Latrine-site use of small-clawed otters (Aonyx cinereus) in tropical rice fields

Dissertation Abstract

Latrine-site use of small-clawed otters (*Aonyx cinereus*) in tropical rice fields

熱帯地域の水田地帯におけるコツメカワウソ(*Aonyx cinereus*) の排糞場所利用

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Chapter 1: General Introduction

Rice fields is the largest single use of land for producing food. Although rice fields are primarily created for food production purposes, rice fields have multiple functions beyond their role of producing food. For example, rice fields can serve as important habitats for aquatic and semi-aquatic wildlife. Owing to increased food production via agricultural intensification and modernization, changes in land use or farming practices have led to loss of aquatic and semi-aquatic organisms that use rice fields as forage or refuge sites.

The small-clawed otter (*Aonyx cinereus*) is an IUCN threatened species that uses rice fields as latrine sites and foraging habitats in South-east Asia. Otter latrine sites play important roles in social interactions among conspecific individuals, such as territorial marking, sexual attraction, and providing social and communication places among conspecific individuals or small groups. In this study, I sought to determine important land-use and/or local environmental variables explaining spatial and/or temporal patterns of latrine-site occurrence and otter visitation to latrine sites in Indonesian rice field landscapes.

Chapter 2: Small-clawed otters (*Aonyx cinereus*) in Indonesian rice fields: latrine-site characteristics and visitation frequency

(Aadrean & Usio, in review in Ecological Research)

Latrine sites, or areas where otters scent-mark and deposit feces, are a habitat feature that serves an important role in communication for many otter species. The small-clawed otter (*Aonyx cinereus*) inhabits both natural and rice-field landscapes in Southeast Asia. However, the latrine-site use by small-clawed otters in rice-field landscapes is largely unknown. Based on a 53-week field survey and landscape analyses, we investigated latrine-site use by small-clawed otters in rice-field landscapes in West Sumatra, Indonesia. Using land-use and/or local environmental variables as predictors (Table 1), we performed generalized linear model analyses to explain the spatial patterns of latrine-site occurrence and otter visitation frequency to latrine sites. We found that small-clawed otters use some latrine sites repeatedly over time; 10 latrine sites were still in use more than seven years after their initial discovery (Fig. 1). Generalized linear model analyses revealed that an intermediate number of rice-field huts was the single most important predictor of the occurrence of latrine sites (Fig. 2; Fig. 3; Table 2), while distance to the nearest settlement, distance to the river, and mean water depth of the rice field adjacent to the latrine site were important predictors of otter visitation frequency to latrine sites (Fig. 4; Table 3). These results indicate that the latrine-site preferences of small-clawed otters in rice-field landscapes are strongly associated with intermediate levels of rice farming activities. Indonesian rice fields are being degraded or disappearing at an accelerating rate due to land conversion and modernization of agriculture. We emphasize the urgent need for the design and implementation of otter-friendly rice farming to conserve the small-clawed otter.

Chapter 3: Temporal use of latrine sites of small-clawed otters in a heterogeneous rice field landscape

(Aadrean & Usio, unpublished manuscript)

The small-clawed otter (*Aonyx cinereus*) is known to use rice fields as latrine sites in South-east Asia. Through a year weekly-survey of latrine sites, we analyzed temporal use of latrine sites of small-clawed otters in rice field landscapes in West Sumatra, Indonesia. On the basis of a generalized linear mixed model (GLMM) analysis incorporating temporal use of latrine sites of small-clawed otters, we revealed that their latrine-site visitation was positively associated with the vegetative stage of rice cultivation, biomass of golden-apple snails, and lagged variable (last week's visitation to the latrine site)(Fig. 5; Table 4). The vegetative stage of rice cultivation was closely associated with the water depth of rice fields and golden-apple snail biomass (Fig. 6). Our results suggest that water and food availability are particularly important in determining temporal use of otter latrine sites. To consistently provide latrine sites for small-clawed otters, we recommend asynchronous rice cultivation.

Chapter 4: Conclusion and Recommendation

The main findings of my study with regards to spatial and temporal use of latrine sites of small-clawed otters are as follows:

- a medium number of rice field huts was the single important factor explaining the occurrence of latrine sites in rice fields (Chapter 2).
- latrine sites that were adjacent to deep-water rice fields, distant from a settlement and close to river experienced the highest visitation frequency by small-clawed otters (Chapter 2).
- latrine sites that were adjacent to the vegetative stage of rice fields with abundant golden-apple snails (*Pomacea canaliculata*) and previously visited site showed the highest probability of visit or re-visit by small-clawed otters (Chapter 3).

