. & Ctrls.	*t*	*Df*	*p*
bm.car.sb.s1 [1]	0.2832	4	0.7911	bm.puc.s1 [2]	1.1175	3	0.3452
bm.car.sb.s2	-0.6362	8	0.5424	bm.puc.s2	0.7120	19	0.4851
bm.car.sb.s3	-1.3954	8	0.2004	bm.puc.s3	1.0314	19	0.3153
bm.car.sb.s4	0.2670	6	0.7984	bm.puc.s4	1.0240	19	0.3187
bm.car.leaves.s1	-0.8732	6	0.4161	bm.puc.s5	3.2408	18	0.0045
bm.car.leaves.s2	-0.2359	8	0.8195	bm.puc.s6	3.9468	10	0.0027
bm.car.leaves.s3	-0.1299	8	0.8999				
bm.car.leaves.s4	2.6645	5	0.0446				

[1] “bm.car.sb.s1”: Comparison of exclosure and control values of mean *Carex aquatilis* stembase biomass at the first sampling. The value table in R contains biomass values of ungrazed exclosure and grazed control plots at the 1st sampling. s1-s4 indicates sampling stages in the course of the season.

[2] “bm.puc.s1”: Comparison of exclosure and control values of *Puccinellia phryganodes* plant biomass at the first sampling. The value table in R contains biomass values of ungrazed exclosure and grazed control plots at the 1st sampling. s1-s6 indicates sampling stages in the course of the season.

4.1.2 Seasonal differences of sward height

Results of *Carex* sward height ANOVA shows highly significant differences between different samplings in ungrazed plots ($p < 0.0001$) and less significant differences in grazed plots ($p < 0.05$).

There is nearly no difference between exclosures and controls in increase of *Carex* sward height (Fig. 4-4). Both *Carex* plot types show the same trend of a steep increase of sward height medians from the first to the third sampling and no further remarkable difference between the third and the fourth sampling step which is supported by the results of post-hoc tests. Grazed *Carex* plots seem to have slightly lower absolute sward height median values and variation is higher than in exclosure plots.

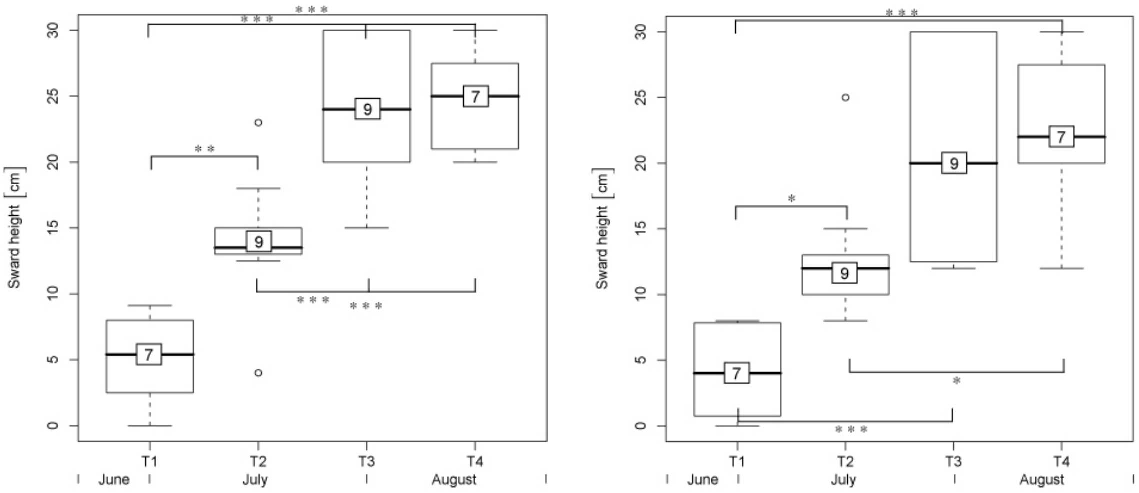


Fig. 4 - 4: Development of *Carex* sward height in ungrazed (left box) and grazed plots (right box) in the course of the summer season. “Star bars” are indicating significances of differences: *p<0.05, **<0.01, ***<0.001.

Tab. 4 - 5: Results of *Carex* sward height ANOVA.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Carex sward height - exclosures	1846.1400	3, 28	615.3800	25.9400	< 0.0001
Error	664.2600		s^2= 23.72		
Carex sward height - controls	1531.8700	3, 28	510.6200	13.4560	0.0127
Error	1062.5500		s^2= 37.95		

Puccinellia sward height ANOVA shows highly significant differences in both grazed and ungrazed plots ($p < 0.001$).

An increasing development of *Puccinellia* sward height medians from the second to the fifth sampling step could be measured in ungrazed plots, while sward height did not differ between the first two and between the last two sampling steps in ungrazed *Puccinellia* plots. Results of post-hoc tests show highly significant differences ($p < 0.001$) of all sampling step combinations except between the first two and between last two samplings. Grazed *Puccinellia* plots show an increase of sward height medians from the first to the fourth sampling step but post-hoc tests suggest less significant differences between the single sampling steps ($p < 0.05$). Puccinellia sward height in exclosures grows more slowly and does not increase after the fourth sampling step. Absolute *Puccinellia* sward height values in grazed plots are lower than in ungrazed plots and variation is higher.

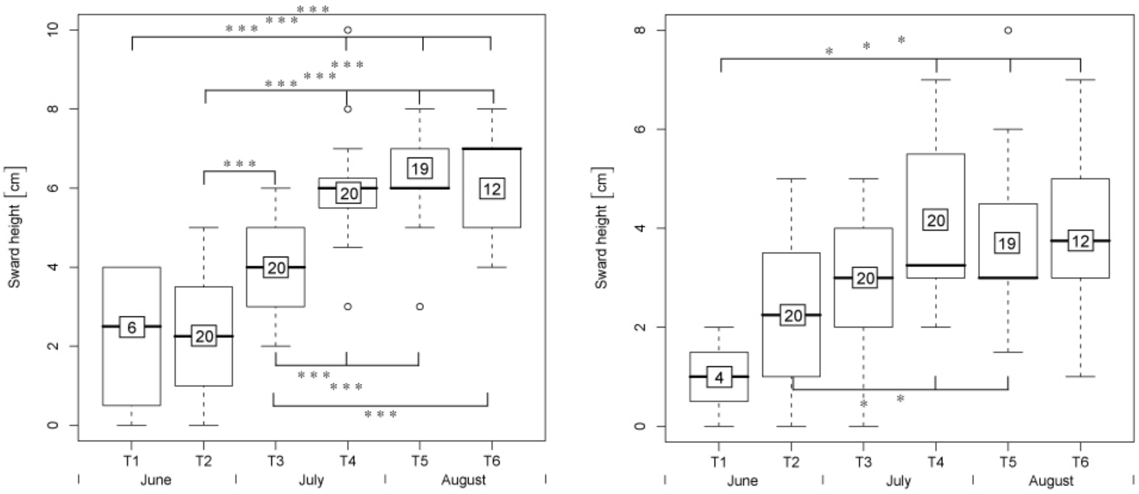


Fig. 4 - 5: Development of *Puccinellia* sward height in ungrazed (left box) and grazed plots (right box) in the course of the summer season. “Star bars” are indicating significances of differences: *p<0.05, **<0.01, ***<0.001.

Tab. 4 - 6: Results of *Puccinellia* sward height ANOVA.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Puccinellia sward height - exclosures	242.7700	5, 89	48.5540	26.0060	< 0.0001
Error	166.1620		s^2= 1.8670		
Puccinellia sward height - controls	65.7410	5, 89	13.1480	5.0748	0.0004
Error	230.5860		s^2= 2.5910		

A comparison of sward height values between exclosure and control plots of *Carex* and *Puccinellia* in each of the four and six different sampling stages of the summer season by using t-tests did not result in significant differences between *Carex* exclosures and controls in any sampling stage. Differences between exclosures and controls of *Puccinellia* increase in the course of the season. There could not be measured any significant differences of exclosures and controls at the first and the second but from the third to the sixth sampling ($p < 0.001$).

Tab. 4 - 7: Significances of sward height differences between exclosures and controls per time step.

