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Low-disturbance control of invasive semi-aquatic rodents in a World Heritage coastal wetland: operational rules from field evidence at Yancheng, China

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Abstract

Coastal wetlands that are bordered by farmland ditches present wetland managers with a practical conflict: invasive semi-aquatic rodents require control, but control work disturbs the waterbirds and wetland habitat that the same ditches support. We compiled georeferenced, time-stamped observations of nutria (*Myocastor coypus*) and muskrat (*Ondatra zibethicus*) from the Yancheng Yellow Sea coastal wetland, a World Heritage site in Jiangsu, China, and converted each record into management-relevant attributes: time window, microhabitat, behaviour, water depth, vegetation cover, and distance to access. Four records from two sites in 2025–2026 met the reporting criteria: two nutria at reed–mud margins in the afternoon, one about 5 m from a farm road in water 1–1.5 m deep, and two muskrat in a crop-adjacent ditch at dusk, one carrying broad bean. Nutria therefore occupied shallow littoral habitat of the kind that waterbirds also use, whereas muskrat use was tied to farmland subsidies in narrow ditches. From this contrast we derive four rules for low-disturbance control: keep connected reed corridors free of routine control; restrict nutria work to mapped littoral hotspots entered briefly and once; prioritize muskrat control in crop-adjacent ditches rather than in refuge vegetation; and schedule muskrat work at dusk and night while avoiding dawn bird peaks, nest microsites, and spotlight sweeping. The sample is small and descriptive, and we make no claim about abundance or distribution; the contribution is an auditable decision layer that wetland managers can apply immediately and test with flush-distance and return-time monitoring.

Introduction

The Yancheng coastal wetland, part of the Migratory Bird Sanctuaries along the Coast of Yellow Sea–Bohai Gulf of China inscribed on the World Heritage List in 2019, is one of the most important staging and wintering landscapes on the East Asian–Australasian Flyway. The property and the wider intertidal system around it support more than 400 species of migratory birds, including a large number of threatened waterbirds, and its flats and reed marshes hold concentrations of shorebirds and waterfowl that depend on a small and shrinking set of stopover sites (UNESCO World Heritage Centre 2019). Population trends for the flyway are not encouraging: taxa that rely most heavily on Yellow Sea mudflats have declined fastest, at rates of 5–6% per year, and census-based analyses show continuing declines across a broad suite of waterbird populations (Studds et al. 2017; Langendoen et al. 2021). The conservation priority in this landscape is therefore defined by wetland-dependent birds rather than by the mammals that share the same water.

That priority is complicated by the fact that the protected area is not a closed reserve. The coastal plain around it is a mosaic of reed marsh, shallow open water, muddy littoral margins, tidal and drainage creeks, aquaculture remnants, and dense networks of irrigation and drainage ditches. Ditches are not merely engineering features: they are wet, vegetated, non-cropped habitats that support aquatic and terrestrial taxa, provide food and water when the surrounding fields are dry, and act as corridors connecting otherwise isolated wetland patches (Herzon and Helenius 2008). Waterbirds use them accordingly, and flooded or irrigated farmland can hold waterbird assemblages of real conservation

value (Elphick and Oring 2003). The practical consequence is that the boundary between refuge and production landscape is porous, and the linear wetlands that carry waterbirds across the mosaic are the same linear wetlands that carry everything else.

Two invasive semi-aquatic rodents now occupy this boundary. Nutria (*Myocastor coypus*), a South American species introduced worldwide for fur farming, has established wild populations in at least six Chinese provinces, including Jiangsu, following escapes and releases from captive stocks (Carter and Leonard 2002; Pedruzzi et al. 2022). Muskrat (*Ondatra zibethicus*), a North American species and one of the most successful vertebrate invaders on record, has spread through Eurasia along watercourses and ditch systems since the early twentieth century (Willner et al. 1980; Danell 1996). Both animals burrow into banks, feed on emergent and cultivated vegetation, and can damage water-control infrastructure, and both are treated as pests where they occur (Carter and Leonard 2002; Bomske and Ahlers 2021). Their effects reach beyond crops. Muskrat activity can alter plant species diversity and habitat heterogeneity in wetlands, although the evidence base is patchy and dominated by short, small-scale studies (Bomske and Ahlers 2021), and burrowing in ditch banks and levees is a recognized maintenance problem in wetland-agricultural mosaics.