Based on these results, I formulate the following management implications for Indonesian rice fields with particular reference to conservation of small-clawed otters:

1. Given that a landscape containing an intermediate number of rice field huts was the important latrine site for small-clawed otters, moderate levels of rice farming activities are encouraged.
2. Although the System of Rice Intensification (SRI), in which less water is used during rice cultivation, is being promoted in Indonesia to conserve water and maximize rice yield, such shallow-flooding practices may have detrimental effects on small-clawed otters. Therefore, otter-friendly farming should be urgently designed and implemented in areas where SRI is promoted.
3. Asynchronous farming practice may be encouraged to maintain landscape heterogeneity and consistent supply of foraging habitats for small-clawed otters. However, a trade-off between

otter conservation and agricultural pest management needs to be considered when designing otter-friendly farming practices or land-use planning.

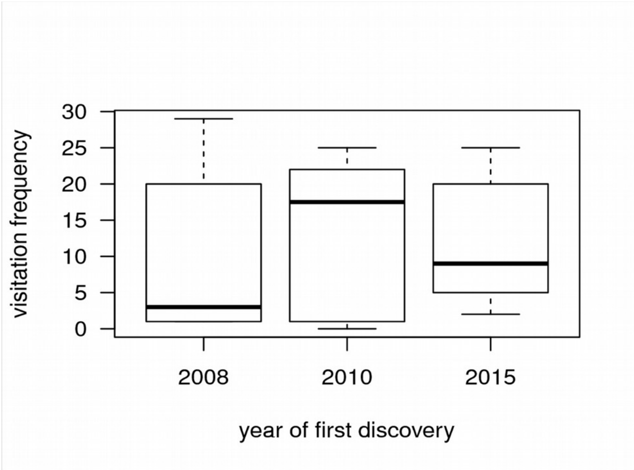

Fig. 1 Box plots of the visitation frequency (over 53 weeks) of small-clawed otters according to the year of first discovery. Thick lines indicate the medians, boxes show inter-quartile ranges (IQR), and whiskers denote 1.5 times the IQR. Visitation frequency did not significantly vary with the year of first discovery (Kruskal–Wallis rank sum test, $\chi^2 = 0.72$, $P = 0.70$)

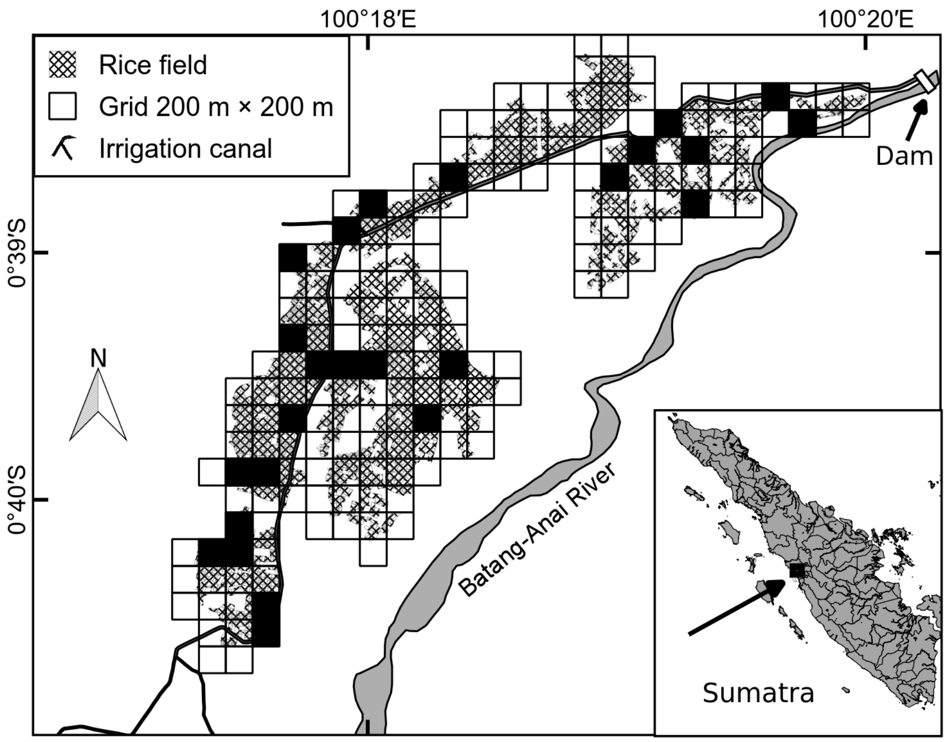

Fig. 2 Study site in the Batang-Anai River drainage area in West Sumatra, Indonesia. Each grid is 200 × 200 m. Filled grids represent areas where latrine sites of small-clawed otters were found in the 2015 survey (conducted over 53 weeks from April 12, 2015, to April 10, 2016). Small effluent ditches flowing from the rice fields to the river are not shown

