CHARACTERISTIC FEATURES OF SKULL AND MANDIBLE OF *BANDICOTA INDICA* (LARGE BONDICOOT RAT) AND *FUNAMBULUS PALMARUM* (INDIAN PALM SQUIRREL) FOUND IN THE DIET OF BARN OWL

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ABSTRACT

The skull morphology and mandibles of different species of field and commensal rodents were species specific which is used as a tool for identification when these portions were recovered from the pellets, etc. Earlier, skull morphology and mandibles of *Bandicota bengalensis, Millardia meltata, Mus booduga, Tateria indica, Rattus rattus*, and *Suncus murinus* were investigated as Barn Owl prey. We found additionally *Bandicota indica* and *Funambulus palmarum* as prey and hence the morphology of skull and mandible are investigated and compared with other species. We conclude that the in the skull morphological dissimilarities in Anterior incisive foramen and Zygomatic arch are species specific in all the eight prey species of Barn Owl which can be used as tool to identify the species in the absence of mandible. Although the species specific notch of the mandible is used for species identification extensively, the coronoid process, condyloid process, angular process and the masseteric process are unique for different species which can be used for identification especially when the notch is in dilemma. It is confirmed that the masseteric process can be used effectively to identify the *B.bengalensis* and *B.indica*, and coronoid processes can be used to identify the *T.indica* and and *M. booduga*. Notch can be used for the identification of *R.rattus* and *M.meltata*. The coronoid processes is primitive and insignificant in *F.palmarum* and in *S.murinus* mandible itself thin and long which can be used to indentify the species.

Key words: Barn Owl, *Bandicota indica, Funambulus palmarum,* Food habit analysis, Mandible, Rodent, Skull

INTRODUCTION

Barn owl (*Tyto alba*) is a birds of prey, extensively feeds on alive animals by hunting which forms a variety of prey species (Nagarajan et al. 1999; Vanitha and Kanakasabai 2009). It is well established that the Barn Owls feed a variety of prey items in Cauvery Deltaic Region of Tamil Nadu and primarily hunt the field rodent pests viz., *Bandicota bengalensis, Millardia meltada, Mus booduga, Tateria indica* and *Rattus rattus* and an insectivore i.e. *Suncus murinus* (e.g. Nagarajan, 1997; Nagarajan et al., 1999). Analytical techniques for the identification of the prey items of owls include pellet analysis, stomach content analysis, examination of uneaten prey in nests, direct and photographic observation of prey delivered to nests (Marti, 1987). Since, the Barn Owl is known to feed on over 20 small mammal genera worldwide (Marti, 1989), a local knowledge on the identification of regurgitated pellets and keys for the identification of prey species is indispensable. The standard and regular method to identify the prey species is pellet analysis which also provides additional knowledge into small mammal communities (Torre et al. 2004, Rickart 1972, Choate 1971, Glading et al. 1943, Errington 1932).

Species identification has been done using the morphological characters and the confirmations are made using the structures of internal organs and skeletal parts (e.g. Adams and Crabtree, 2012) and in which mostly skull, pelvic girdle, mandibles, etc., of different species were used for such identification (Nagorsen, 2002). But occasions when the whole animal body is not available, experts use some of the skeletal parts to identify the species. The skeleton of any animal presents two sets of characters, morphological/ structural character which is connected with an animal's position in the class of vertebrates (Peter and Roger 1980). Generally, the species identification of rodents from the diet of Barn Owl pellet was done using species specific mandibles (Nagarajan et al. 1999, Neelanarayanan et al. 1998). Some time, mandible may not full and in smaller size mandibles, the key structural characteristic features may not be clear and in such situations, an alternative character would be useful to confirm the prey species. Earlier, we suggested that skull as an alternative tool for the identification of rodents in the pellets of Barn Owl. Therefore, Kaliamoorthy et al. (2013) explored the dissimilarities in the morphology of skull of the rodents i.e. *B.bengalensis, M.meltata, M.booduga, T.indica, R.rattus*, and *S. murinus.* Kaliamoorthy and Nagarajan (2015) compared the morphology of skull and mandible of of different species belonging to same genus i.e. *B.bengalensis* and *B.indica*. Further, the two species of *B.indica* (Large Bandicoot Rat) and *F.palmarum* (Indian Palm Squirrel) were found in the diet of Barn

Owl when the pellets were collected from different districts of Tamil Nadu. Hence, the morphology of skull and mandible of *B.indica* (Large Bandicoot Rat) and *F.palmarum* (Indian Palm Squirrel) is investigated in this paper and the morphology is compared with other species.