Compared plots: Excl. & Ctrls.	*t*	*Df*	*p*	Compared plots: Excl. & Ctrls.	*t*	*Df*	*p*
th.car.s1 [1]	0.7634	6	0,4742	th.puc.s1 [2]	1.4639	3	0.2394
th.car.s2	1.1892	8	0,2685	th.puc.s2	0.4620	19	0.6493
th.car.s3	2.0845	8	0,0706	th.puc.s3	3.0529	19	0.0065
th.car.s4	0.8900	6	0,4077	th.puc.s4	6.1644	19	0.0001
				th.puc.s5	5.7533	18	0.0001
				th.puc.s6	4.8211	11	0.0005

[1] “th.car.s1”: Comparison of exclosure and control values of mean *Carex aquatilis* sward height at the first sampling. The value table in R contains sward height values of ungrazed exclosure and grazed control plots at the 1^{st} sampling. s1-s4 indicates sampling stages in the course of the season

[2] “th.puc.s1”: Comparison of exclosure and control values of *Puccinellia phryganodes* sward height at the first sampling. The value table in R contains sward height values of ungrazed exclosure and grazed control plots at the 1^{st} sampling. s1-s6 indicates sampling stages in the course of the season.

4.2 Seasonal differences of food plant quality

Plant quality was considered in analysing C and N content of forage plants whose results are described in the following chapter.

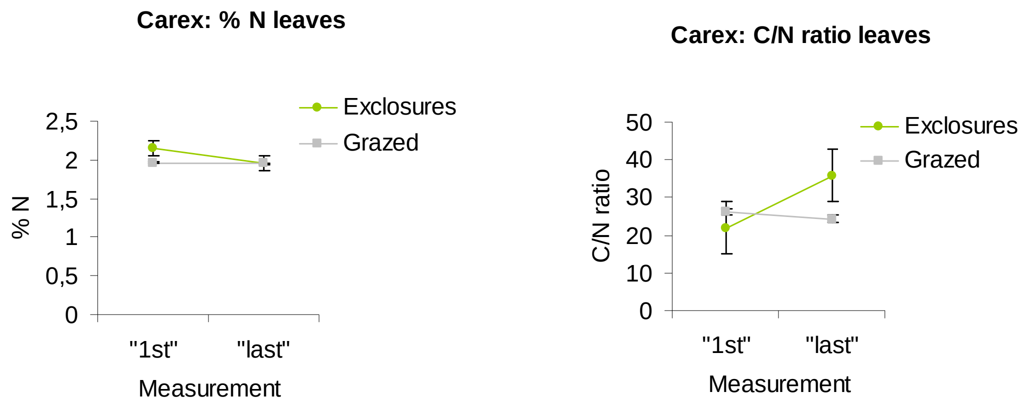


Fig. 4 - 6: N content and C/N ratio of *Carex* leaves (n_{all}= 9) at the first and the last sampling of 2008 field season in grazed control and ungrazed exclosure plots. Error bars indicate standard errors of means.

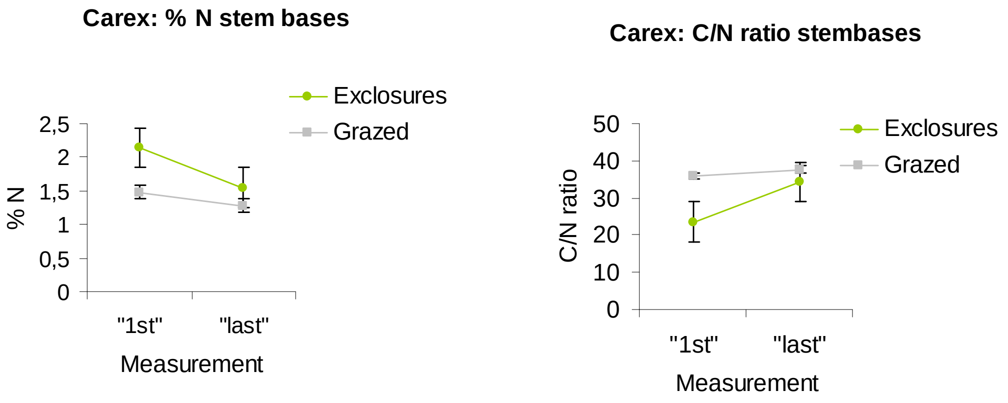


Fig. 4 - 7: N content and C/N ratio of *Carex* stem bases (n_{all}= 9) at the first and the last sampling of 2008 field season in grazed control and ungrazed exclosure plots. Error bars indicate standard errors of means.

Fig. 4 - 8: N content and C/N ratio of Puccinellia ($n_{\text{N Excl. first}}= 19$, $n_{\text{N Excl. last}}= 23$, $n_{\text{N Grazed first}}= 15$, $n_{\text{N Grazed last}}= 16$, $n_{\text{C/N Eexcl. first}}= 19$, $n_{\text{C/N Excl. last}}= 23$, $n_{\text{C/N Grazed first}}= 15$, $n_{\text{C/N Grazed last}}= 16$) at the first and the last sampling of 2008 field season in grazed control and ungrazed exclosure plots. Error bars indicate standard errors of means.

A slight decline of N contents of *Carex* leaves within exclosures is visible while there are no visible differences in N contents within control plots. There are no remarkable differences of grazed and ungrazed plots at the beginning and the end of the season. The leaf C/N ratio graph increases within exclosures while C/N ratio of leaves in grazed plots decreases slightly resulting in a difference between exclosure and control plots at the last sampling. N contents of *Carex* stem bases show a decline both in exclosure and control plots from the first to the last sampling. *Carex* stem base C/N ratio shows a slight seasonal decline within exclosures while it was apparently inclining in grazed plots. There is a remarkable difference between both plot types at the beginning of the season.

There are no visible differences in *Puccinellia* N contents between exclosure and control plots, neither at the beginning nor at the end of the season. Nevertheless a seasonal N decline in both plot types can be found. C/N ratio of Puccinellia shows a seasonal increase both within exclosure and control plots while there are no differences between the plot types at the beginning and at the end of the sampling period. All abovementioned differences between exclosure and control plots and within the same between the first and the last measurements were tested by using paired t-tests.

Tab. 4 - 8: Significances of differences in N and C/N.

Compared plots: Excl. & Ctrls. [1]	*t*	*Df*	*p*	Compared plots: 1^{st} & last [2]	*t*	*Df*	*p*
car.cn.leaf.first [3]	-1.3961	8	0.2002	car.cn.leaf.c [5]	0.9429	8	0.3733
car.cn.leaf.last	0.7671	8	0.4650	car.cn.leaf.x	-1.3162	8	0.2246
car.cn.stem.first	-2.2202	8	0.0572	car.cn.stem.c	-0.3943	8	0.7073
car.cn.stem.last	-0.5217	8	0.6160	car.cn.stem.x	-1.6724	8	0.1330
car.n.leaf.first	1.0184	8	0.3383	car.n.leaf.c	0.0537	8	0.9585
car.n.leaf.last	0.1120	8	0.9136	car.n.leaf.x	1.1489	8	0.2838
car.n.stem.first	2.2788	8	0.0522	car.n.stem.c	1.2038	8	0.2631
car.n.stem.last	1.1996	8	0.2646	car.n.stem.x	2.5245	8	0.0356
puc.cn.first [4]	0.5110	11	0.6194	puc.cn.c [6]	-2.0316	9	0.7275
puc.cn.last	1.8434	14	0.0865	puc.cn.x	-3.2454	17	0.0047
puc.n.first	-0.4720	11	0.6462	puc.n.c	2.2740	10	0.0463
puc.n.last	-1.6913	14	0.1129	puc.n.x	3.4945	17	0.0028

[1] The left half of the table contains significances of differences between grazed and ungrazed plots.

[2] The right half shows significances of differences between first and last samplings.

[3] "car.cn.leaf.first": Plant species *Carex aquatilis*, C/N ratio of leaves analysed, first sampling.

[4] "puc.cn.first": Plant species *Puccinellia phryganodes*, plant C/N ratio analysed, first sampling. The value tables in R contain C/N ratio values of ungrazed exclosure and grazed control plots at the 1^{st} sampling.

[5] "car.cn.leaf.c": Plant species *Carex aquatilis*, C/N ratio of leaves analysed in a control plot.

[6] "puc.cn.c": Plant species *Puccinellia phryganodes,* plant C/N ratio analysed in a control plot. The value tables in R contain C/N ratio values of 1^{st} and last sampling in a control plot.

There were no significant differences in N contents and C/N ratio of Carex leaves and stem bases between ungrazed and grazed plots from the first to the last sampling. The comparison of differences between first and last sampling of *Carex* and *Puccinellia* within an exclosure or control plot, shows higher *p*-values in C/N ratios and N contents compared to lower p-values in ungrazed exclosure plots.