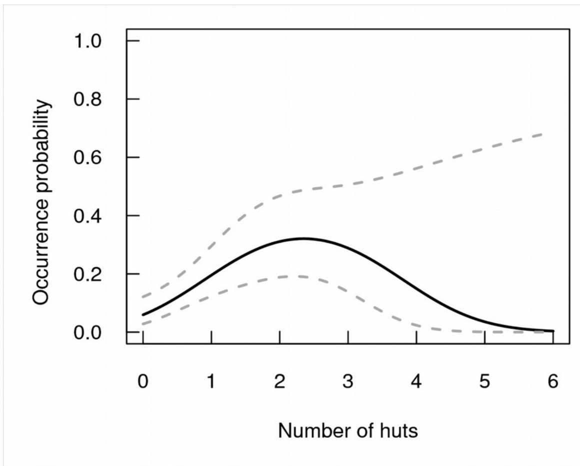

Fig. 3 Relationship between the number of huts and latrine site occurrence of small-clawed otters. The solid line indicates the predicted value. Grey dashed lines indicate approximate 95 % confidence limits (± 2 standard errors of the generalized linear model fit)

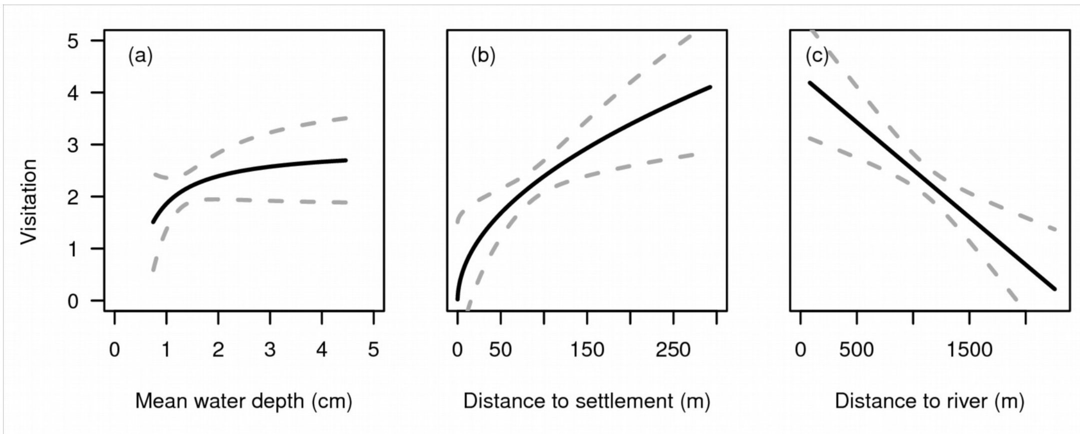

Fig. 4 Relationships between the visitation frequency of small-clawed otters to latrine sites and mean water depth of the rice field adjacent to the latrine site (A), distance to a settlement (B), and distance to the Batang-Anai River (C). The solid lines indicate predicted values. Grey dashed lines indicate approximate 95% confidence limits (± 2 standard errors of the generalized linear model fit). Note that the predictors have been back-transformed to show the actual associations with the response

