A Post-Hatch Study of Larynx and Syrinx in Kuttanad Ducks *(Anas platyrhynchos domesticus)*

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Abestract: A developmental study of the larynx and syrinx in Kuttanad ducks was carried out using seventy-eight female birds ranging from one day to twenty-four weeks of age. The material was collected from six birds in each group at fortnightly intervals. Caudal to the base of the tongue protruding on the floor of the pharynx was a conspicuous elevation, known as the laryngeal mound. In this study, it is a raised, elongated lozenge-shaped structure occupying the caudal third of the floor of the pharyngeal cavity. The larynx is formed by cricoid, procricoid and paired arytenoid cartilages which become ossified with progression of age. The procricoid was found to be the smallest median cartilage of the laryngeal skeleton placed dorsally. An increase in the laryngeal length and width was observed as the age advanced; both attained their maximum value by the eighteenth week of age. The laryngeal mound is covered by stratified squamous epithelium with numerous pointed caudally directed papillae. These papillae are covered by the keratinized epithelium. The syrinx is a laterally dilated organ, situated ventral to the esophagus above the base of heart at the thoracic inlet, suspended within the clavicular air sac. In Kuttanad ducks, the syrinx is of a tracheobronchial type; *viz.* formed by the transformed six caudal rings of trachea and four to five rings of extrapulmonary primary bronchi. The skeleton of the syrinx consists of three components, namely the cranial cartilages (tympanum), rings of the dilated part, and the pessulus. The length of the syrinx increased linearly from the first day to the twenty-fourth week of age recording a maximum growth by week twenty-four. The width of the syrinx also increased with age. A slight decrease was observed in twenty-week-old birds followed by an increase in the succeeding groups.

Keywords: Larynx, syrinx, Kuttanad duck, post-hatch.

Introduction

The respiratory system is a good model for studying optimization from a functional perspective because it consists of linked structures with defined design parameters and an overall function that has a measurable upper limit, the maximum rate of oxygen consumption. Although, relentlessly being well studied for over four centuries in biology, few organs have withstood as much scientific interrogation such as the respiratory apparatus of birds, the lung-air sac system which has remained profoundly intractable.

The investigations of the respiratory tract concentrate on several aspects, including bioacoustics, neuroanatomy, the respiratory system physiology, morphological-ecological analyses of the relation of the respiratory tract structure to the life habits yet without any concentration on developmental descriptions (Weibel, 1998). Among the morphoanatomical investigations of birds, a certain attention is devoted to the studies of the respiratory tract. The factors determining the designs of the vertebrate respiratory systems include the physiochemical characteristics of the respiratory medium used, the nature of habitat occupied, and the lifestyle pursued. This in turn reflects the structural variations in animals and birds residing in a particular area. The extensive anatomical plan of the lung

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air-sac system of birds has speculatively been alleged to predispose it to fast diffusion of air-borne diseases while intensifying the spread of harmful effects of toxic air pollutants. The poultry industry in India is mainly oriented towards chicken production. Ducks are the second important species among poultry. The indigenous varieties contribute more than 90 per cent of the total duck population in the country, and are being reared extensively under free range and backyard conditions. Kuttanad duck is the most popular waterfowl of Kerala. The literature gives only sporadic information on the sequential developmental pattern of different structural components including the larynx and syrinx of the respiratory system in water birds. Hence this research paper describes the normal post-hatch development of the larynx and syrinx in Kuttanad duck.

Materials and Methods

A developmental study of the larynx and syrinx in Kuttanad ducks is conducted using seventy-eight female birds ranging in age from one-day-old ducks to ones with sexual maturity i.e at the twenty-fourth week of age. The material was collected from six birds in each group at fortnightly intervals from a single hatch reared at the University Poultry and Duck Farm, Mannuthy under a semi-intensive system of management. After collecting, the material was fixed in 10 per cent neutral buffered formalin. The material was processed using routine procedures, and paraffin sections of a 5 µm thickness were taken for histological and histochemical studies. The sections were stained using the Haematoxylin and Eosin (H&E) staining technique for the routine histological studies (Luna, 1968), the Gomori's rapid one-step trichrome method for connective tissue fibres (Luna, 1968), Periodic acid Schiff's (PAS), and the Alcian blue method for mucopolysaccharides and the Best's carmine method for glycogen (Bancroft and Stevens, 1996).

