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Ornithological Methods

An inexpensive "smart" trap to capture nestbox-breeding owls and reduce sex biases in ringing data

Una trampa "inteligente" de bajo costo para capturar búhos que nidifican en cajas nido y reducir los sesgos de sexo en los datos de anillado

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ABSTRACT. The ringing and controlling of previously marked birds are invaluable tools for studying the survival, productivity, and movement of birds. To maximize the value of ringing data, it is important to minimize any potential biases. For some species, such as nestbox-breeding owls, ringing records are typically heavily skewed toward females because they generally are easier to catch. The use of traditional mechanical nestbox traps can be vulnerable to false activation, incur lengthy disturbance and be labor-intensive to capture both members of a breeding pair. Here, we describe the design and construction of an inexpensive "smart" trap that provides a highly efficient method to capture nestbox-breeding owls and raptors. The trap is operated by a Raspberry Pi microcomputer and can send a text message to a designated phone number, allowing rapid retrieval of the captured bird and re-setting of the trap. From 2020 to 2023, using the smart trap, we successfully captured all the breeding male Tawny Owls *Strix aluco* in our study population. The trap also facilitated the capture of both adults of a breeding pair twice during the breeding season (to deploy and retrieve GPS loggers). By making this trap design openly available, we hope that more ornithologists will start to routinely catch male, as well as female, nestbox-breeding owls, thereby reducing the marked sex bias in ringing data. The trap can also be easily modified to facilitate capture of other nestbox-breeding birds and raptors.

RESUMEN. El anillado y el control de aves previamente marcadas son herramientas invaluables para estudiar la supervivencia, productividad y movimientos de las aves. Para maximizar el valor de los datos de anillado, es importante minimizar cualquier sesgo potencial. En algunas especies, como los búhos que nidifican en cajas nido, los registros de anillado suelen estar fuertemente sesgados hacia las hembras, ya que generalmente son más fáciles de capturar. El uso de trampas mecánicas tradicionales en cajas nido puede ser propenso a activaciones falsas, causar disturbios prolongados y requerir mucho esfuerzo para capturar a ambos miembros de una pareja reproductora. Aquí describimos el diseño y la construcción de una trampa "inteligente" de bajo costo que proporciona un método altamente eficiente para capturar búhos y rapaces que nidifican en cajas nido. La trampa es operada por una microcomputadora Raspberry Pi y puede enviar un mensaje de texto a un número de teléfono designado, lo que permite una rápida recuperación del ave capturada y reactivación de la trampa. Entre 2020 y 2023, utilizando esta trampa inteligente, logramos capturar con éxito a todos los machos reproductores de *Strix aluco* en nuestra población de estudio. La trampa también facilitó la captura de ambos adultos de una pareja reproductora en dos ocasiones durante la temporada de cría (para colocar y recuperar registradores GPS). Al hacer que el diseño de esta trampa esté disponible de forma abierta, esperamos que más ornitólogos comiencen a capturar rutinariamente machos, además de hembras, de búhos que crían en cajas nido, reduciendo así el marcado sesgo de sexo en los datos de anillado. La trampa también puede modificarse fácilmente para facilitar la captura de otras aves y rapaces que nidifican en cajas nido.

Key Words: *banding; capture methods; nestbox; owls; raptors; ringing; trap*

INTRODUCTION

The ringing of birds, and controlling of previously ringed birds, are invaluable for studying the survival, productivity, and movement of birds (Anderson and Green 2009). This is especially true for long-lived birds, where there is a higher chance of recapturing individuals throughout their lives. National ringing schemes, such as Constant Effort Sites (CES) and the British Trust for Ornithology's Retrapping Adults for Survival (RAS), are good examples of how repeated captures of marked individuals can give valuable insight into population demography, for example, how survival rates vary over time (Robinson et al. 2010). For ringing data to be of the greatest value for monitoring populations, it is important to minimize potential biases. It is well-known that some methods of capturing birds can be biased because of differences in capture probabilities between the sexes (Amrhein et al. 2012; Domènech and Senar 1998) or between juvenile and adult birds (DomèNech and Senar 1997). If these biases are not taken into account, this can result in misleading estimations of, for example, adult sex ratios (Amrhein et al. 2012) or sex variation in migratory routes (Schekkerman 1999) and limit the usefulness of ringing data in rigorous population monitoring.