Controlling such animals requires exactly the kind of field activity that wetland conservation is organized to limit. Trapping means repeated human presence at the water's edge, often at dawn or dusk; bank repair means machinery, excavation, and vegetation clearance; monitoring means walking the same levees week after week. Waterbirds respond to these stimuli. Flushing distances have been measured for decades, and recommended set-back distances of about 100 m for wading-bird colonies and 180 m for mixed tern and skimmer colonies are widely applied in Florida and elsewhere (Rodgers and Smith 1995). Buffer distances have also been derived for foraging and loafing waterbirds, which are the birds most likely to be encountered in a ditch or littoral margin rather than at a colony (Rodgers and Smith 1997). Yet a single radius is a blunt instrument. Flight-initiation distance depends on how the approach begins, so the same person at the same distance can produce different responses depending on the intruder's starting point (Blumstein 2003). More importantly for reserve operations, disturbance effects scale with the number of visits rather than with a fixed distance: where visitor numbers fluctuate, fixed set-back distances may be the wrong conservation measure altogether (Beale and Monaghan 2004). Wetland management actions also tend to produce species- and guild-specific responses rather than uniform ones, as shown for water-level manipulations in managed impoundments (Owen et al. 2026). What a manager needs, then, is not only a radius but a schedule and a route.

Regional work on these rodents does not supply that. Studies tend either to model habitat suitability or to document impacts, and both leave the operational question unanswered: a high-resolution suitability surface tells a warden where an animal probably is, but not whether it is acceptable to walk in, when to walk in, or how many times. Here we take a deliberately narrower and more modest approach. We ask when, in which microhabitat, and with what behaviour nutria and muskrat enter wetland that waterbirds can use, and we translate each observation into rules stating when control is possible, where it is not, and what distance from access points and sensitive microsites should be respected. We do not build a

distribution model, estimate abundance, or infer waterbird numbers; the dataset is small, and its value lies in the precision of its metadata rather than in its size.

Methods

Study area

Records were collected in the Yancheng coastal wetland–farmland mosaic, Jiangsu Province, China, within and adjacent to the World Heritage property. Natural components of the mosaic include reed marsh dominated by *Phragmites australis*, shallow open water, muddy littoral margins, and tidal and drainage creeks. Agricultural components include narrow irrigation and drainage ditches, cropped field edges, farm roads, small ponds and aquaculture remnants, and reed fringes along ditch margins. The two systems are hydrologically connected: ditches drain the fields into the creeks and marshes, and water levels in both respond to the same rainfall and irrigation schedule.

Field records

We retained only observations that carried enough metadata to be operationally useful: date, time or time class, coordinates or a named site, evidence of species identification, behaviour, habitat, water depth where available, vegetation, and distance to roads or obvious human disturbance. Three observation classes were admitted: direct visual records with photographs or video; georeferenced photograph or GPS screenshots with coordinates, altitude, time, and location notes; and verified observer logs with standardized entries for species, behaviour, habitat, and land-use context.

Only four records from opportunistic observations in 2025 and 2026 met all criteria; we report all four because the framework depends on the contrasts among them. Landscape photographs that showed waterbird congregations in the same ditch network were not used as count data; they served only to confirm that these shallow channel networks attract waterbird aggregations and should therefore be treated as sensitive access corridors.

Management coding

Each record was coded for five attributes. Time window was classified as day, dusk–night, or unknown. Microhabitat was classified as natural reed margin, shallow littoral mudflat, crop-adjacent ditch, or open deep channel. Waterbird sensitivity was scored high for connected reed corridors and shallow littoral foraging margins, moderate for reed-fringed farm–wetland transition, and low for steep-banked, deep, reinforced conveyance channels. Disturbance exposure was the recorded distance to the nearest road or established human access. Control suitability recorded whether rapid, localized control could plausibly be carried out without chronic entry into the habitat.