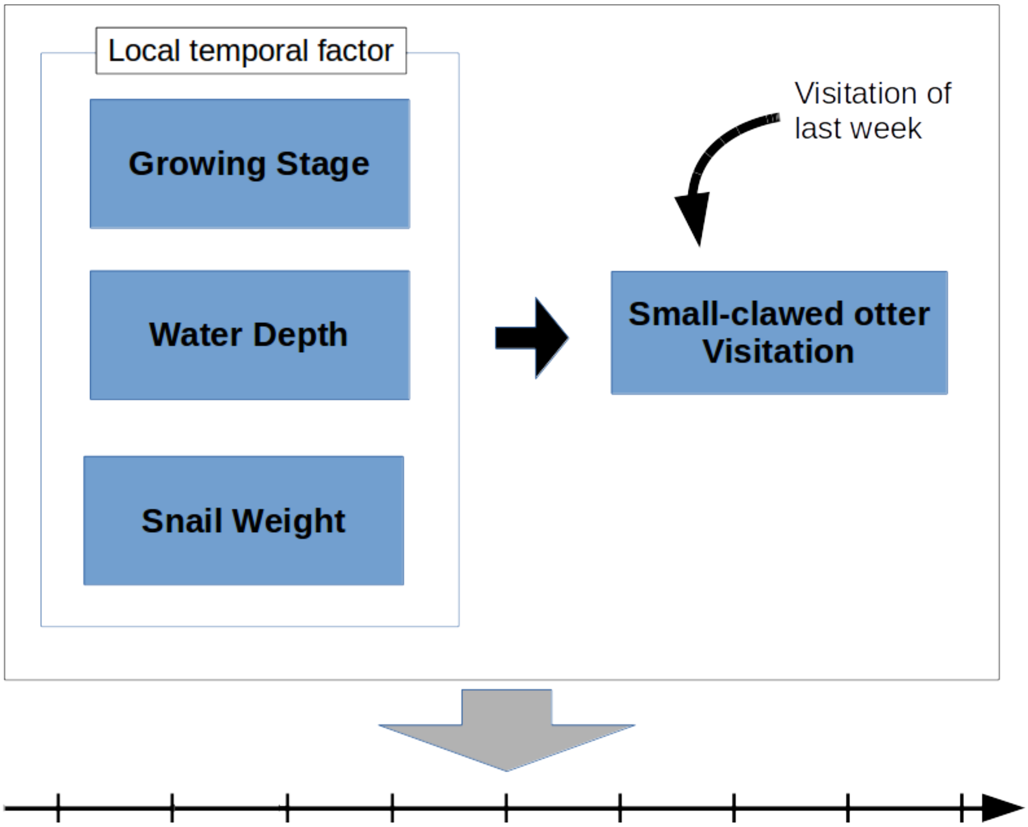

Fig. 5 Model of temporal use of latrine sites of small-clawed otters (*Aonyx cinereus*) in rice field landscapes of the Batang Anai River drainage, West Sumatra, Indonesia.

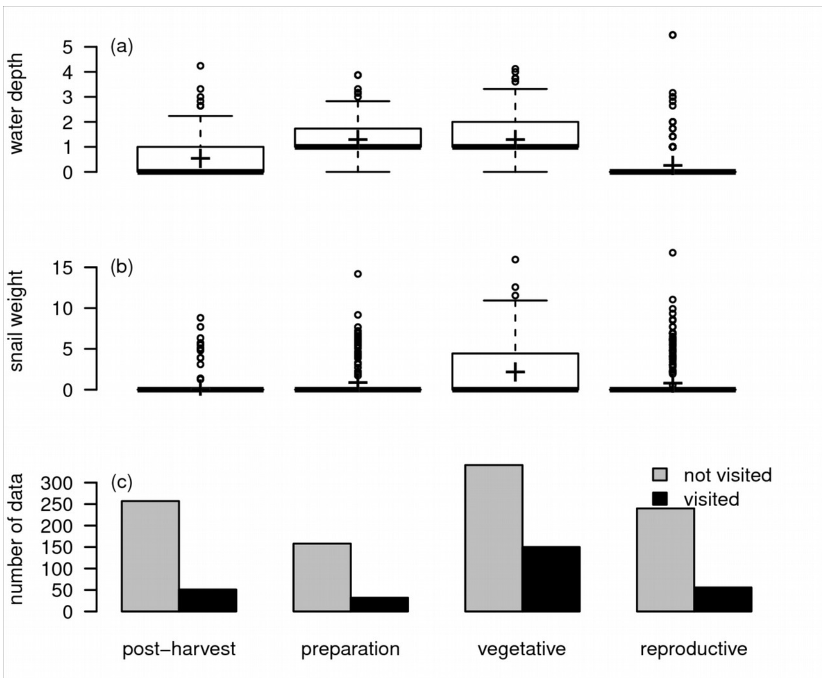

Fig. 6 a) Average water depth and b) average snail wet biomass adjacent to the latrine sites of small-clawed otters and c) visitation to otter latrine sites according to the four rice growing stages. The data for water depth and snail biomass were square-root transformed.