Owls are an example of a taxonomic group in which data on the marking and recapture of breeding individuals are typically heavily skewed toward one sex, the female, at least in the case of nestbox-breeding species. This is exemplified in national ringing data. For example, in Sweden, over the period 2000–2020, 1049 breeding female Tawny Owls *Strix aluco* were ringed, while only 41 breeding males were ringed, equating to 3.8% of the total number of adult Tawny Owls ringed during this 21-year period

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(data provided by the Swedish Ringing Centre, 7 January 2021). Furthermore, of the 41 breeding males ringed during this period, 27 (66%) were ringed in our project located in southern Sweden between 2017 and 2020. In the UK, it is a similar story, where only 17% of Tawny Owls ringed between February and October during 2009–2019 were male. Ringing data of other nestbox-breeding owl species, in the UK, reveal similar patterns, with 13% of marked Little Owls *Athene noctua* and 35% of marked Barn Owls *Tyto alba* reported as male (data provided by the British Trust for Ornithology, 22 January 2021).

The underlying cause of the sex bias in the ringing and controlling of nestbox-breeding owls is likely because of sex differences in breeding behavior, which lead to differences in the likelihood of capture between females and males. Although the female spends a lot of time in the nestbox during incubation and early chick-rearing, the male visits the nestbox less frequently, primarily for provisioning (Sasvári et al. 2000). This makes it relatively straightforward to catch female owls during the day at the nestbox (e.g., with a hand-net), and it is common for researchers to catch and ring females alongside the chicks. Males, on the other hand, are infrequently caught, as demonstrated by ringing data (see above). To catch males during breeding, a nestbox trap can be deployed (e.g., Saurola 1987). In the case of Tawny Owls, this usually involves setting a trap in the evening, while the female is in the box, and returning in the morning to see if the male has been successfully captured. Similarly, if a female cannot be caught by hand (or with a hand-net) on the nest (e.g., if brooding has terminated or she is flushed from the nest), a nestbox trap can be used to catch her. Although some research projects have routinely used traps to catch males (e.g., Saurola 1987, Karell et al. 2017), they are not widely used among amateur ornithologists, resulting in a marked bias of ringing and retrapping adults toward female owls.

The original trap design used to catch nestbox-breeding owls (as described by Saurola 1987) has limitations for catching nocturnal birds, namely that (i) its use can be labor intensive, potentially limiting the number of birds captured and restricting the possibility to repeatedly capture birds during a breeding effort, (ii) it is vulnerable to false triggering, and (iii) it can result in extended periods of disturbance to the breeding pair. In the case where the female cannot be captured by hand net on the nest and the trap is set and only returned to the following morning, it is only feasible to catch one individual per night. There is no guarantee that a second night of trapping effort would capture the second member of a breeding pair, and a further night of trapping prolongs the disturbance caused to the birds. To catch both members of a breeding pair on a single night, the operator has to repeatedly check the trap, which can be labor intensive, as well as requiring working during unfavorable nocturnal hours. If a visit finds a bird captured, the bird can be removed, and the trap reset in the hope of catching the second bird during the same night. With this level of labor required for one trapping event, it may be unfeasible to catch all individuals from a study population. It may also be impractical to capture the same individual more than once during the breeding season, something that might be desirable for research projects deploying tracking devices or where multiple sampling points (e.g., biometrics or blood) from the same individuals are needed over the breeding season.

If the trap is not checked until the following morning, provisioning is prohibited, and either one bird or two birds (depending on whether the female was present in the box when the trap was set) are trapped inside the nestbox for the duration of the night. Furthermore, in our early trials with traditional traps, we found the mechanical hinge mechanism for the gate (that entraps the bird) to be highly sensitive, and we lost many nights of trapping effort due to false triggers of the gate. Causes of such false triggers are likely to be wind or a bird landing on top of the trap. False triggers might then lead to additional trapping nights and/or increased frequency of checks throughout the night, thus resulting in increased disturbance to breeding birds and an increase in effort.