Toluidine Blue-alizarin Red S Staining

The specimens were subjected to toluidine blue-alizarin red S staining after formalin, acetic acid and alcohol (FAA) fixation having the ratio of three components as 1:1:8 for approximately forty minutes. Further specimens were stained in 0.06 per cent toluidine blue in 70 per cent ethyl alcohol for forty-eight hours at room temperature. Twenty volumes of the stain solution to the estimated volume of the specimen were used. Soft tissues were destained in 35 per cent ethyl alcohol for twenty hours; 5 per cent for twenty-eight hours and 70 per cent for eight hours respectively. The specimens were counterstained in a freshly prepared 1 per cent aqueous solution of Potassium hydroxide to which was added 2-3 drops of 0.1 per cent alizarin red S per 100 ml of solution. The specimens were transferred into the fresh 1 per cent KOH-alizarin mixture daily for three days, or until the bones had reached the desired intensity of red and soft tissues. The specimens were rinsed in water, placed in a 1:1 mixture of glycerol and ethyl alcohol for 1-2 hours, and were then transferred into fresh glycerol-alcohol for final clearing and storage.

Results and Discussion

Larynx

Protruding caudal to the base of the tongue on the caudal third of the floor of the pharyngeal cavity is the elongated lozenge-shaped laryngeal mound. The inlet of the larynx is a narrow slit on the dorsal aspect of the laryngeal mound guarded by rows of caudally directed cone-shaped papillae on either side of its rim and with scattered papillae on its surface (Figure 1). Similar observations are reported in turkey, fowl and goose (Getty, 1975), in Crow (Bock, 1978) and in long legged buzzard (Kabak *et al.,* 2007). The papillae are absent in ostrich (Pasand *et al.,* 2010) whereas in Stork, Onuk *et al.* (2011) reported the absence of papilla only along the laryngeal sulcus. The laryngeal mound is covered by stratified squamous epithelium with numerous pointed caudally directed papillae. These papillae are also covered by the keratinized squamous epithelium (Figure 2). At the inlet, the stratified squamous epithelium changes into pseudostratified ciliated columnar epithelium with numerous

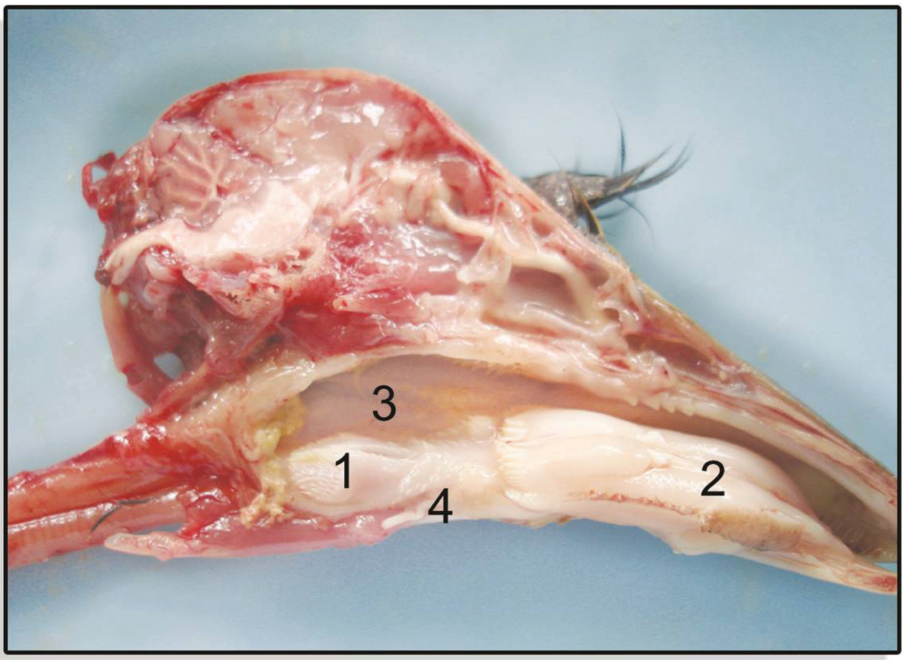

Figure 1. Laryngeal mound on floor of pharynx 1.Larynx 2. Tongue 3. Roof of larynx 4. Floor of larynx

simple tubular or alveolar mucous glands (Figure 3).