Table 1 Predictor variables used in two generalized linear models investigating the occurrence of otter latrine sites (occurrence model) and visitation frequency of small-clawed otters to latrine sites (frequency model). Transformation refers to the type of data transformation used to normalize the predictor variable

Variable	Description	Mean	SD	Range	Transformation
Occurrence model					
ricefieldprop	Proportion of rice field area in the grid	0.45	0.30	0.00–1.00	$\arcsin(\sqrt{x})$
treeprop	Proportion of tree patch area in the grid	0.09	0.10	0.00–0.42	$\arcsin(\sqrt{x})$
streetsettleprop	Proportion of street and settlement areas in the grid	0.13	0.19	0.00–1.00	$\arcsin(\sqrt{x})$
canalprop	Proportion of canal area in the grid	0.02	0.04	0.00–0.16	$\arcsin(\sqrt{x})$
dryfarmprop	Proportion of dry farmland area in the grid	0.04	0.06	0.00–0.32	$\arcsin(\sqrt{x})$
hutnumber	Number of rice-field huts in the grid	0.75	1.10	0–6	None
gridriverdist	Nearest distance (m) from the centroids of the grids to Batang-Anai River	1141	564.1	15.6–2377.0	None
Frequency model					
Landscape factors					
dryfarmdist	Linear distance (m) to the nearest dry farmland	132.5	95.5	32.8–421.2	$\log(x)$
treedist	Linear distance (m) to the nearest tree patch	74.8	68.0	0.0–257.8	$\sqrt[4]{x}$
streetdist	Linear distance (m) to the nearest street	170.3	77.7	52.4–304.4	None
riverdist	Linear distance (m) to the Batang-Anai River	1204.0	595.5	82.2–2258.0	None
canaldist	Linear distance (m) to the nearest irrigation canal	162.0	142.5	9.3–555.0	$\sqrt[4]{x}$
settlementdist	Linear distance (m) to the nearest settlement	97.1	77.1	0.0–292.6	$\sqrt{x}$
hutdist	Linear distance (m) to the nearest rice-field hut	73.2	79.6	0.0–243.1	$\sqrt[4]{x}$
Local environmental factors					
watermean	Mean water depth (cm) of adjacent rice field (over 53 weeks)	1.66	0.80	0.79–4.51	$\frac{1}{x}$
snailweightmean	Mean weights (g) of golden-apple snails in adjacent rice field (over 53 weeks)	8.06	6.77	0.63–21.32	$\sqrt[4]{x}$

Table 2 Summary of the model selection results for the occurrence of latrine sites (occurrence model) of small-clawed otters in the Batang-Anai River drainage area in West Sumatra, Indonesia. Bold-faced font indicates the best model based on the lowest ΔAIC_c (Akaike's Information Criterion correction for small samples) and the most parsimonious model (fewest variables among models with $\Delta AIC_c < 2$). See Table 1 for abbreviations of the predictors

Model	K[1]	AIC_c	ΔAIC_c	Weights
Occurrence ~ hutnumber + canalprop + treeprop + ricefieldprop – hutnumber^2 – dryfarmprop – streetsettleprop – riverdist	8	147.29	7.86	0.0067
Occurrence ~ hutnumber + canalprop + treeprop + ricefieldprop – hutnumber^2 – dryfarmprop – streetsettleprop	7	145.26	5.83	0.0184
Occurrence ~ hutnumber + canalprop + treeprop + ricefieldprop – hutnumber^2 – dryfarmprop	6	143.36	3.93	0.0476
Occurrence ~ hutnumber + canalprop + treeprop + ricefieldprop – hutnumber^2	5	141.65	2.22	0.1118
Occurrence ~ hutnumber + canalprop + treeprop – hutnumber^2	4	140.26	0.83	0.2245
Occurrence ~ hutnumber + canalprop – hutnumber^2	3	139.43	0	0.3405
Occurrence ~ hutnumber – hutnumber^2	2	140.16	0.73	0.236
Occurrence ~ hutnumber	1	146.02	6.59	0.0126
Occurrence ~ 1	0	149.7	10.27	0.002

[1] Number of parameters

Table 3 Summary of model selection results for the visitation frequency of small-clawed otters to latrine sites (frequency model) in the Batang-Anai River drainage area in West Sumatra, Indonesia. Bold-faced font indicates the best model based on the lowest AIC_c (Akaike's Information Criterion correction for small samples) and the most parsimonious model (fewest variables among models with $\Delta AIC_c < 2$). Note that the sign of "watermean" has been back-transformed from the Box–Cox-transformed estimate to indicate the actual association with the response. See Table 1 for abbreviations of the predictors