Here, we present a "smart" trap that is a modification of the traditional owl nestbox trap (as described by Saurola 1987) and that provides a highly effective method for catching female and male owls. Using the smart trap increases the chances of catching both members of a pair in one night, by reducing the effort required, reducing the likelihood of trap failure, and reducing disturbance to the breeding pair. Furthermore, these features of the smart trap facilitate the capture of individuals on multiple occasions throughout the breeding season. The trap uses inexpensive and readily available electronic components and allows the operator to receive a text message to their mobile phone when the trap is activated. This makes it possible to retrieve the bird shortly after trapping, reducing the amount of time the bird spends in the trap, and thus minimizing stress and interference with nocturnal parental care activities. Furthermore, this also allows for the trap to be reset, creating the possibility of catching both adults of a breeding pair on the same night. By making this trap design openly available to the ornithological community, we hope that more ringers and researchers will start to routinely catch male, as well as female, owls, which will greatly increase the value of ringing data.

METHODS

Trap design

The trap described here was designed for capturing Tawny Owls in nestboxes (under license from the Swedish Ringing Centre), but the dimensions of the trap can easily be adapted for other species of owls and nestbox-breeding birds. The trap is made to fit the nestboxes in our study area, which have the following dimensions: 30 × 30 × 45/55 cm (width × depth × height of front/back) and a circular entrance hole of 14 cm in diameter. The trap is constructed from 15 mm plywood, with four sides assembled to form a square tunnel 20 × 20 × 40 cm (width × height × depth). A detailed diagram of the trap is shown in Figure 1 and a photo of the trap in situ is shown in Figure 2. At the entrance to the trap, there is a metal gate (cut to size from a metal-wire shelf), the top bar of which sits in indentations in the wood on either side of the trap, such that it is suspended from the inside roof of the trap. The gate is held open with the support of a servomechanism. It is this gate that seals off the trap and entraps the bird. A lip at the front base of the trap prevents the gate from being able to swing outwards, once it has closed. The trap hangs on the front of the nestbox by two hooks formed by two lengths of perforated metal band fixed to the roof of the trap. The ends of the metal hooks provide attachment points for a second metal gate, on the inside of the nestbox entrance. The inner gate is able to swing freely inwards toward the nestbox, thereby allowing a bird to enter the nestbox from the trap but preventing a bird in the nestbox from entering the trap and triggering the closure mechanism. Inside the trap is a foot pedal made of 2 mm aluminum sheet (17 × 15 cm) situated just over half-way into the trap from the outer gate. The foot pedal is secured to the floor at the end closest to the nestbox by a fabric hinge (~5 cm wide) that is bolted to the pedal with pop rivets and stapled to the trap floor. The pedal sits at a shallow angle supported by a spring-loaded push-button situated at the nestbox end of the trap (see Fig. 1).

Fig. 1. Scaled diagram of the nestbox trap attached to a nestbox.

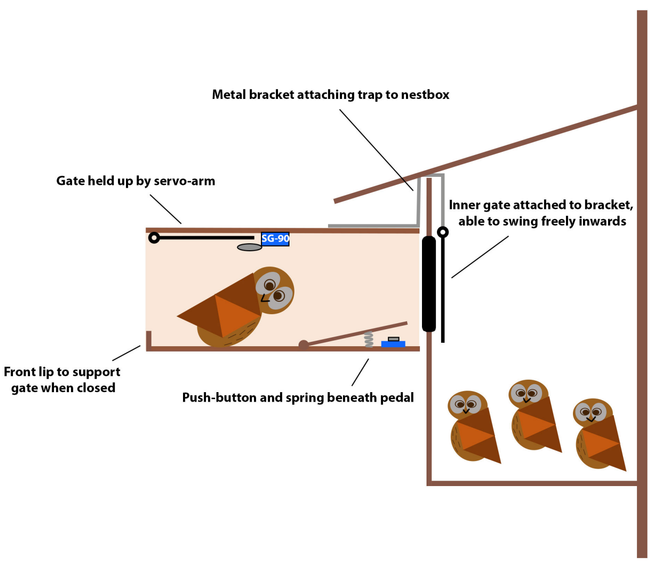


Fig. 2. A "smart" trap fitted to a nestbox, with a PVC box housing the electronics and a power cable leading to a car battery situated at the base of the tree.