No inferential statistics were used and no effect sizes were estimated. The coding was intentionally conservative: where a record fell inside a sensitive waterbird microhabitat, the segment was assigned to avoid or restrict rather than to a graded risk category. Rules were then derived by mapping each coded attribute to a single operational decision, following the sequence shown in Fig. 1b: whether the segment is a connected reed-lined corridor, whether the record is nutria in a shallow natural margin, and whether the record is muskrat in a crop-adjacent ditch.

Ethics

No animals were captured or handled. All observations were made from existing access points, with photographs and video taken at a distance; no vegetation was cleared and no bank was modified for the purposes of this study.

Results

Field records

Four records qualified (Table 1). Two concerned nutria. On 29 October 2026, in the afternoon, an animal was photographed at the reed–mud margin of a shallow margin near Haibei Farm (33.414810° N, 120.630204° E), where reed, wild soybean, and weedy vegetation grew in water about 1–1.5 m deep and a farm road lay about 5 m away; the photographs show the animal moving from water onto muddy substrate at the reed edge. A second georeferenced record from the Dafeng area (33.408920° N, 120.682360° E) placed an animal at a reed-dominated edge between natural wetland and farmland, with water depth not recorded and a farm and road landscape in the vicinity.

Table 1

Management-coded field records of nutria (*Myocastor coypus*) and muskrat (*Ondatra zibethicus*) from the Yancheng coastal wetland–farmland mosaic, Jiangsu, China, 2025–2026. Coordinates are WGS84; waterbird sensitivity follows the scoring described in Methods

Record	Species	Date and time	Coordinates	Behaviour recorded	Microhabitat and conditions	Management inference
NT-20261029-a	Nutria	29 Oct 2026, afternoon	33.414810° N, 120.630204° E (Haibei Farm)	At reed–mud margin, moving from water onto mud	Reed margin and shallow littoral; water 1–1.5 m; reed, wild soybean, weeds; farm road about 5 m	High waterbird sensitivity; restrict access
NT-20261029-b	Nutria	29 Oct 2026, daytime	33.408920° N, 120.682360° E (Dafeng)	Location context only	Reed-dominated natural–farm edge; depth not recorded; farm and road landscape	Confirm littoral margin use; avoid repeated entry
MUS-20250515-01	Muskrat	15 May 2025, evening	33.2712° N, 120.5248° E (Fangqiang Farm)	Swimming low; carrying broad bean toward cover; wary; dusk-active	Crop-adjacent ditch; shallow; broad bean field edge; moderate farm disturbance	Agricultural subsidy; dusk–night control candidate
MUS-video-a	Muskrat	15 May 2025, evening	Same as above	Low swimming profile; concealed movement	Narrow ditch at crop edge; depth not measured; bank vegetation as reflection	Nocturnal–crepuscular; avoid daylight work in reed margins

Two records concerned muskrat and came from the same evening. On 15 May 2025 at Fangqiang Farm (33.2712° N, 120.5248° E), photographs and video showed an animal swimming low in the water and carrying a broad bean toward cover at the edge of a broad bean field. The observer described it as wary and dusk-active, emerging late and leaving after only two photographs. A second video record from the same evening showed the low swimming profile and concealed movement along a narrow ditch at the crop edge, with water depth not measured and bank vegetation visible only as reflection.

A contrast rather than a statistic

The two species did not present equivalent management problems. Nutria records fell in natural or semi-natural shallow margins, where waterbird sensitivity is high and where repeated entry for trapping or bank repair would accumulate disturbance along exactly the edge that birds use. Muskrat records fell in a narrow ditch beside a crop field, where the primary conflicts are crop loss, bank instability, and farm infrastructure rather than refuge integrity, and where activity was concentrated in a short dusk window.

Waterbird congregations were visible in the same ditch network in landscape photographs taken during the observation period, which is consistent with treating these corridors as waterbird habitat rather than as pure infrastructure. We do not quantify that use here, and the photographs are not counts. The contrast is therefore qualitative in origin but explicit in consequence: in connected reed margins, even infrequent human entry can accumulate; in crop-adjacent ditches, disturbance can be reduced by keeping work out of reed corridors and by timing it away from dawn activity and breeding microsites.

Nutria control here is mainly a question of where; muskrat control is a question of when and where together. The rules below follow that asymmetry.