STUDY AREA

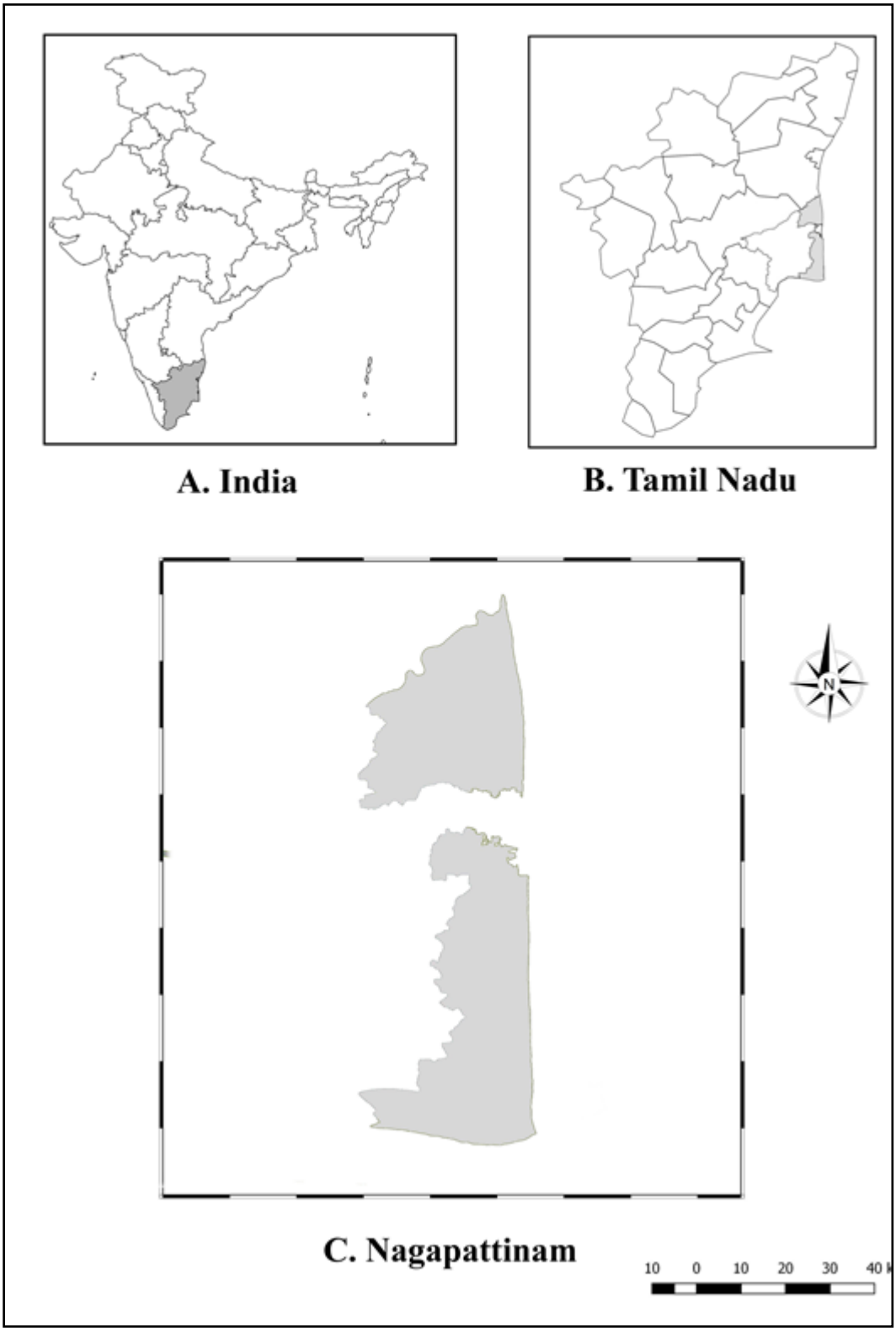
Rodent species were collected from agricultural fields, man-made structures and human habitations from different areas of Nagapattinam District of Tamilnadu, Southern India (Fig.1). The study area is dominated by wet agricultural lands irrigated by river Cauvery and its tributaries viz., Kolidam, Uppanar, Vellar, Maanjalar, Arasalar, etc. as the major perennial water sources. Because of very large scale agricultural operation involving cultivation of paddy, sugarcane, groundnut, banana, pulses and other cereals, the area is called as "Granary" of south India. The agricultural fields are acting as wonderful foraging grounds for Barn Owls. The terrain of this area is flat and consists of fine alluvial soil though sandy soil, sandy clay soil and red soil could also be found in few places. Generally, December- January is the coolest period and April- May is the warmest in the study area. The northeast monsoon usually brings rain to this study area during October- December (65% of the total rainfall in a year) and so is the deciding factor to demarcate various seasons (Nagarajan, 1998 and Nagarajan et al. 2002). Nearly 150 species of plants have been recorded in the study area belonging to 49 families (Karunanithi, 1987). Woody vegetation is mainly in the form of groves which are having old and big trees with cavities. The area has many old temples, monuments, and man-made unused buildings. The old trees and these man-made structures act as suitable nesting and roosting places for Barn Owls.