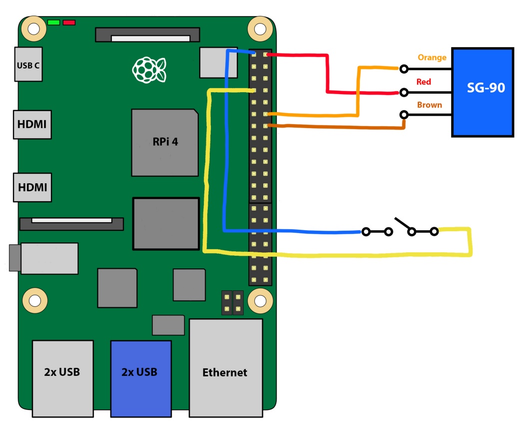
If nestboxes are not all identical in size and structure, it may be necessary to have multiple traps of slightly different dimensions. If nestboxes vary in the thickness of the wood of the front panel of the nestbox and/or the height from the top of the front panel to the nestbox entrance, one could have multiple sets of interchangeable "hooks" of differing length and/or width, by which the trap hangs on the nestbox. Although the nestbox trap can be easily modified for other large nestbox breeding birds, the electronics could also be adapted to work with smaller nestbox traps, e.g., snap traps, for small nestbox-breeding birds.

Hardware

The trap is operated by a Raspberry Pi 4 microcomputer (RPi, https://www.raspberrypi.org/). The RPi is powered by a USB-C connector, which is connected to a DC/DC converter (CPT UL 1, 12 V/5 V) and powered by a 12 V battery. The RPi, DC/DC converter, and cables are housed in a PVC electrical box (with dust and water protection rated at IP65) attached to the side of the trap (see Fig. 2). To make the trap more portable, the battery cable is connected to the PVC box with a waterproof DC-connector (AMP SuperSeal), allowing the trap to be put in position without the power cable attached.

The trap is activated when a bird enters the trap and steps on the foot pedal, which subsequently depresses the push-button (Adafruit tactile button) that is located underneath the pedal and connected to the General-Purpose Input/Output (GPIO) pins 1 (3.3 V) and 7 (GPIO 4) of the RPi. Activation of the push-button subsequently triggers the release mechanism for the trap gate, which is controlled by a micro servo (Tower Pro SG-90) connected to the RPi GPIO as follows: servo red (+) to pin 2 (5 V), servo orange (pulse-width modulation, PWM) to pin 12 (GPIO 18) and servo brown (ground) to pin 14 (ground; see Fig. 3). To allow SMS texts to be sent following trap activation, the RPi is connected via Wi-Fi to the Internet using a standard mobile broadband router. If no broadband router is connected, the trap will still operate but will not send an SMS. The overall construction cost of the trap, including a mobile broadband router, is approximately 130 EUR/150USD. All components are readily available from online or physical electronics or DIY stores.

Fig. 3. Schematic drawing depicting the wiring from the RPi GPIO pins to the SG-90 servo and the push-button.



Software

The RPi runs on a standard installation of Raspberry Pi OS. The trap script is written in Python 3 and is automatically executed when the RPi starts up. In this way, the trap can be easily set (i.e., the outer gate placed in a raised [open] position and the electronics activated) after placing the trap on the nestbox and connecting the power source to the trap. The program runs in a loop, such that when the push-button is activated by applying pressure to the foot pedal, the program triggers the servo arm to swing downwards from a horizontal to vertical position, thereby releasing the trap gate; after 1 s, the servo arm returns to its original horizontal position. When setting the trap and between these two movements of the servo arm, the gate should be raised manually by the operator; once the servo arm returns to its initial horizontal position, the operator can release the gate to sit in an open position, resting on the servo arm. It is only following a second activation of the push-button (when a bird enters and steps on the foot pedal) that the program sends an SMS to a pre-programmed mobile number and the loop terminates. By allowing for two activations of the push-button before a text is sent, it is possible to set the trap in the field by manually pressing the foot pedal once and subsequently leaving the gate in the open raised position. The trap is now in the "set" position.

To send an SMS, an account with an SMS service provider is needed. There are several options available, but in this example, GatewayAPI is used (http://gatewayapi.com). If another service provider is used, the code for sending the text message in the trap script needs to be modified according to their API. Detailed software instructions and code for the trap script are available at: https://github.com/owlecology/trap.