Differences in *Carex* mostly remain non-significant although significant differences of the N content of stems between first and last measurements in the ungrazed plots could be measured. *Puccinellia* shows significant differences between first and last sampling in C/N ratio ($p < 0.01$) and N contents ($p < 0.01$) of exclosure plots. N contents of *Puccinellia* in control plots differ less significantly ($p < 0.05$).

4.3 Seasonal differences in grazing pressure

Differences in grazing pressure are described in the following by counting droppings in the surroundings of exclosure and control plots and by doing so within control plots.

4.3.1 Exclosure and control plot surroundings

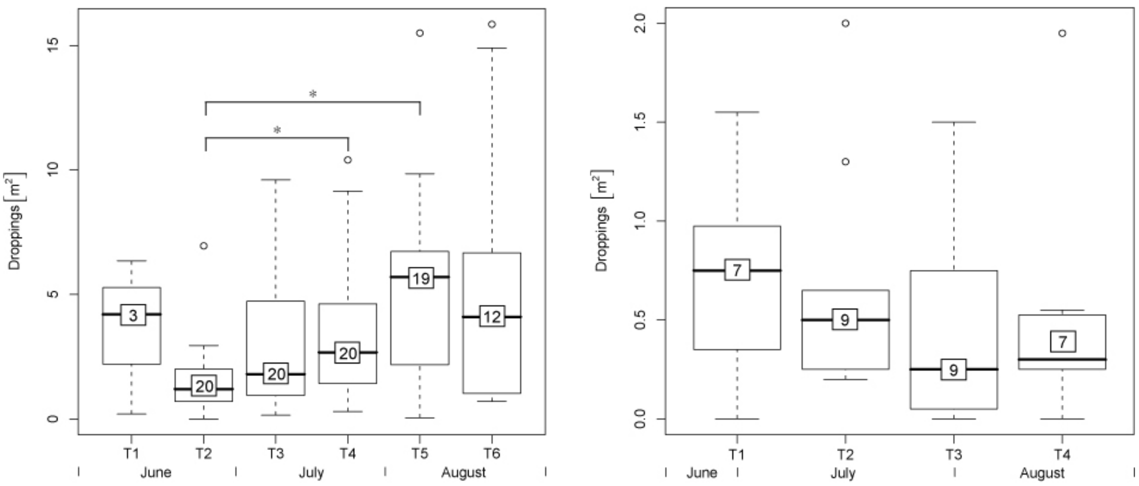


Fig. 4 - 9: Dropping values of *Puccinellia* (left box) and *Carex* (right box) exclosure and control surroundings in the course of the summer season. “Star bars” are indicating significances of differences: *p<0.05.

When accounting for the whole season, grazing intensity increased only in *Puccinellia* plots while it decreased in *Carex* plots.

A closer look on ANOVA and Kruskal-Wallis tests shows a general significant difference in seasonal stages of grazing intensity only in the surroundings of *Puccinellia* plots ($p < 0.05$, Tab. 4-9 below). Around those plots significant differences could be shown between initial stages of grazing and stages in late July and August ($p < 0.05$). *Carex* plot surroundings show a decline in medians of grazing intensity until the third sampling step. ANOVA did not show general significant differences between the sampling steps in the course of the season. Absolute dropping values around *Puccinellia* plots are on average five times higher than dropping values around *Carex* plots. Both dropping density measurements show high variation.

Tab. 4 - 9: Results of grazing pressure ANOVA in the surrounding of *Carex* plots.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Dropping counts – Surrounding of *Carex* plots	0.2654	3, 28	0.0885	0.2431	0.8655
Error	10.1893		s^2= 0.3639		

Tab. 4 - 10: Results of Kruskal-Wallis test for factor grazing pressure in the surrounding of Puccinellia plots.

Source	χ^2	*Df*	*p*
Dropping counts – Surrounding of *Puccinellia* plots	14.5137	5	0.0127

4.3.2 Control plots

Seasonal differences in grazing pressure could also be measured by considering dropping count values within grazed control plots. It is to be expected that there are no or only little differences between the amount of droppings in control plots and dropping values in surrounding areas. Ideally, a control plot is supposed to reflect grazing pressure of its surroundings.

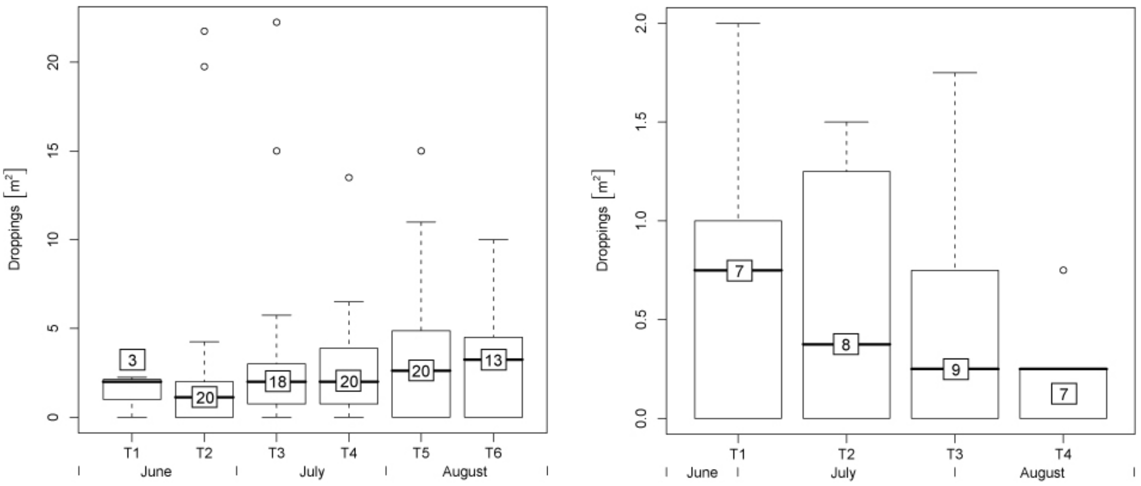


Fig. 4 - 10: Grazing intensity in *Puccinellia* control plots (left box) and *Carex* (right box) in the course of the summer season.

Puccinellia control plots show a slight incline of grazing pressure medians from the second to the last sampling step (Fig. 4-10) thus basically reflecting the situation in the surrounding areas. *Carex* control plots show a clear grazing pressure decline from the first to the third sampling step and nearly no median difference of the third and the last sampling step. ANOVA did not result in any significant differences of both *Puccinellia* and *Carex* control plots. In contrast to the abovementioned results of grazing pressure in the surrounding of *Puccinellia* plots, post-hoc tests did not show any significant results between single sampling steps, neither in *Carex* nor in *Puccinellia* plots. Again dropping counts in Puccinellia plots resulted in numbers, suggesting grazing pressure which is on average five times higher than grazing intensity in *Carex* plots.

Tab. 4 - 11: Results of grazing pressure ANOVA in *Carex* and *Puccinellia* control plots.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Dropping counts – *Carex* control plots	0.8847	3, 27	0.2949	0.7781	0.5165
Error	10		s^2= 0.379		
Dropping counts – *Puccinellia* control plots	16.7800	5, 88	3.3600	0.1525	0.9788
Error	1937.1100		s^2= 22.0100		

4.4 A direct approach: Radio tracking

The radio tracking approach was facing numerous constraints concerning technical and topographical aspects which are discussed in chapter 5.1.2. It was therefore producing limited results which are displayed in the following. Regular tracking of brood-rearing EWfG from 14th July to 10th August resulted in a mere 17 fixes of females with radio neck collars. Two out of ten individuals (X-BB & E-71) could not be found again after radio neck collar application. Most of the successful fixes could be reached in the period right after applying neck collars whereas in the later summer season we could not achieve repeated fixes of individuals. There were only two brood-rearing females detected with each one and three young. Paired adults could only be found again four times. Individuals with radio neck collars could often be detected in flocks. In this case it was hard to determine family relationships properly. Most of the early and late fixes differ in habitats the geese were situated in to the time of tracking. Early fixes could mostly be made in the nesting sites whereas late fixes suggest that geese are situated near tundra lakes and pools. Tab. 4-12 below shows individuals, their family status and fixes after tagging.

Tab. 4 - 12: Results of radio tracking.