Lymphocytic infiltration was observed at the transitional zone. Lamina propria is thin and is composed of collagen and elastic fibres, blood vessels, and nerves also at the ventral median ridge of the cricoid cartilage. The submucosa contains the laryngeal salivary glands, collagen and elastic fibres, blood vessels and nerves (Figure 4). The connective tissue of the submucosa forms a thin capsule around the glands and the trabaculae extends through the parenchyma from the capsule. At the anterior part of the larynx they were smaller in size and lateral to arytenoid cartilages. At the middle part of the laryngeal mound, the glands are larger, and are situated more towards the lateral side of the arytenoid cartilages. At the level of the laryngeal fissure, few glands were also observed just beneath the epithelium. The epithelium and mucous glands showed a positive reaction for glycogen and PAS (Figure 5).

The main function of the larynx is the prevention of the entry of foreign bodies into the respiratory tract. The presence of the large numbers of papillae provide aid for this function. The shape of the larynx, which is a raised elongated lozenge-shaped structure,

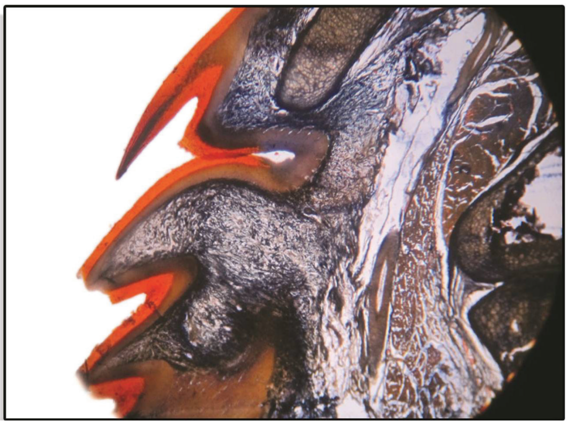

Figure 2. Cross section of larynx showing keratinised stratified epithelium of papillae (14 weeks). Ayoub Shaklar staining x 400.

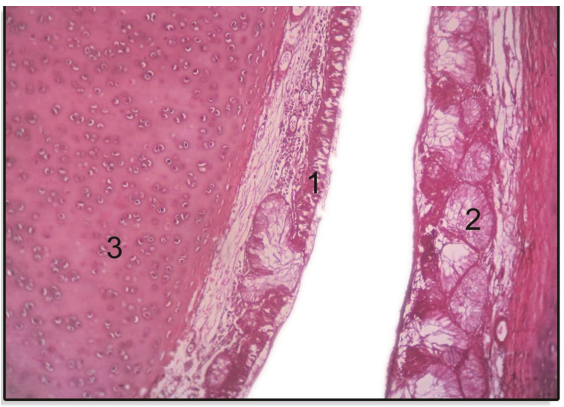

Figure 3. Cross section of larynx showing lining epithelium (12 weeks) H & E x 400 1.Pseudo stratified ciliated columnar epithelium 2. Mucous gland 3. Cartilage .