RESULTS

Trap operation

Our experience of operating the trap is for capturing Tawny Owls, though the general principles will likely apply to other nestbox-breeding owls and birds. The most efficient method to trap both adults is to capture the brooding female at the nestbox with a hand-net or directly on the nest (if the female is not quick to flush from the box). While the female is temporarily held out of the nestbox, the trap is installed and set. Once the female has been processed as required (e.g., ringed, controlled, biometrics recorded, etc.), the bird is returned to the nestbox, where the inner gate of the trap will prevent her from leaving the nestbox. Females are used to spending time in the nestbox and brooding the nestlings, and at least in our experience of Tawny Owls, females remain calm in the nest. At some point during the night, the male will (hopefully) enter the trap, activating the closure of the gate by stepping on the foot pedal and triggering the SMS messaging service. The bird may then choose to remain in the trap or enter the nestbox by gently pushing against the freely swinging inner gate. The receipt of an SMS message allows immediate visit and retrieval of the male, if desirable and/or feasible; alternatively, the male can be retrieved the following morning. Of course, a prompt retrieval of the bird and removal of the trap will minimize disturbance and interference with provisioning the young. By notifying the user immediately with an SMS, the smart trap offers a significant improvement for animal welfare compared with the traditional nestbox trap because the time an individual is trapped can be minimized. Even if the trap is not deployed for the entire night, there will still be some disruption to food provisioning, and we suggest providing supplementary food, following the removal of the trap. The type and amount of supplementary food should be chosen based on the species and number of and age/size of the young.

If trapping is being carried out after the cessation of brooding and the female is not in the nestbox, the procedure is to set the trap as described above. In our experience with Tawny Owls, the female is usually the first bird to enter the trap (68% of instances) and typically enters within one hour of sunset because she performs most of the provisioning visits and more readily enters the nestbox. Following the capture of the first bird and receipt of an SMS, the nestbox can be visited and the trap reset, to enable the possibility of the capture of the second adult of the pair. In the case of Tawny Owls, if the female is caught first, we recommend leaving her in the nestbox; she is used to being with the brood and is usually calm in the nestbox. If the female is released, there is the possibility that the female enters the trap again, delaying the successful capture of the male and causing extended disturbance. If the male is caught first, we recommend processing him and releasing him. Because the male does not normally spend time in the nestbox, trapping him in the nest could cause unnecessary stress and reduce the female's confidence to enter the trap and nestbox. We have never captured a male Tawny Owl twice in one night, following this procedure. However, behavior and environmental factors are highly variable between species and individuals, thus it is important to make informed decisions based on knowledge of the species, population and/or individuals concerned.

Because the trap can only send an SMS if the mobile broadband has sufficient cellular coverage, it is important to check the trap promptly in the morning even if no SMS was received. The trap will still function without Wi-Fi or cellular connection, potentially catching a bird without notification if reception is poor. In remote areas where cellular coverage is consistently poor or even completely lacking, the smart trap may not offer such a strong advantage over the traditional mechanical trap because the user might opt to periodically check the trap during the night or invest in additional nights of trapping if only one bird can be captured in a night. However, the smart trap still offers the benefit of a reduced likelihood of false triggering of the trap mechanism, thus reducing the likelihood of birds being prevented from provisioning chicks for extended periods. We recommend using newly recharged batteries for each trap deployment because a loss of power would leave the trap partly inoperable (a bird could theoretically still enter the nestbox through the open trap, but the trap mechanism would not be triggered, and no SMS would be sent).

Effectiveness of the smart trap

Over four years, from 2020 to 2023, we have conducted 152 nights of trapping effort of breeding Tawny Owls using the smart trap at nestboxes. On 67 nights, when the female was first captured on the nest with a hand net, the male was subsequently captured in the trap on 88% of nights (Table 1). In this scenario, there is overall less disturbance imparted on the birds because (i) there is no period during which the trap is closed and one bird is outside of the nestbox and unable to enter, and (ii) if the male enters the trap early in the night, this facilitates the processing of the birds and removal of the trap that night, allowing provisioning to resume that same night. On occasions when the female was no longer brooding and there was a requirement to trap both adults (n = 78 nights), capture rates were 86% and 77% for females and males, respectively (Table 1). In this scenario, we captured both the female and male in the nestbox trap on 51 out of 78 nights (65%). When attempting to catch both the female and male in the trap, only one adult was captured on 25 nights (32%), and there were only two nights (3%) where neither adult was captured. On a further seven nights of trapping, only the female was required, and she was caught on all these nights.