Ring	Date of tagging	Fixes after tagging	d to nest [m]	Date of tracking	Family status Adults	Juv.	Habitat
X-JZ	July 15	2	140	July 15	2		Nesting site
			160	July 16	1		Nesting site
X-GG	July 15	2	0	July 16	1		Nesting site
			773	July 18	1		Lake
X-UU	July 14	3	1390	July 29	1		Lake
			1390	Aug. 8	1		Lake
			1390	Sept. 3	1	1	?
X-NN	July 14	3	?	July 18	1		Lake
			1178	July 18	1		Hill ridge
			848	July 18	1		Pool
X-PP	July 16	2	0	July 16	1		Nesting site
			2765	July 18	2	3	Lake
A-EU	July 14	2	0	July 18	1		Nesting site
			847	July 29	2		Lake
E-67	July 15	2	0	July 15	2		Lake
			0	July 16	1		Lake
X-CC	July 13	1	0	July 16	1		Nesting site

4.5 Spatial Aspects of EWfG habitat use

The following chapter contains an analysis of the influence of spatial parameters lake and forage habitat size and distance to the lakes on grazing pressure caused by geese.

4.5.1 Forage habitat sizes and lake sizes

It could be shown, that forage habitats which are situated in greater distances to the lake shores show declining medians of forage habitat size with declining lake sizes while there is no clear decreasing or increasing trend recognizable in medians of lake-nearest forage habitat size (Fig. 4-11). Differences between single size classes of both forage habitats remain non-significant in all lake size classes ($p > 0.05$) but there is a clear difference in significance between ANOVA for the size of nearest and farthest habitats.

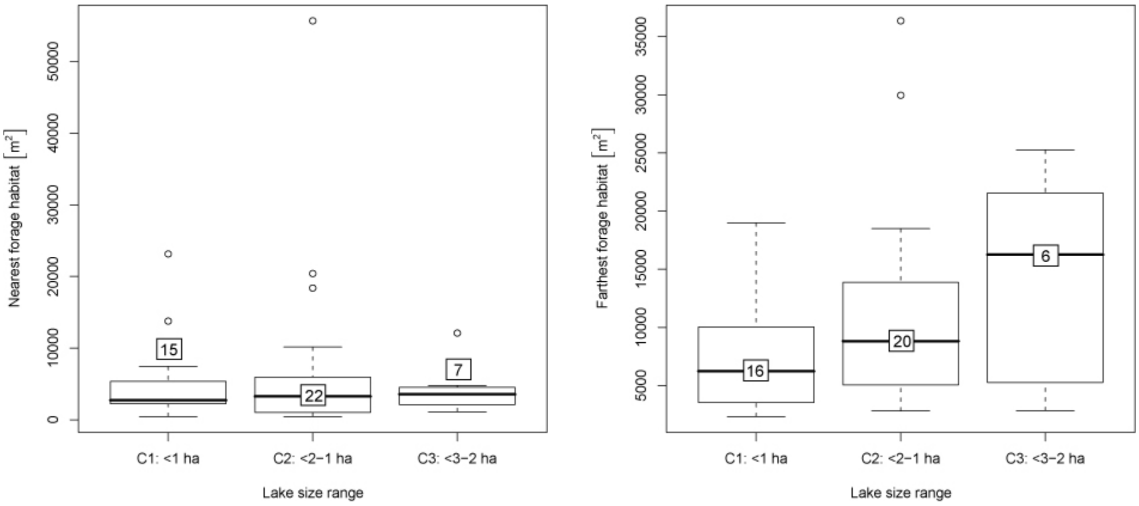


Fig. 4 - 11: Distribution of nearest (left box) and farthest (right box) forage habitat area sizes among different lake size ranges.

Tab. 4 - 13: ANOVA results of nearest and farthest forage habitat area sizes.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Nearest forage habitats	54791405	2, 41	27395702	0.3066	0.7376
Error	3662961335		s^2= 89340520		
Farthest forage habitats	233219568	2, 39	116609784	1.9869	0.1508
Error	2288896665		s^2=58689658		

4.5.2 Relationship of grazing pressure and lake size

There is no clear trend in the distribution of average grazing intensity of lake-nearest and lake-farthest forage habitat grazing intensities among different lake size classes and overall differences remain non-significant (p > 0.05, Tab. 4-14 below). But the result can be differentiated by distinguishing between grazing pressure caused in lake-nearest and in lake-farthest forage habitats. Then, a clear trend of declining grazing pressure with declining lake size in lake-farthest forage habitats is recognizable (p of Kruskal-Wallis <0.01) and post-hoc test shows significant differences between lake classes of 3 to 2 ha and those smaller than 1 ha. Lake-nearest forage habitats do not show significant differences between classes of bigger and smaller lakes (p > 0.05), although median grazing pressure is lowest at the smallest lake class <1 ha and higher at lakes exceeding 1 ha. Absolute grazing pressure in lake-nearest forage habitats is on average twice as high as in lake farthest habitats.

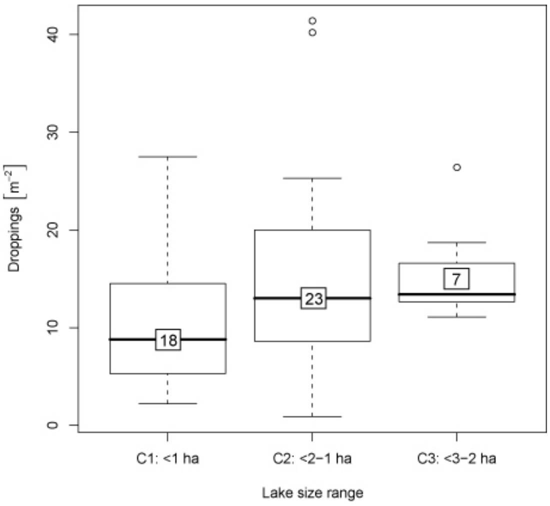


Fig. 4 - 12: Average grazing intensity distribution among different lake size ranges.

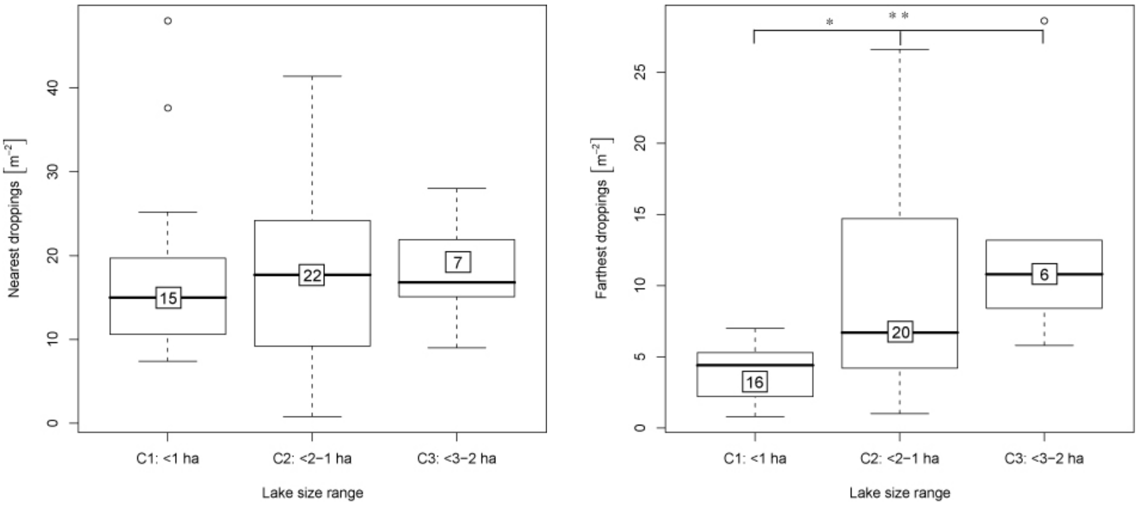


Fig. 4 - 13: Grazing intensity distribution in lake-nearest forage habitats (left box) and lake-farthest forage habitats (right box) among different lake size ranges. “Star bars” are indicating significances of differences: *p<0.05, **<0.01.

Tab. 4 - 14: ANOVA results of grazing intensity in different lake size classes.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Average Grazing intensity	42.9000	2, 45	21.5	0.2203	0.8031
Error	4386.3000		s^2= 97.5000		
Grazing intensity – Nearest	0.4	2, 41	0.2	0.0015	0.9985
Error	48314		s^2= 117.8		

Tab. 4 - 15: Results of Kruskal-Wallis test for grazing intensity in lake-farthest forage habitats.