Management framework

We propose four rules, summarized operationally in Table 2 and in panel b of Fig. 1. The rules are stated as procedures so that a warden, a farm manager, and a reserve biologist can apply them to a specific ditch segment and record the decision.

Table 2
Operational windows for low-disturbance control by zone. Zones are defined by connectivity to reed-lined waterbird corridors and by microhabitat, not by administrative boundary

Zone or condition	Routine control	Permitted action	Timing	Avoid
Connected reed-lined waterbird corridor	No	Monitoring only	Non-breeding, low-tide, low-use windows	Trapping grids, bank work, vegetation clearance
Shallow nutria margin outside refuge corridor	Only with justification	One rapid targeted visit	Midday, short duration, pre-mapped access	Dawn and dusk peaks, repeated visits
Crop-adjacent muskrat ditch	Yes, prioritized	Targeted control	Dusk to night, after local evening settling; check breeding status	Spotlight sweeping of reed margins, blocking escape routes
Deep reinforced conveyance channel	Low priority	Patrol only	Any	Unnecessary habitat entry

Rule 1. Connected reed corridors are no-routine-control zones. Reed-lined margins and shallow littoral edges should be treated as waterbird refuge habitat. Any nutria control there requires site-specific

justification, a rapid entry and exit, no vegetation clearance, and no bank reshaping unless safety-critical, timed outside peak staging and local breeding periods.

Rule 2. Daytime nutria records are high-sensitivity confirmation, not permission for repeated access. Because nutria were observed by day on muddy reed edges, apparently quiet littoral margins should be assumed to be used by both rodents and waterbirds. Control should use pre-mapped access points and avoid creating new trails along narrow levees.

Rule 3. Muskrat control is concentrated in crop-adjacent ditches. Records of broad bean carrying indicate an agricultural subsidy pathway. Control can therefore be prioritized where the conflicts are crop loss, ditch-bank instability, and farm infrastructure, provided that the ditch segment is not a connected reed-lined corridor.

Rule 4. Muskrat work is scheduled for dusk and night, but not at any cost. Nocturnal timing reduces overlap with diurnal waterbird activity, but crews should not sweep spotlights across reed margins, enter nest or chick microsites during the breeding period, or block escape routes in ways that force animals into refuge vegetation.

Discussion

The framework proposed here is a decision layer, not a prediction. Its purpose is to make the reasoning behind a control decision explicit and auditable, so that the people responsible for a ditch can disagree about a specific segment rather than about general policy. This is a different product from a habitat suitability map. A model can rank a landscape at fine resolution, but the operational questions in a ditch mosaic concern entry, timing, and repetition, and those are properties of a work plan rather than of a surface. Our four records are too few to support inference, but they are sufficient to show what a management-relevant record looks like: a coordinate, a time, a behaviour, a water depth, a vegetation type, and a distance to access.

The emphasis on timing and route follows from the disturbance literature rather than from our data. Fixed buffers are a reasonable first approximation for colonies, where the birds are concentrated and the approach is predictable (Rodgers and Smith 1995, 1997), but they perform poorly where use is dispersed and repeated, because the response depends on the number of visits and on how each approach begins (Blumstein 2003; Beale and Monaghan 2004). In a ditch network, a crew that stays outside a nominal radius but walks the same levee four times a week may cause more disturbance than a single short visit that comes closer. This is why pre-mapped access, single visits, and no new trails appear in our rules as substantive measures rather than as housekeeping. It is also why a daytime nutria record is a warning rather than a permission: repeated daylight entry at an active edge displaces birds without ever being recorded as an incident.

The emphasis on place follows from habitat structure and from what the rodents were doing. Reed–mud margins and shallow littoral flats are the same physical template that foraging and loafing waterbirds

select, so a control action there is not merely near bird habitat, it is inside it. Crop-adjacent ditches are different in kind. The muskrat carrying a broad bean is a direct observation of crop use, and it locates the invasion pathway in the agricultural subsidy rather than in the marsh: farmland provides food that is available when natural wetland production is low, and ditch networks provide the linear habitat that connects fields to marsh (Danell 1996; Bomske and Ahlers 2021). If that reading is correct, then the highest-value control is not at the refuge edge but at the subsidy, and effort spent in crop ditches reduces pressure on the marsh while leaving the marsh itself unvisited.