METHODOLOGY

Bandicota indica (Large Bandicoot rat) is a common pest in storehouses, godowns, poultry forms, vermicomposting forms, and also can be seen in the urban drainage systems. The dead specimens were collected from these forms. *Funambulus palmarum* (Indian Palm Squirrel) was collected from the road kills which is common in the rural roads. The dead specimens of these two species were collected, preserved in sample bag, labelled the details and were brought to the laboratory. The skin and digestive system of the specimens were removed. The remaining contents were boiled by pressure cooker for ten minutes. Then the specimen was cleaned with water and bones, mandibles, skulls, pelvic, and pectoral girdles,

limb bones, were extracted from the content. Of these, skulls and mandibles were selected for observation, analysis and preparation of keys for prey species identification. The skulls and mandibles were dried and different parts of skull and mandibles were observed carefully by using the hand lances for dissimilarities and species specific characters (Kaliamoorthy et al. (2013).

Figure 1: Map showing the study area.



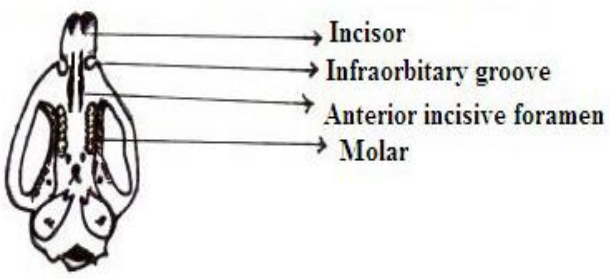
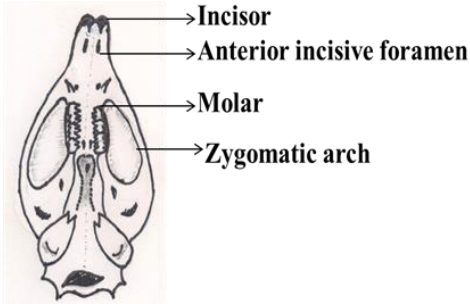
OBSERVATION AND RESULTS

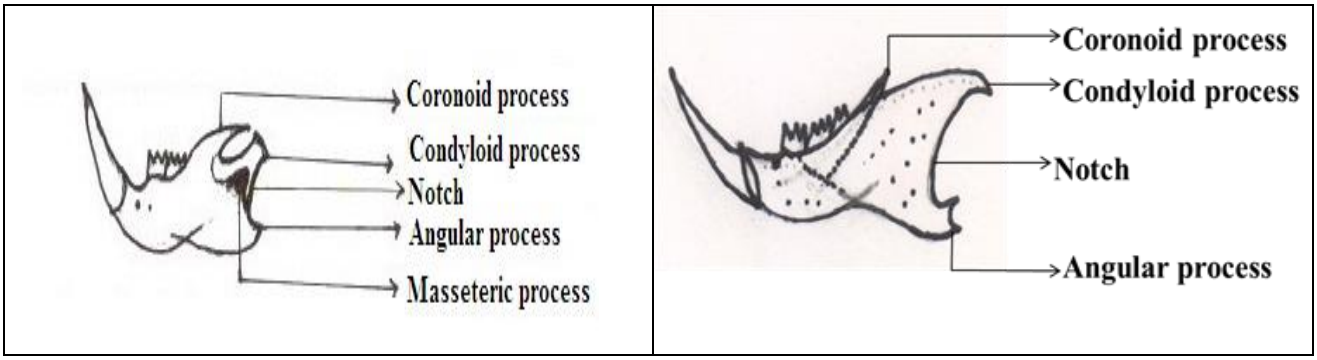
The skulls of *Bandicota indica* (Large Bandicoot rat) and Indian palm squirrel (*Funambulus palmarum*) were placed adjacent each other. A hand lens was used to observe different parts of the skull viz., incisor, infraorbitary groove, anterior incisive foramen, and Zygomatic arch. Among these four parts, dissimilarities between species were prominent in anterior incisive foramen and Zygomatic arch. These two characters are in anterior portion of the skull. In addition, this is the portion can be obtained from pellet without any damage or loss. Hence, using these two characteristic features is useful for identifying the prey species.