Source	χ^2	*Df*	*p*
Grazing intensity - Farthest	11,9846	2	0.0025

4.5.3 Relationship of grazing pressure and forage habitat size

Goose grazing pressure in relation to size of forage habitat does not differ significantly between different forage habitat size classes (*p* > 0.05, Tab. 4-16 & 17 below) but there is a decline in median grazing pressure with decreasing size of both lake nearest and lake farthest forage habitats and it could be shown that the smallest forage habitat size classes of both types bear a lower grazing pressure than the bigger ones, although it came out that there are no significant differences between single forage habitat size classes. The impression could be proved that grazing pressure in lake-nearest forage habitats is twice as high as in lake-farthest forage habitats.

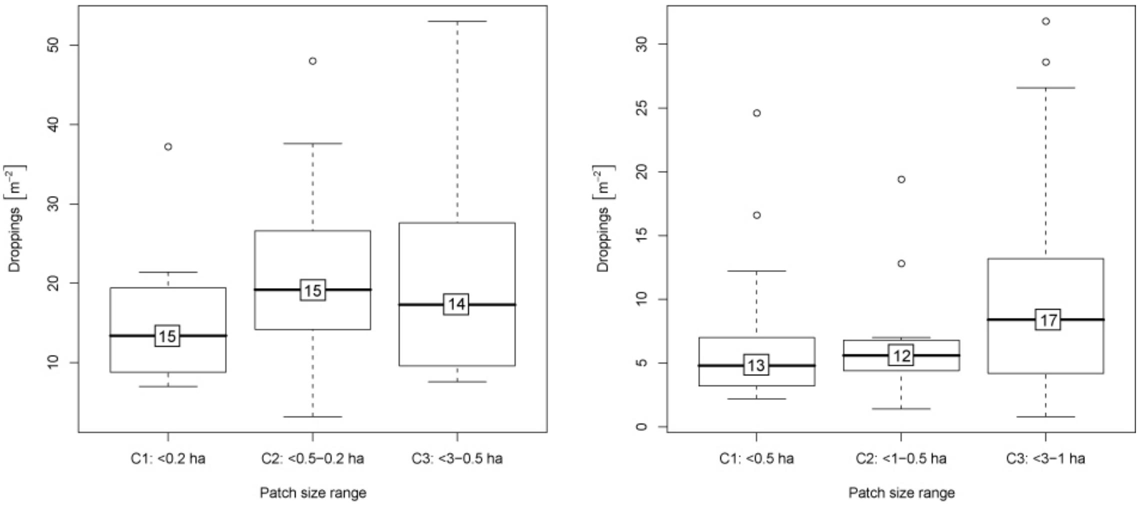


Fig. 4 - 14: Grazing intensity distribution among different ranges of forage habitat patches situated in the direct vicinity of lake shores (left box) and in more remote patches (right box).

Tab. 4 - 16: ANOVA results of grazing intensity in lake nearest forage habitats.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Nearest forage habitats	366.4000	2, 41	183.2000	1.4159	0.2543

Error	5305.0000		s^2= 129.4000		

Tab. 4 - 17: Results of Kruskal-Wallis test of grazing intensity in lake-farthest forage habitats.

Source	χ^2	*Df*	*p*
Farthest forage habitats	1.7494	2	0.4170

4.5.4 Relationship of grazing pressure and distance to the lakes

Concerning distance values of dropping counts to the lake shore taken in lake nearest and lake farthest forage habitat types, it can be said that there is a trend of increasing dropping counts with decreasing distance of counts to the lake shore. Grazing intensity in distances below 10 m is twice as high as grazing intensity in distances exceeding 10 m. Differences between single distance classes remain non-significant (*p* > 0.05, Tab. 4-18 and Tab. 4-19 below).

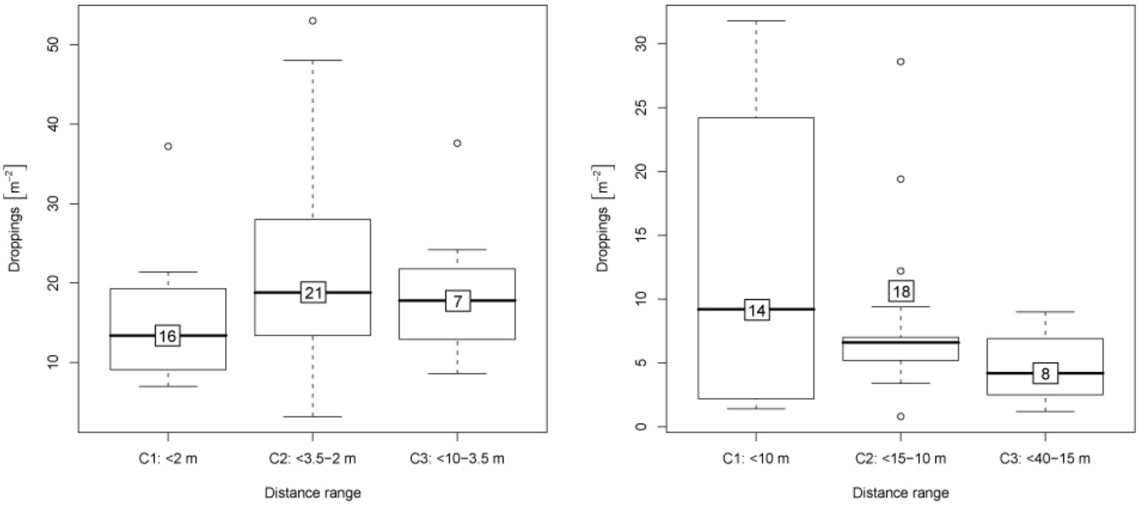


Fig. 4 - 15: Grazing intensity distribution among different classes of distances to the lakes taken in lake-nearest forage habitats (left box) and in lake farthest forage habitats (right box).

Tab. 4 - 18: ANOVA results of grazing intensity in nearer distances to the lakes.

Source	Sum of squares	*Df*	Mean square	*F* ratio	*p*
Grazing intensity - Near	519.3000	2, 41	259.7000	2.0664	0.1396
Error	5152.1000		s^2= 125.7000		

Tab. 4 - 19: Results of Kruskal-Wallis test of grazing intensity in more remote distances to the lakes.

Source	χ^2	*Df*	*p*
Grazing intensity - Far	2.8187	2	0.2443

5. Discussion

5.1 Discussion of methods

The methods applied during fieldwork on Kolguev, which are discussed in the following, proved partly successful. The exclosure and control survey to analyse grazing patterns and the cumulative end-of-the-season survey will be highlighted as positive examples delivering reliable data whereas the obstacles in radio-tracking of geese are to be named among the measures which proved less successful.

5.1.1 Exclosure and control concept

The exclosure and control method delivered reliable data on the whole. Plot selection in the beginning of the field season was the most difficult part of the experiment since the snow cover on possible plot sites in depressions was lasting longer than on plain sites. Therefore, erection of a distinct plot did not always follow the real beginning of goose grazing because it was hard to keep track of the conditions in a large survey area in the beginning. Dropping counts in *Carex* plots turned out to be difficult because it was hard to distinguish old and new droppings on extremely humid surfaces.

Concerning a proper function of exclosure and control approach, the aspect of critical mass has to be considered because grazing effects can better be shown the higher the grazing pressure per time and area is. In comparison to other goose species, feeding behaviour of EWfG corresponds to scythes more than to the mowing machine-like behaviour of flock-grazing Barnacle Geese *Branta leucopsis*. EWfG show a more scattered grazing on larger areas, thus evoking effects less conspicuous. The consequences for a single exclosure and control plot-combination are less significant differences in grazing intensity and enhanced compensatory growth of grasses.

Reindeer migration was another problem for exclosures. The construction was suitable to fence out geese while it was not able to resist migrating reindeers trampling down exclosures. Due to the limited transport capacity of MI-8 helicopters, erecting reindeer-proof constructions which consisted of more resistant and thus heavier materials was simply not possible. As soon as I recognized a destroyed exclosure, I immediately re-built it and checked for eventual traces of grazed tillers. In most of the cases the tillers were non-grazed and a further comparison to the adjacent control plot and earlier or later stages of grazing was acceptable. If the plot was grazed in that intermediate period, it was noted for further consideration in the analysis.

Another aspect to be named are plot checks intervals. It was not always possible to keep regular sampling intervals upright.

Spatio-temporal autocorrelation was intended to be minimized by selecting an area which was in my discretion large enough to exclude this factor.

5.1.2 Radio-tracking

Problems in radio-tracking are discussed more detailed than the results and the part the method played in the whole project might suggest, but an exact description of methodological difficulties might help to improve an actually interesting approach to gain data on patterns of habitat use.

A major problem was the insufficient range of the transmitters used at the geese in combination with several obstacles concerning weather and topography which were additionally decreasing transmitter range.