This is also the only allocation consistent with what is known about control effort. Muskrat populations decline only when trapping effort exceeds a threshold sustained over successive years, on the order of 1.4 field hours per km of waterway in the Dutch programme (van Loon et al. 2017). Effort of that intensity cannot be distributed across sensitive margins without conflict, so it should be concentrated where it is legitimate. The corollary is uncomfortable but should be stated: a framework that protects refuge corridors by deferring control to crop ditches accepts that nutria in the marsh will be monitored rather than removed until a site-specific case is made, and that muskrat control in ditches may not affect the marsh population if dispersal continues. We prefer this explicit trade-off to an implicit one. Many programmes already make it implicitly, by avoiding places where access is difficult or where a complaint is likely. Writing the reasoning down is the contribution.

For wetland management more generally, the framework has three implications. First, invasive rodent control in wetland mosaics is a scheduling problem as much as a spatial one, and management plans that specify only where trapping is permitted will miss the dominant disturbance pathway, which is repetition. Second, the agricultural subsidy is part of the wetland problem: as long as crop edges and ditch banks supply food, removal in the marsh will be offset by production in the fields, so catchment-level planning is more effective than site-level trapping. Third, the indicators that would justify a rule change, flushing distance, return time, and nest microsite occupancy, are cheap for wetland managers to collect and are the same variables used in the buffer-zone literature (Rodgers and Smith 1997; Blumstein 2003). Where management actions are already known to generate guild-specific bird responses (Owen et al. 2026), monitoring those indicators is the only way to tell whether a rule is working.

The limits of the evidence are equally explicit. Four records from two sites, collected opportunistically in two different years and seasons, cannot establish frequency, seasonality, or population status, and they cannot distinguish between habitats that rodents avoid and habitats that observers happened not to visit. Species identification rests on photographs and video rather than on capture. No flushing distance was measured, no waterbird count was made, and no control operation was observed before and after. Muskrat records are biased toward individuals that stayed long enough to be filmed. These constraints are the reason the output is a set of procedural rules with stated conditions rather than a map or an index.

Testing the framework requires data that a reserve can collect without a research programme. A disturbance log kept by control crews would record flushing distance, species flushed, return time after

the crew leaves, and the number of visits per segment per month. Nest and chick mapping during the breeding season would identify the microsites that Rule 4 protects, and trail cameras on ditch segments would separate rodent activity from observer presence. A before–after comparison around the first control operation in a crop ditch, with an unmanipulated ditch as reference, would test whether concentrating effort there reduces sign in adjacent marsh. None of this requires a distribution model, and all of it would make the rules falsifiable.

The framework is transferable in structure, though not in its thresholds. Any wetland mosaic that combines protected marsh with farmland ditches faces the same choice between controlling an animal and disturbing a bird, and the same shortage of operational guidance. The sequence we used, from segment connectivity to microhabitat to taxon-specific timing, can be applied elsewhere; the specific distances and windows should be set locally, from measured flushing distances and local breeding phenology rather than from this paper. Framed this way, the question for management is not where the rodents are but where entry is defensible, and that question can be answered with a notebook, a camera, and a map.

Conclusions

In a World Heritage coastal wetland bordered by farmland ditches, low-disturbance rodent control is primarily a problem of scheduling and route discipline rather than of spatial prediction. Four time-stamped, georeferenced records were enough to separate a where problem, nutria in shallow reed margins, from a when-and-where problem, muskrat in crop ditches, and to convert that separation into four operational rules. The rules are provisional and are meant to be tested by the crews who use them, with flushing distance and return time as the first indicators.

Declarations

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

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Author Contribution

Yanyu Zhao conceived the framework, collated and coded the records, and drafted the manuscript. Yanzhou Zhang and Yahui Li checked species identifications, verified coordinates and metadata, and revised the manuscript. All authors read and approved the final manuscript.

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Data Availability

The four coded records underlying this study are reported in full in Table 1, including coordinates, dates, and habitat attributes. Landscape photographs and video are available from the corresponding author on reasonable request, subject to the access conditions of the landholders.