Skull bone

The structure and parts of skull bones of *B.indica* and *F.palmarum* differed between species. The three key features compared on the ventral side are i) The area in which the infraorbitary groove starts with reference to anterior incisive foramen ii) The widening nature of the anterior incisive foramen and iii) The ending region of the anterior incisive foramen in relation to the first molar teeth. In addition, the nature of the Zygomatic arch on the ventral side to dorsal side was also compared. These four key characters yielded variations between the prey species. The details and descriptions are shown in figure 2.

Figure 1. Morphological characteristic features of skull and lower mandible of *Bandicota indica* (Large Bandicoot Rat) and *Funambulus palmarum* (Indian Palm Squirrel) found in Nagapattinam District of Tamil Nadu, Southern India.

Bandicota indica (Large Bandicoot Rat)	*Funambulus palmarum* (Indian Palm Squirrel)
	



Anterior incisive foramen starts above infraorbitary groove which is long and ends at the first molar in *B. indica*. The anterior and posterior ends of the anterior incisive foramen is similar and uniform in shape. Whereas in *F.palmarum* the anterior incisive foramen starts just below the incisor and ends before infraorbitary groove. Infraorbitary groove starts before the first molar in *F.palmarum* and in *B. indica*, it starts just below the anterior incisive foramen. Zygomatic arch was varying between the species. In *B. indica*, it starts as curve and leads straight downwards and form thin groove. In *F. palmarum*, the starting region is not clear but it was thin at the front and back, whereas in the middle region it is thick (Fig. 2; Table 1).

Table 1: Key morphological characteristic features of skull of *Bandicota indica* (Large Bandicoot Rat) and *Funambulus palmarum* (Indian Palm Squirrel) found in Nagapattinam District of Tamil Nadu, Southern India.

Species	Anterior incisive foramen	Zygomatic arch
Bandicota indica (Large Bandicoot Rat)	i) Anterior incisive foramen is almost similar across the whole. ii) Anterior incisive foramen starts above infraorbitary groove which is long and ends at the first molar.	It starts as curve and leads straight downwards and form thin groove
Funambulus palmarum (Indian Palm Squirrel)	i) Anterior incisive foramen is short ii) Anterior incisive foramen starts just below the incisor and ends before infraorbitary groove.	The starting region is not clear but it was thin at the front and back, whereas the middle region is thick

Mandible

Different parts of mandible viz. coronoid process, condyloid process, notch and masseteric process are observed. In *F. palmarum*, the coronoid process is short and does not form any shape with condyloid process. There is no masseteric process. The notch formed between condyloid process and angular process was shallow but wide. The angular process

moved inward. In *B. indica*, the coronoid process is long and forms deep curvature with condyloid process. The masseteric process is prominent but does not form any gap. The notch formed between condyloid process and angular process was deep but narrow. The angular process is just below the condyloid process (Fig. 2; Table 3).

Table 2: Key morphological dissimilarities in coronoid process, condyloid process, notch, angular process and masseteric process in the mandibles of *Bandicota indica* (Large Bandicoot Rat) and *Funambulus palmarum* (Indian Palm Squirrel) found in Nagapattinam District of Tamil Nadu, Southern India.