After fixing the neck collar and re-releasing the geese we could test the transmitter range by repeated tracking of the geese finishing breeding on the nest and subsequently leading the young away from the nest. In that ideal situation of reliable information of the exact position of an individual it could be shown that the maximum transmitter range at which a very weak signal-“beep” was just audible was up to 1.5 km.

It could additionally be shown that the transmitter range decreases rapidly once the geese is situated behind physical obstacles such as hills in the tundra or even little willow shrubs. Another important obstacle occurred with the beginning period of geese presence at the lakes. Most of the tundra lakes are situated in more or less shallow depressions posing an obstacle for radio waves. Moreover, geese in the pelagial of a lake occasionally dip their head and neck under water which leads to a total loss of the signal in the moment of dipping. I could ascertain the latter on a lake by simultaneous observation and radio detection of a tagged goose.

We made the experience that even cold and rainy weather is negatively affecting transmitter range and obviously the receiver capacity, too. It might be possible, that humidity is influencing electric components stronger than the used sealing suggests and coldness is certainly influencing battery power negatively.

Another problem in effective emitting the transmitter signal is the variable transmitter position at an individual goose. The position of neck collars and receiver antennas in relation to the goose body influences signal strength and is moreover impeding detection of signal direction. While fixing the neck collar it is important to consider seasonally different body mass states of the goose resulting in different neck diameters. Therefore one had to leave enough space between collar and neck in order to avoid strangling the geese. This gap leads to a circular motion of the transmitter "around" the neck in times of lower body mass.

In the light of the abovementioned problems it is most likely that enhanced transmitter performance (wider range at the same weight, format and battery life) would definitely result in increased probability of detection.

A major problem of the described lack of transmitter range are the comparatively high costs of "Running for tracking" instead of "Tracking geese running" i.e. a too high cost-benefit ratio of the selected method. The low range often meant too long walks until a signal was detectable (or not). Depending on the abovementioned weather conditions and topographic situation the signal range often was within the flight distance of the cautious EWfG. A spotting scope to check neck collar codes traditionally was sometimes even more effective in re-detecting a marked goose in a flock, when a certain lake or lake area was already known as preferred by this individual. Nevertheless, mobility of individuals and flocks was in the end too high for the limited transmitter range especially considering the moulting and brood-rearing period when the geese use to run long distances rapidly on the ground to compensate intermittent loss of their ability to fly.

5.1.3 End-of-the-season-survey

All methods used during the final survey of the 2008 field season could be applied successfully. The selected extent of survey area was disadvantageous concerning the big efforts in reaching the selected lakes and the number of lakes reached was smaller than expected in the first instance. Next to European White-fronted geese *Anser a. albifrons*, Bean geese *Anser f. fabalis* and Barnacle geese *Branta leucopsis* are co-occuring goose species on Kolguev, thus influencing the results of grazing pressure measurements. I tried to select lakes preferred by EWfG, but it cannot be ruled out that dropping count values represent grazing pressure caused by other goose species than White-fronted geese.

5.2 Discussion of results

5.2.1 Biomass

Biomass values of *Puccinellia* in ungrazed exclosure and in grazed control plots show increasing trends in both exclosures and controls but it could be shown that grazing pressure geese influences the increase of biomass in grazed *Puccinellia* plots significantly in later stages of the seasons in August, when geese are concentrating in feeding flocks together with their young. They are then able to influence biomass of arctic grasses. Decreasing biomass in grazed plots seems to mark the post-breeding period of geese. In early stages of the season in June and beginning July biomass values show a constant increase in both exclosure and control plots and an undisturbed development of the grasses in these stages because geese are yet showing a scattered distribution before aggregating for brood-rearing and moulting.

Carex stembase biomass does not show any significant differences between single sampling stages of exclosures and controls. The assumed consumption of stembase parts in the beginning of the season could not be displayed in the survey.

Carex leaf biomass shows the expected increase of leaf material in the course of the season. The lack of difference between single sampling stages of grazed and ungrazed plots indicates an absence of further *Carex* consumption throughout the season. In the course of the season, plants invest in structural elements more than in nutrient enrichment thus becoming uninteresting for migrating geese which have to ingest as much nutrients as possible (VAN DER GRAAF et al., 2006).

5.2.2 Sward height

As it was expected after field observations, *Carex* sward height of different sampling stages differs significantly and shows an equal increase in both ungrazed and grazed areas in the course of the summer season because *Carex* is not part of the diet of White-fronted geese, as soon as it is to high to be fed and contains too much structural elements. *Carex* is able to compensate initial grazing pressure, as far as the latter exists. Unfortunately, initial grazing pressure could not be displayed by the survey design (see remarks on consumption of stembase biomass in chapter 5.2.1). VAN DER GRAAF et al. (2006) stress on the importance of low canopy height for areas which are preferred by grazing geese.

Puccinellia sward height increases in both ungrazed and grazed areas but sward heights in grazed Puccinellia plots are on average one third lower than in plots excluded from the influence of geese. It could be shown, that Puccinellia is able to compensate consumption by the geese. Grazed areas show a constant growth of Puccinellia from the end of July to the end of August and grazing seems to stop growth of Puccinellia on a lower level than absolute sward height values in ungrazed areas suggest. Significant differences between single sampling stages of *Puccinellia* sward height in ungrazed and grazed plots indicate a beginning grazing in July when brood-rearing White-fronted Geese begin to feed in flocks .

5.2.2 Food plant quality

The quality of *Carex* leaves and stembases decreases slightly during the season marked by decreasing N contents and increasing C/N ratios. It remains to say that nutrient content of *Carex* is not suitable to explain a decreasing quality properly in this study. Inevitable errors during the sorting process of leaves and stembases might have lead to inaccurate measurements. But a general tendency of decreasing quality in *Carex* leaves as well as in stembases could be shown. This result is supporting the assumption of a rapid quality loss of *Carex* forcing the geese to switch to other herbal food sources.

Decreasing N values of Puccinellia indicate a loss of quality in forage plants from the beginning to the end of the season and increasing C/N ratios give witness of structural investment of plants which is disadvantageous for feeding geese. We could not figure out to what extent the loss of quality is influencing geese. As flexible migrants geese have to maximize nutrient intake and have to cope with nature's trade-off between quality consisting of N content and quantity of plants consisting of structural investments with C-accumulation (VAN DER GRAAF et al., 2006).

5.2.3 Grazing pressure

It could be shown that goose grazing pressure in the course of the season is decreasing in *Carex* plots and increasing in *Puccinellia* plots. *Carex* plots were grazed twice as intensively at the beginning of the season than at the end. Droppings counts as a basis for grazing intensity show a presence of geese in *Carex* dominated areas and indicate an initial grazing in these areas. Later numbers on grazing pressure can also result from the abovementioned difficulties in estimation of correct dropping numbers (see chapter 5.1.1). In reality, most of the Carex dominated areas are avoided by the geese after early stages of grazing in May. Grazing pressure on *Puccinellia* plots increased markedly in the course of July. This result is strongly supporting biomass and sward height data which indicate a beginning or intensified grazing on *Puccinellia* in July. Grazing in a control plot itself does basically reflect grazing in the surrounding of exclosures and controls.

5.2.4 Radio tracking

The primordial target to follow brood-rearing geese in the course of the season by regular fixes was missed and the little number of fixes cannot explain patterns of habitat use as well as expected. It remains to say that the seasonally different results of habitats, the geese were situated in to the time of tracking, reflect the overall difference between nesting habitats and subsequently used brood-rearing habitats. The latter consist of tundra lakes and pools which serve as forage habitats as well as protective elements against aerial and terrestrial predators. The assumption of a scattered geese distribution to the time of breeding, followed by an aggregated distribution to the time of brood-rearing and moulting, could basically be found in radio tracking results.

5.2.5 Spatial aspects of habitat use

There could be found a preference of geese for lakes exceeding 2 ha and decreasing grazing pressure with decreasing lake size for habitats in more remote distances (>10 m) to the lakes. The size of these habitats increases with increasing lake size whereas size of habitats in the direct vicinity of lake shores does not vary greatly among different lake sizes. Grazing pressure in habitats in the direct vicinity of a lake shore does not vary clearly among different lake sizes. A comparison of grazing pressure in different forage habitat size classes did not result in a clear preference of the geese for a certain habitat size although there are slight preferences for wider forage habitats.

Comparing the abovementioned factors forage size of lakes and size of forage habitats with the factor distance to the lakes, it could clearly be shown that the distance to the lakes has a major influence on habitat selection and lake nearest forage habitats up to 10 m away from the lake shores bear a grazing pressure which is twice as high as grazing pressure in distances exceeding 10 m.