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Figures

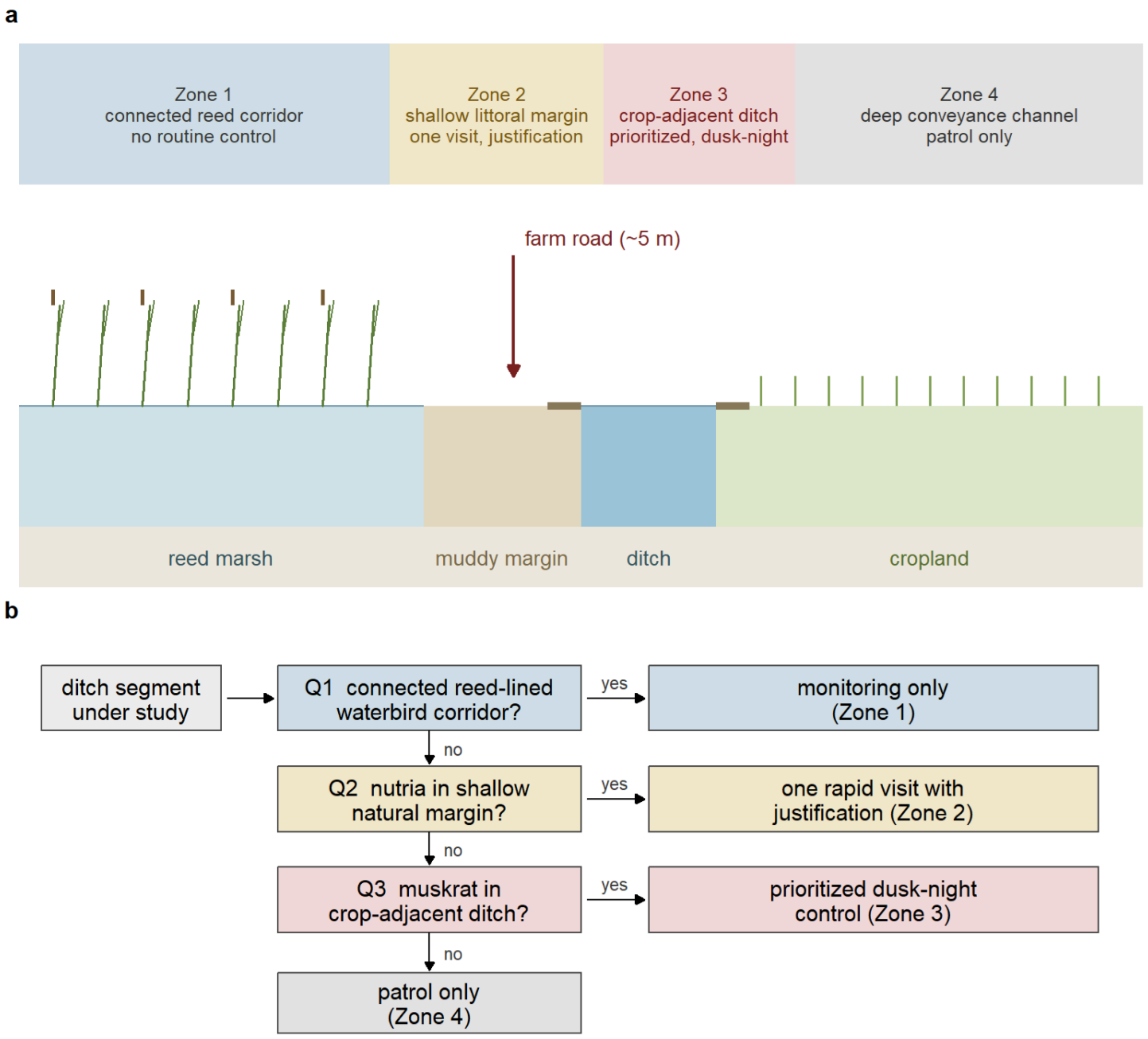


Figure 1

Low-disturbance control zoning and decision sequence for a coastal wetland–farmland ditch mosaic. (a) Schematic cross-section from reed marsh to cropland, showing the four zones used in the rules; the farm-road arrow refers to the access distance recorded for one nutria observation. (b) Decision sequence applied to a ditch segment; the sequence is a procedural aid, not a predictive model