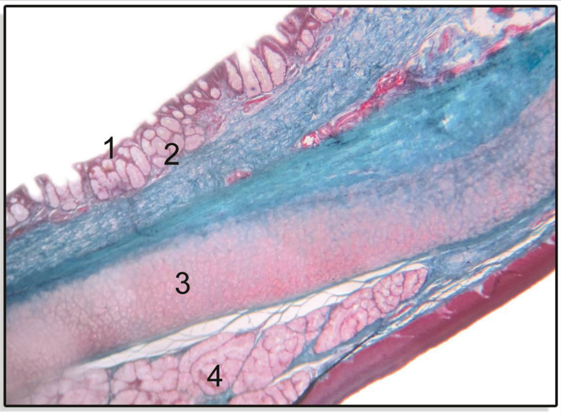

Figure 4. Cross section of larynx showing submucosal salivary glands (14 weeks) Gomori's one step trichrome method with fast green x 400 1. Lining epithelium 2. Mucous gland 3. Cartilage 4. Salivary gland.

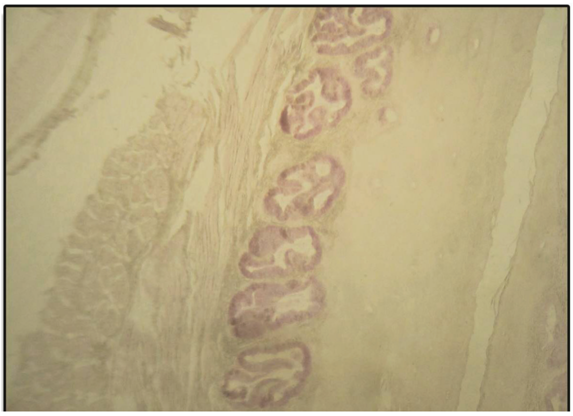

Figure 5. Cross section of larynx showing mucous glands positive for PAS. (12 weeks) x 400.

helps facilitate swallowing. During the ingestion of solid particles by ducks during foraging, the laryngeal mound moves a little caudally against the roof of the pharynx. During this movement, the caudally pointing papillae will help the mound to drag the particles into the esophageal pharynx. Besides, the larynx and upper trachea also help in the modulation of voice.

An increase in the laryngeal length and width was observed as the age advanced and both attained their maximum values by the eighteenth week as 1.923±0.005 cm and 1.351±0.005cm respectively. The difference observed may be attributed to the variation in the age, sex, and the natural habitat occupied. Two groups of salivary glands, *viz.* caudal and lateral cricoarytenoid glands, were observed grossly under the caudal aspect of the laryngeal mound and on its lateral border, respectively. Being situated caudal to the base of the tongue, the larynx has some resemblance to the tongue architecture. The presence of salivary glands on the larynx depicts this relation. Besides, although ducks enjoy little natural lubrication during feeding fully complemented by the salivary glands, the primary function of these glands appears to be mucogenesis.

The larynx is formed by cricoid, procricoid, and paired arytenoid cartilages (Figure 6), which become ossified as the age advances in accordance with the findings of Bradley and Grahame (1960) in relation to fowls, King and McLelland (1975) in relation to turkey, ducks, geese, Tabas *et al,* (1994) in denzil cocks, Pierko (2007) in mallards, Kabak *et al* (2007) in long legged buzzards, Tadjally *et al*. (2008) and Pasand *et al* (2010) in ostrichs and Onuk *et al* (2010) in storks. However, Bock (1978) reported that in crows, a complex of eight skeletal partially or completely ossified elements constitutes the larynx.

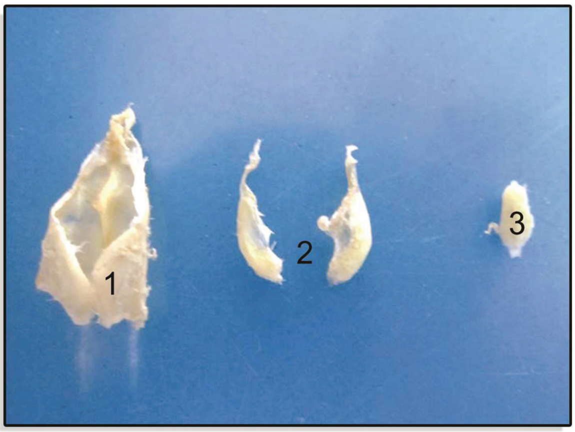

Figure 6. Cartilages of larynx (12 weeks) 1. Cricoid 2. Paired arytenoid 3. Procricoid

The unpaired cricoid cartilage in Kuttanad ducks is the largest among the laryngeal cartilages; it is triangular with broad caudal and pointed cranial ends, a body, and two wings (Figure 7). The medial border of both of the wings is articulated by a synovial joint with the procricoid. Similar findings have been reported by Zweers *et al.,* (1981) in pigeons.