The important role of lakes for brood-rearing White-fronted Geese providing protection against predators is clearly reflected by this result.

6. Conclusions and perspectives

The results of the exclosure and control approach and the final survey on grazing pressure suggest a combinated forage- and predator-driven system of habitat use of EWfG on Kolguev. White-Fronted Geese are able to find optimized food sources to the right time in spring when they feed on early accessible sedges breaking through the ice and snow cover of shallow depressions in the tundra. Biomass and sward height data on *Carex aquatilis* suggest an early consumption of the sedges. White-Fronted Geese combine finding food sources with evasive behaviour towards predators in later stages of the summer season in July and August to the time of brood-rearing and moulting when snow has finally melted and arctic grasses are available. Further research is needed to clarify the role of predators and the actual pressure they are causing on geese. One possibility for further calculating the 2008 field data would be a comparison of structural parameters such as tiller height and density with dropping density. Another field of research on Kolguev can consist in defining vegetational units the geese are using combined with enhanced radio tracking measures. The temporal aspect of foraging behaviour consists of the shift from arctic sedges to grasses of the tundra and could be figured out well in this thesis, whereas numerous spatial aspects mentioned above could not be treated sufficiently.

7. Abstracts

7.1 Summary

The study on habitat use of European White-fronted Geese (*Anser a. albifrons*) described in the thesis presented was carried out in a breeding site of this goose species on Kolguev island in the Russian Arctic during the summer season 2008. Observations during former expeditions on habitat use of White-fronted Geese suggest a shift in distribution of the geese from scattered breeding in the tundra to a subsequent aggregating movement of brood-rearing and moulting geese to the tundra's numerous lakes.

The study aims to figure out to what extent this spatiotemporal system of habitat use is influenced by the seasonally different occurrence and quality of the selected plant species *Carex aquatilis* and *Puccinellia phryganodes*. The field survey design for the thesis follows a multi-level sampling approach consisting of an exclosure and control survey to estimate plant consumption and growth, radio tracking of White-fronted Geese with the help of radio neck collars and a final survey on grazing pressure to asses spatial patterns of habitat use. Radio tracking attempts remained mostly unsuccessful but our plant study and the final grazing pressure study was successful.

White-fronted geese feed on fresh *Carex aquatilis* shoots breaking through the snow cover at the time of arrival from the central European wintering grounds and switch to arctic grasses such as *Puccinellia* and other species as soon as these are available after snow melt. The combination of ungrazed exclosures and grazed control plots could reflect the switch of food source. Co-occurrence of predators such as Arctic Fox (*Alopex lagopus*) and Red Fox (*Vulpes vulpes*) strongly influences habitat selection from the first scattered breeding to aggregated occurrence of geese at the tundra lakes to the time of moulting and guiding the young right before the island is left again at the end of the summer. Influence of predators was considered by analyzing the factor of distance of geese to the lakes. It could be shown, that geese prefer the nearest vicinity of the lakes because it is providing a combination of fast protection and good food sources.

7.2 Zusammenfassung

Die Studie zu Habitatnutzungsmustern von Blässgänsen, welche in der vorliegenden Diplomarbeit vorgestellt wird, wurde im Sommer 2008 auf der russischen Insel Kolguev, einem Brutgebiet dieser Art in der russischen Arktis, durchgeführt. Beobachtungen zur Habitatwahl der Art auf früheren Expedition legen räumlichen und zeitlichen Wechsel in der Habitatwahl von Blässgänsen im Verlaufe einer Sommersaison nahe. Die Tiere beginnen nach der Ankunft über die ganze Tundra verstreut mit dem Brutgeschäft und aggregieren während Jungenaufzucht und Mauser an den zahlreichen Seen der Tundra. In der Studie wird versucht, anhand der beispielhaft ausgewählten Nahrungspflanzen *Carex aquatilis* und *Puccinellia phryganodes*, herauszufinden, in welchem Ausmaß dieses raum-zeitliche System der Habitatnutzung von der saisonal unterschiedlichen Qualität und dem saisonal unterschiedlichen Auftreten dieser Pflanzenarten beeinflusst ist. Die verwendeten Methoden in der Geländephase bestanden aus einem Ausschluss- und Kontrollflächenprinzip, um Nahrungspflanzenwachstum und -konsumption abzuschätzen, dem Versuch, die Tiere mittels Radiohalsbändern zu telemetrieren, und einer abschließenden Untersuchung zum Beweidungsdruck am Ende der Geländephase (Kotzählungen). Während die Radiotelemetrie von einigen Schwierigkeiten gekennzeichnet war, lieferten die Pflanzenuntersuchungen und Kotzählungen verlässliche Daten. Blässgänse fressen nach ihrer Ankunft aus den mitteleuropäischen Überwinterungsgebieten vornehmlich grüne Seggen-Triebe, die bereits aus dem Schnee ragen und wechseln im Saisonverlauf zu *Puccinellia* und anderen Gräsern, sobald diese nach der Schneeschmelze verfügbar sind. Die Habitatwahl von Gänsen wird stark durch das Auftreten von Prädatoren wie Polarfuchs (*Alopex lagopus*) und Rotfuchs (*Vulpes vulpes*) beeinflusst, das dazu führt, dass die Gänse nach dem verstreut geschehenden Brutgeschäft an den Seen aggregieren, weil die Tiere auf dem Wasser Schutz suchen. Der Einfluss von Prädatoren wurde in der Studie durch die Untersuchung des Faktors “Abstand zum See” berücksichtigt und es konnte gezeigt werden, dass die Tiere seenahe Nahrungspflanzenvorkommen bevorzugen, weil diese eine optimal Kombination aus schnell erreichbarem Schutz und Nahrungspflanzenverfügbarkeit bieten.

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Transliteration of Russian and Nenets personal and location names and other vocabulary originally written in Cyrillic characters follows Library of Congress system for transliteration of modern Russian published by Shaw (1967).

[Squared brackets] indicate downloaded data and software used for data processing.

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Appendix

Data-CD [data_cd]:

Excel-sheet containing all calculations [data]

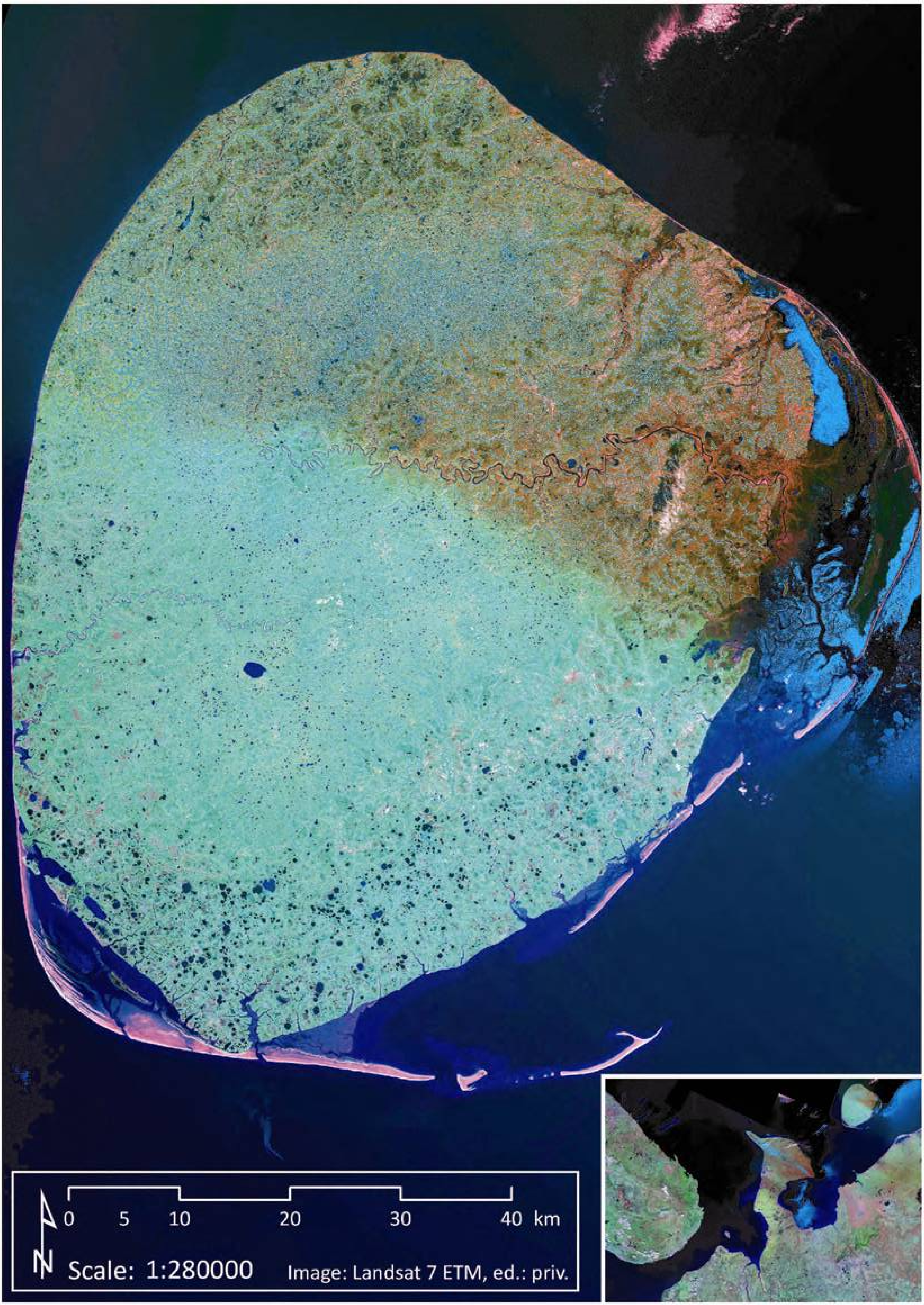
Excel-sheet containing field and lab data [fielddata]