Model	K[1]	AIC_c	ΔAIC_c	Weights
Frequency ~ settlementdist + watermean + hutdist + snailweightmean + treedist + streetdist – riverdist – dryfarmdist – canaldist	9	198.04	23.19	0
Frequency ~ settlementdist + watermean + hutdist + snailweightmean + treedist + streetdist – riverdist – dryfarmdist	8	191.46	16.61	0.0001
Frequency ~ settlementdist + watermean + hutdist + snailweightmean + treedist – riverdist – dryfarmdist	7	186.28	11.43	0.0015
Frequency ~ settlementdist + watermean + hutdist + snailweightmean + treedist – riverdist	6	181.9	7.05	0.0138
Frequency ~ settlementdist + watermean + hutdist + snailweightmean – riverdist	5	178.42	3.57	0.0782
Frequency ~ settlementdist + watermean + hutdist – riverdist	4	176.51	1.66	0.2032
Frequency ~ settlementdist + watermean – riverdist	**3**	**174.85**	**0**	**0.4649**
Frequency ~ settlementdist + watermean	2	177.17	2.32	0.1464
Frequency ~ settlementdist	1	178.89	4.04	0.0617
Frequency ~ 1	0	180.33	5.48	0.0301

[1] Number of parameters

Table 4 Summary result of model selections for temporal patterns of latrine site occurrence of small-clawed otters in Batang-Anai River drainage in West Sumatra, Indonesia. Bold-faced font indicates the best model based on the smallest number of parameter that has $\Delta AIC_c < 2$ from the lowest AIC_c. Rice growing stage (Stage), water depth (Water), golden apple snail biomass (Snail), and lagged variable (LagVisitation) were treated as fixed factors and week nested in latrine site ID (Week | LS) was treated as a random factor.

Formula	AIC_c	Weights	ΔAIC_c
Visitation ~ Stage + √(Snail) + LagVisitation + (Week | LS)	**1055.96**	**1**	**0**
Visitation ~ Stage + √(Water) + √(Snail) + (Week | LS)	1088.63	0	32.67
Visitation ~ Stage + √(Snail) + (Week | LS)	1088.88	0	32.92
Visitation ~ Stage + (Week | LS)	1097.16	0	41.2
Visitation ~ Stage + √(Water) + (Week | LS)	1099.15	0	43.19
Visitation ~ √(Snail) + (Week | LS)	1103.88	0	47.92
Visitation ~ √(Water) + √(Snail) + (Week | LS)	1105.52	0	49.56
Visitation ~ √(Water) + (Week | LS)	1127.4	0	71.44

平成２９年　８月　４日

学位論文審査報告書（甲）

１．学位論文題目（外国語の場合は和訳を付けること。）

Latrine-site use of small-clawed otters (*Aonyx cinereus*) in tropical rice fields

熱帯地域の水田地帯におけるコツメカワウソ(*Aonyx cinereus*)の排糞場所利用

２．論文提出者　(1) 所　　属　自然システム学　　　専攻

(2) 氏　　名（ふりがな）　Aadrean

３．審査結果の要旨（600～650 字）

これまでのカワウソ類の排糞場所利用の研究は、原生自然の保護区域を対象とした研究がほとんどであったのに対し、Aadrean の研究は、水田地帯でその環境特性を明らかにした点が新しい。一年以上（53 週間）に及ぶ精力的な野外調査と統計モデル、GIS 解析に基づき、非同調的な稲作と中程度の人間活動がコツメカワウソの存続に重要であることを示した。主要研究成果は、Ecological Research 誌に投稿し、微修正後に受理可と判定されている（2017 年 8 月 2 日現在）。その後、2017年8月4日にEcological Research誌に受理された。

学位論文の公聴会では、コツメカワウソの排糞場所利用は特定の環境要因の影響を大きく受けていない可能性があること、非同調的な稲作がコツメカワウソなどの野生生物にとって必ずしもベストではない可能性があること、将来的に地域住民とコツメカワウソはどのように関わっていくべきか等の質問・コメントが出た。

Aadrean は、研究計画の立案、助成金の獲得、フィールド調査、データ解析、論文執筆等すべての面において主体的に取組み、研究成果の一部は国際誌に投稿している。また、これまで日本生態学会大会（2016、2017）、日本陸水学会大会（2016）、国際カワウソ類シンポジウム（2016）、国際生態学会(INTECOL)(2017 予定)で精力的にポスター・口頭発表を行ってきた。以上の研究実績を鑑み、博士の学位を付与するに相応しいと判断された。

４．審査結果　(1) 判　　定（いずれかに○印）　合　格　・　不合格

(2) 授与学位　博　士（　理学　）