The median aspect of the cricoid cartilage showed a triangular elevated prominence in the present study. Nazan and Gulsun (2010) also observed a similar

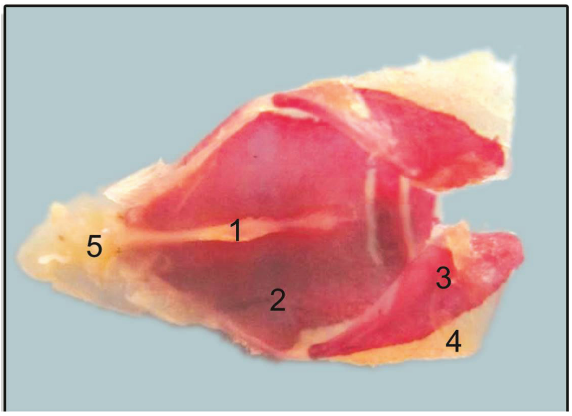

Figure 7. Dorsal surface of cricoid cartilage (14 weeks) 1. Median prominence 2. Body of cricoid cartilage 3. Wing of cricoid cartilage 4. Fibrous tissue 5. Rostral shovel part

a protuberance named crista ventralis in sea gulls. In Kuttanad ducks, the paired arytenoid cartilages shape the margins of the glottis and are sickle-shaped with a body and rostral and caudal processes. (Figure 8) Onuk *et al,* (2010) observed split glottis in geesse. The procricoid is the smallest median cartilage of the laryngeal skeleton placed dorsally (Figure 9). It is hammer-shaped with a rostral body and caudal tail. The bodies of arytenoid cartilages are joined with one another dorso-cranially by fibrous tissue, articulated with the procricoid caudo-medially by a synovial joint, and also glided closely on the dorsal border of the cricoid wing. On the other hand, the bilateral arytenoids in pigeons are only hinged to the body of the procricoid as a result of their particularly shaped articulation facets (Zweers *et al.*, 1981). The main function of the laryngeal cartilages is to provide the rigidity to the larynx. A protective function to any of the soft tissue cannot be ascertained because of the absence of soft structures such as the vocal cords in birds. The synovial joints formed by these cartilages with one another help change frequency, and, therefore, the pitch of the sound or the song produced. In Kuttanad ducks, there are five paired and one unpaired intrinsic ligaments. The paired ligaments are lateral cricoid, lateral crico-arytenoid, caudal crico-arytenoid, procrico-arytenoid, and procrico-cricoid. As observed in this study, the aryteno-arytenoid ligament was unpaired and the strongest among these ligaments. All these ligaments provid stability

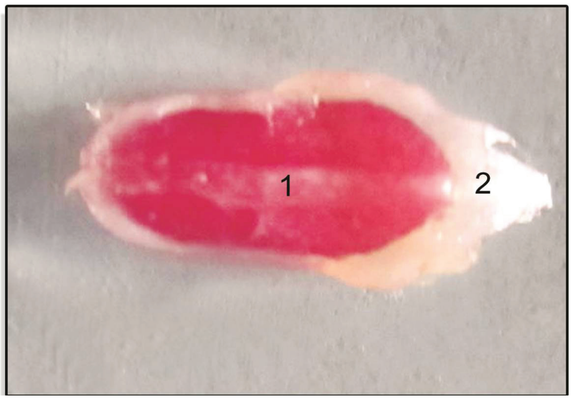

Figure 8. Procricoid cartilage with body and tail (14 weeks) 1. Body of procricoid 2. Tail of procricoid.