R-Scripts and tables [data]

Diploma thesis [thesis]

Tab. A 1: Coordinates and characteristics of exclosure and control plots.

Plot No.	Coordinates Excl. (dec. deg.)		Coordinates Ctrl. (dec. deg.)		Plot type
	N	E	N	E	
1	69.16812	48.91807	69.16826	48.91855	car_aq
2	69.16697	48.92908	69.16700	48.92858	puc_phr
3	69.17372	48.91759	69.17400	48.91707	puc_phr
4	69.16972	48.87483	69.16990	48.87536	puc_phr
5	69.16378	48.93401	69.16388	48.93334	car_aq
6	69.13798	48.92324	69.13817	48.92013	puc_phr
7	69.10520	48.82159	69.10519	48.82139	puc_phr
8	69.10723	48.88311	69.10718	48.88297	car_aq
9	69.10941	48.87475	69.10937	48.87449	puc_phr
10	69.11581	48.86683	69.11545	48.86705	puc_phr
11	69.16363	48.88943	69.16376	48.88957	car_aq
12	69.10554	48.84715	69.10561	48.84700	puc_phr
13	69.14510	48.89511	69.14514	48.89545	car_aq
14	69.13449	48.87501	69.13441	48.87510	puc_phr
15	69.13550	48.87425	69.13549	48.87459	car_aq
16	69.15869	48.87971	69.15864	48.87965	puc_phr
17	69.14191	48.91618	69.14208	48.91625	car_aq
18	69.13820	48.90018	69.13827	48.90021	puc_phr
19	69.12524	48.89940	69.12563	48.89966	puc_phr
20	69.16234	48.92074	69.16228	48.92135	puc_phr
21	69.15448	48.93116	69.15440	48.93154	car_aq
22	69.13856	48.96151	69.13844	48.96147	car_aq
23	69.14375	48.95612	69.14382	48.95618	puc_phr
24	69.12806	48.93232	69.12813	48.93236	puc_phr
25	69.15770	48.94533	69.15795	48.94488	puc_phr
26	69.13959	48.94177	69.13952	48.94129	puc_phr
27	69.11634	48.90569	69.11631	48.90608	puc_phr
28	69.11974	48.89414	69.11963	48.89393	puc_phr
29	69.11313	48.89469	69.11320	48.89487	puc_phr
30	69.12640	48.87473	69.12639	48.87498	puc_phr
31	69.20105	48.85717	69.20114	48.85736	puc_phr
32	69.20622	48.84899	69.20611	48.84923	puc_phr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20
30
40 km
Scale: 1:280000
Image: Landsat 7 ETM, ed.: priv.

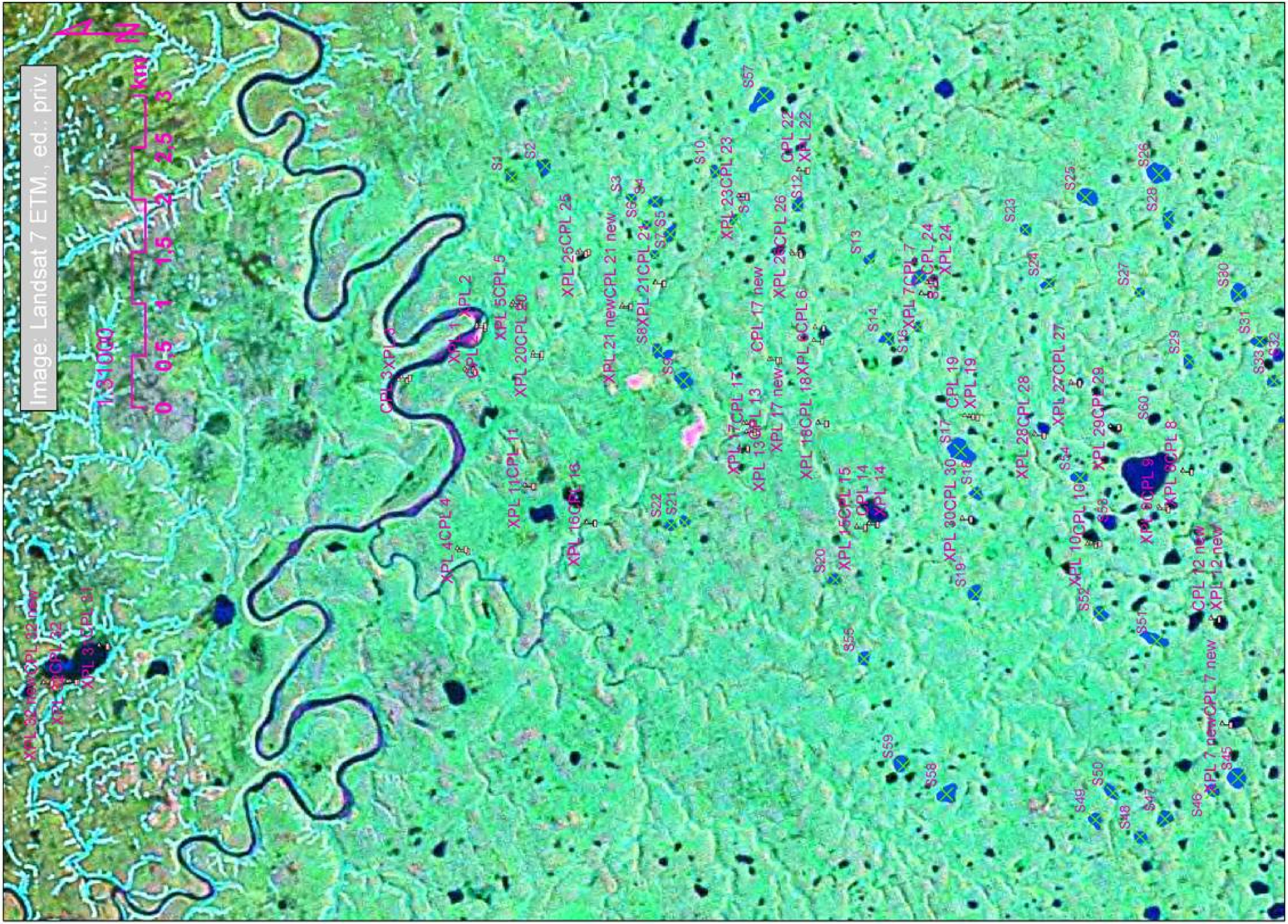

Image: Landsat 7 ETM, ed.: priv.
1:31000
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XPL 23CPL 23
CPL 17 new
XPL 17 new
XPL 26CPL 26
XPL 6CPL 6
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XPL 15CPL 15
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Eidesstattliche Erklärung:

Hiermit versichere ich, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt habe. Außerdem versichere ich, dass ich die allgemeinen Prinzipien wissenschaftlicher Arbeit und Veröffentlichung, wie sie in den Leitlinien guter wissenschaftlicher Praxis der Carl von Ossietzky Universität Oldenburg festgelegt sind, befolgt habe.

Oldenburg, d. 15.9.09

Christian Ketzer