Table 1. Summary of effectiveness of the "smart" trap for capturing breeding Tawny Owls (*Strix aluco*) over 152 nights of trapping during 2020–2023. There were three trapping scenarios: (i) the female was captured while brooding on the nest with a hand net and a trap was set for the male, (ii) brooding had ceased and a trap was set to capture both the female and male, and (iii) brooding had ceased and a trap was set to capture only the female.

Trapping scenario	Female in nest, male to be captured	Female not in nest, female and male to be captured	Female not in nest, female to be captured
Number of traps	67	78	7
Females			
Captured	NA	67 (86%)	7 (100%)
Not captured	NA	11 (14%)	0 (0%)
Males			
Captured	59 (88%)	60 (77%)	NA
Not captured	8 (12%)	18 (23%)	NA

Approximately three quarters of the failed trappings are likely attributed to behavior and a reluctance to enter the trap. This is more marked among males because, in the case of the Tawny Owl, the male typically passes food to the female, who then enters the nestbox and feeds the nestlings. However, in almost all cases, birds were captured on a second trapping attempt (usually carried out 1 or 2 days later). The other quarter of the failed trappings occurred when the first capture was not made until the early hours of the morning, and the trap was not revisited and reset again on that same night, thus preventing the possibility of capturing the second member of the pair. It is estimated that, on fewer than 5% of total trapping nights, failure to catch a bird can be attributed to human error (e.g. dead battery) or trap failure (e.g., faulty push-button or poor cellular signal).

Where there is a need for repeated captures of adults in one breeding season and therefore the requirement to capture birds after the cessation of brooding by the female, the smart trap can be especially valuable. Between 2020 and 2023, at 50 out of 55 nests, we successfully captured both members of the breeding pair twice during the chick-rearing period (to deploy and then subsequently retrieve GPS loggers). At 29 of the 50 nests where both adults were captured twice, the female and male were successfully captured and recaptured in two nights of trapping with a gap of ~9–14 days between the first and second trapping events. At the remaining 21 nests, three nights of trapping were required to capture both birds for GPS deployment and subsequent retrieval. At five nests where only one adult was recaptured during the same breeding season, the other adult was recaptured in the territory using a mist net in winter, and all GPS loggers were retrieved.

DISCUSSION

We describe the materials and design, and provide code, for constructing a smart trap to facilitate catching breeding owls at nestboxes, with the aim of reducing the marked sex bias in the ringing and controlling of nestbox-breeding owls and other raptors. By making this trap design available to the ornithological community, we hope that more ornithologists will start to routinely catch male, as well as female, owls and raptors. The extreme sex bias in the mark-recapture data of owls risks limiting the value of collected data. With a little extra effort, it is possible to markedly increase the value of ringing effort for nestbox-breeding owls, such as we describe here for Tawny Owls. Since we started using the smart trap in 2019, we have captured > 97% of the breeding males in our study population. We have also successfully used the trap to catch both adults of a breeding pair twice during the breeding season (to deploy and retrieve GPS tags), with most recapture failures being caused by nest failure and subsequent departure of the nestbox. Please bear in mind that, depending on national/local legislation, a license or permit may be required to use a trap for capturing birds, and the national ringing agency should be consulted.

Author Contributions:

Johan Nilsson: Conceptualization (lead), Methodology (lead), Software (lead), Investigation (equal), Data Curation (equal), Writing - Original Draft (equal), Writing – review and editing (equal), Visualization (equal).
Hannah Watson: Formal analysis (lead), Investigation (equal), Data Curation (equal), Writing - Original Draft (equal), Writing – review and editing (equal), Visualization (equal).

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Data Availability:

Detailed software instructions and code for the trap script are available at: https://github.com/owlecology/trap. A snapshot of the current trap code is available at Zenodo: https://doi.org/10.5281/zenodo.15526652.

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