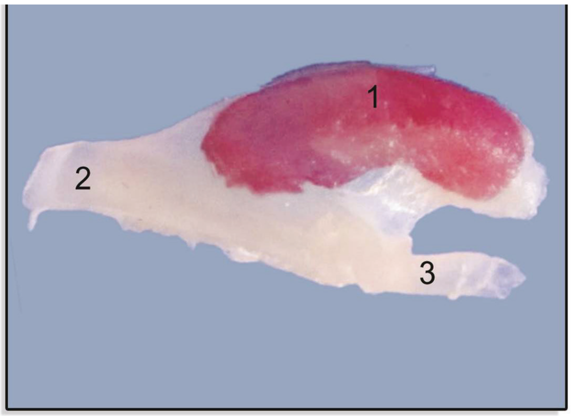

Figure 9. Lateral surface of Paired arytenoid cartilage (14 weeks) 1 Body of arytenoid 2. Rostral process 3. Caudal process

for the larynx which is particularly important during gasping with the marked rostral movements of whole mound. Two pairs of the intrinsic laryngeal muscles *viz.* dilator and constrictor were seen. These intrinsic muscles, in particular the constrictor, help in the continuous and rapid opening and closing of the glottis, which require high acceleration and a large force development. Moreover, if the glottis is to be opened and closed in a rapid succession over a period of time or if the glottis is to be held fully-opened or tightly closed against some resistance for a long period of time, such actions would require the presence of these muscles with a large cross-sectional area to avoid fatigue. These intrinsic muscles thus help the glottis to play role in respiration, swallowing, or sound production. Three pairs of extrinsic laryngeal muscles were also present; *viz.* tracheolateralis, cricohyoidius, and cleidotrachealis.

The complex arrangement of the extrinsic laryngeal muscles allows for a multitude of laryngeal movements depending on which muscle parts contract synchronously with others. If all the parts of the cricohyoideus contract simultaneously, the larynx will be protracted relative to the hyoid skeleton, and if the various slips of the tracheolateralis contract simultaneously, the larynx will be retracted relative to the hyoid skeleton. However, if the rostral slip of the tracheolateralis contracts at the same time as the dorsal part of the cricohyoideus, or if the caudal slip of the tracheolateralis contracts at the same time as the ventral part of the cricohyoideus, then the cricoid will pivot on top of the laryngeal chamber and, thereby, will change the configuration of this resonating chamber considerably (Homberger, 1999). The length and width of the larynx and glottis are presented in Table 1 and Figure 10. All the parameters were in significant positive correlation with age (r=0.782, 0.844, 0.642 and 0.840), body weight (r=0.704, 0.980, 0.823 and 0.967) and weight of the respiratory tract (r=0.772, 0.904, 0.706 and 0.895) respectively, as shown in Table 2. An increase in the laryngeal length and width was observed as the age advanced, and both attained their maximum value by the eighteenth week. A slight decrease was observed in length and width between the 18th and the 22nd week of age. As observed, the length and width of the glottis increased gradually as the age advanced.

Syrinx

The syrinx is found to be a laterally dilated organ, situated ventral to the esophagus above the base of the heart at the thoracic inlet (Figure 11), similar to the findings of Koch (1973) and Konig (2001) regarding song birds.

In Kuttanad ducks, the syrinx is of the tracheobronchial type, formed by thetransformed six caudal rings of trachea and four to five rings of extrapulmonary primary bronchi (Figure 12). The syrinx has been classified to be tracheobronchial in most common birds such as hens (Hummel, 2000; King, 1989; Nickel *et al*., 1977), ostriches (Yıldız *et al*., 2003), Bursa

Table1. Length and width of larynx and glottis in Kuttanad ducks at different ages (Mean±S.E)