Species	Coronoid process	Condyloid process	Notch	Angular process	Masseteric process
Bandicota indica (Large Bandicoot Rat)	Long and forms deep curvature with condyloid process	Broad and forms curvature	Between condyloid process and angular process was deep but narrow	As that of condyle	Prominent but does not form any gap
Funambulus palmarum (Indian palm squirrel)	Short and does not form any shape with condyloid process.	Comparatively shorter than *B. indica*	Shallow but wide	Moved inward than condyloid process	Absent

DISCUSSION

The skull was used as an alternative tool for identifying the rodent and an insectivore species from the pellets of Barn Owl (Kaliamoorthy et al., 2013). In the skull, the ventral side are i) The area in which the infraorbitary groove starts with reference to anterior incisive foramen ii) The widening nature of the anterior incisive foramen and iii) The ending region of the anterior incisive foramen in relation to the first molar teeth. In addition, iv) the nature of the Zygomatic arch on the ventral side to dorsal side were compared. These four key characters yielded variations between the prey species. However, the prominent dissimilarities were observed in the anterior incisive foramen and Zygomatic arch. The differences among the species are given in table 3 and in which the anterior incisive foramen was species specific and the dissimilarity was slight between *Rattus rattus* and *Mus booduga* and hence the confirmation should be done by thorough analysis.

Table 3: Morphological dissimilarities in Anterior incisive foramen and Zygomatic arch in the skulls of six other prey species of Barn Owl compared with *Bandicota indica* (Large Bandicoot Rat) and *Funambulus palmarum* (Indian Palm Squirrel).

Species	Anterior incisive foramen	Zygomatic arch
Bandicota indica (Large Bandicoot Rat)	i) Anterior incisive foramen is almost similar across the whole. ii) Anterior incisive foramen starts above infraorbitary groove which is long and ends at the first molar.	It starts as curve and leads straight downwards and form thin groove
Funambulus palmarum (Indian Palm Squirrel)	i) Anterior incisive foramen is short ii) Anterior incisive foramen starts just below the incisor and ends before infraorbitary groove.	The starting region is not clear but it was thin at the front and back whereas the middle region is thick
Bandicota bengalensis (Lesser Bandicoot Rat)	i) Infraorbitary groove starts where the Anterior incisive foramen ends ii) Anterior incisive foramen narrower in the back end than that of the front end iii) Back end of the Anterior incisive foramen ends in the middle of the first molar	It leads straight downwards and form a thin groove
Millardia meltada (Soft-furred Field Rat)	i) Infraorbitary groove starts middle of the Anterior incisive foramen ii) Front and back ends of the Anterior incisive foramen narrower than that of the middle portion where it is widest. iii) Back end of the Anterior incisive foramen ends in the end of the first molar.	It leads straight downwards and form a wide opening
Mus booduga (Indian Field Mouse)	i) Infraorbitary groove starts just below the front end of the Anterior incisive foramen ii) The whole area of the Anterior incisive foramen is almost same. iii) Back end of the Anterior incisive foramen ends in the beginning of the first molar.	It forms short but wide groove.
Tatera indica (Indian Gerbil)	i) Infraorbitary groove starts in the middle of the Anterior incisive foramen ii) Anterior incisive foramen is narrower in the front and gets wider across iii) Back end of the Anterior incisive foramen ends before the beginning of the first molar	It leads as curved groove and run downwards
Rattus rattus (House Rat)	i) Infraorbitary groove starts where the Anterior incisive foramen ends ii) Anterior incisive foramen is narrower in the front and gets wider across iii) Back end of the Anterior incisive foramen ends before the beginning of the first molar	It leads as a short tube but ends in wide opening
Suncus murinus (Grey Musk Shrew)	i) Anterior incisive foramen absent. ii) Pointed molar teeth.	Absence of Zygomatic arch

Earlier, Sivaprakasam (1988) and Neelanarayanan et al. (1998) used mandible as a tool for identifying the rodent prey species from the pellets of owls. They used the shape and position of Coronoid process, Condyloid process, Notch, and Angular process for the identification of species of rodents, whereas Ramanujam (2004) included in addition to the above structures, the masseteric process too. They used the shape of the notch as major identification key. From the current research, it is confirmed that the masseteric process can be used effectively to identify the *Bandicota bengalensis* and *Bandicota indica*, and coronoid processes can be used to identify the *Tateria indica* and and *Mus booduga*. Notch can be used for the identification of *Rattus rattus* and *Millardia meltata*. The coronoid processes is primitive and insignificant in *Funambulus palmarum* and in *Suncus murinus* mandible itself thin and long which can be used to indentify the species.

CONCLUSION

We conclude that the morphological dissimilarities in Anterior incisive foramen and Zygomatic arch are species specific in all the eight prey species of Barn Owl which can be used as tool to identify the species in the absence of mandible. Although the species specific notch of the mandible is used for species identification extensively, the coronoid process, condyloid process, angular process and the masseteric process are unique for different species which can be used for identification especially when the notch is in dilemma.

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