Age	Length(cm)		Width(cm)	
	Larynx	Glottis	Larynx	Glottis
Day old	0.670 ±0.007	0.380 ±0.006	0.364 ±0.002	0.162 ±0.002
2 week	1.451 ±0.004	0.421 ±0.005	0.642 ±0.004	0.240 ±0.005
4 week	1.501 ±0.004	1.100 ±0.003	0.891 ±0.003	0.191 ±0.003
6 week	1.503 ±0.003	1.212 ±0.004	1.441 ±0.010	0.230 ±0.004
8 week	1.580 ±0.007	1.260 ±0.004	1.492 ±0.009	0.230 ±0.005
10 week	1.850 ±0.005	1.301 ±0.005	1.550 ±0.008	0.240 ±0.451
12 week	1.861 ±0.005	1.330 ±0.005	1.551 ±0.007	0.240 ±0.451
14 week	1.861 ±0.005	1.331 ±0.005	1.570 ±0.005	0.281 ±0.003
16 week	1.880 ±0.011	1.341±0.011	1.592 ±0.009	0.311 ±0.002
18 week	1.923 ±0.005	1.351 ±0.005	1.592 ±0.007	0.311 ±0.005
20 week	1.901±0.031	1.351 ±0.005	1.581 ±0.004	0.320 ±0.005
22 week	1.901±0.017	1.340 ±0.003	1.590±0.004	0.320 ±0.001
24 week	1.910 ±0.031	1.350 ±0.002	1.581 ±0.002	0.320 ±0.001

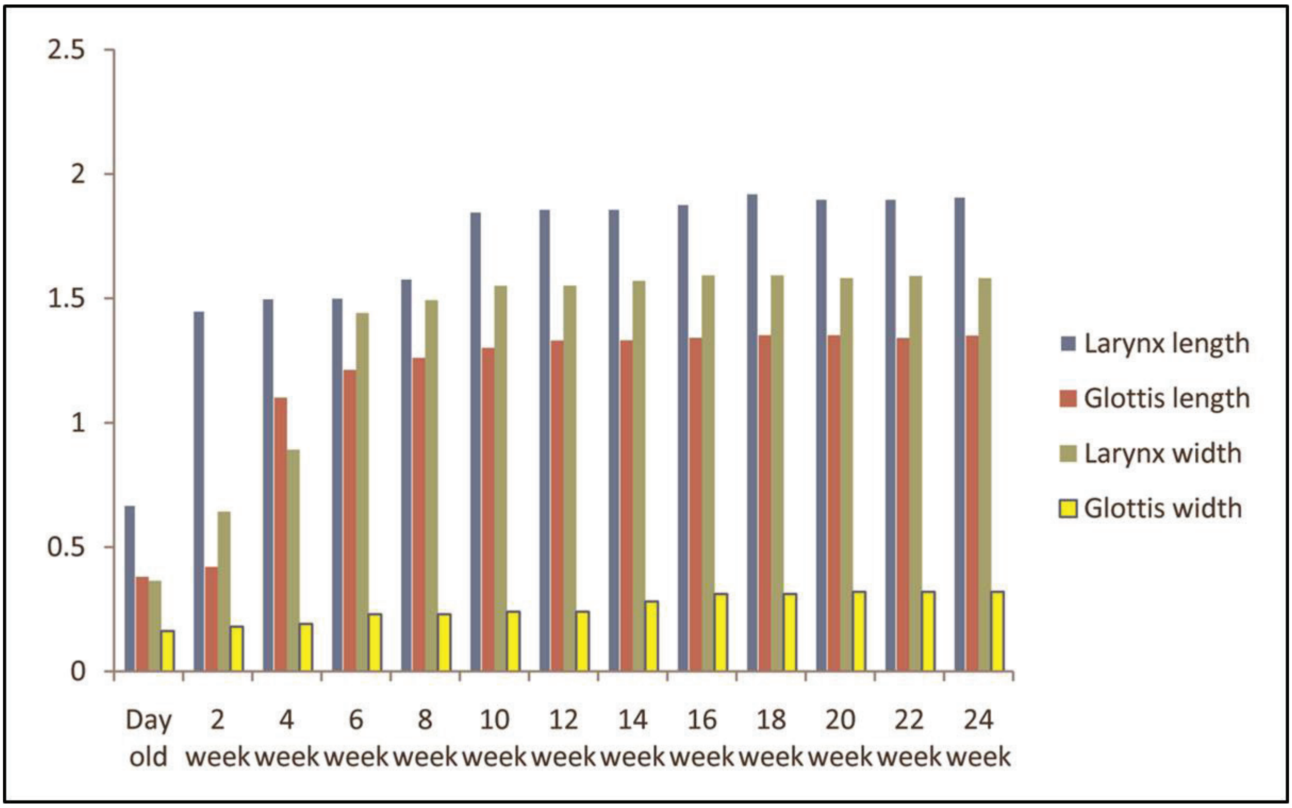

Figure 10. Age related changes in larynx in Kuttanad ducks

Table.2 Pearson's correlation coefficients (r) of larynx and syrinx with age, body weight and weight of respiratory system in Kuttanad ducks **Correlation is significant at the 0.01 level (2-tailed)

Width of glottis	0.840**	0.967**	0.940**
Width of Syrinx	0.757**	0.958**	0.902**

roller pigeons (Yıldız*et al.*, 2005), the white turkey (Arican *et al.*, 2007; Khaksar *et al.*, 2012), geesse (Onuk *et al.*, 2010), long-legged buzzards (Kabak *et al.*, 2007), quails (Bayram and Liman, 2000; Çevik *et al.* 2007) and in sea gulls (Ince *et al*, 2012).

The skeleton of the syrinx in Kuttanad ducks consists of three components, namely the cranial cartilages (tympanum), rings of the dilated part, and the pessulus. Similarly, the Yildiz *et al.* (2003) reported the same findings in ostriches, Yildiz *et al.* (2005) in pigeons,Frank *et al.* (2007) in mallards and Khaksar *et al.* (2012) in female and male turkeys. The tympanum had six complete rings similar to Bursa roller pigeons (Yıldız *et al.*, 2005), long-legged buzzards (Kabak *et al.*, 2007), sea gulls (İnce *et al*, 2012), geesse (Onuk *et al.*, 2010) and Japanese quails (Çevik *et al.*, 2007). This finding was in contrary to five in pigeons (Yildiz *et al.* 2005) and four in mallards (Yilmaz *et al.* 2012). The tympanum presented paired lateral and medial tympaniform membranes similar to the findings stated in regard to quails by Bayram and Liman (2000). The rings of the dilated part of the syrinx consisted of four

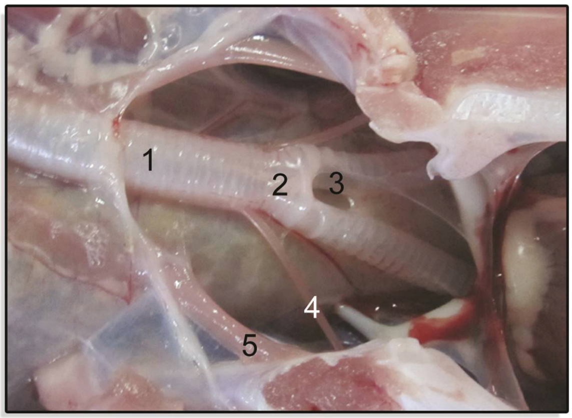

Figure 11. ***Insitu*** **position of syrinx (10 weeks)** Trachea 2. Syrinx 3. Tympanic membrane 4. Sternotrachealis muscle 5. Cleidotrachealis muscle.

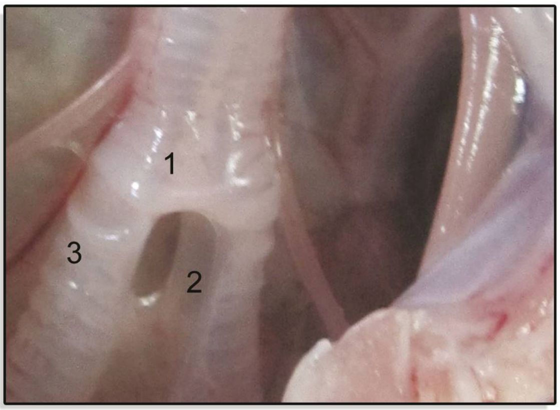

Figure 12. Composition of syrinx in Kuttanad ducks (10 weeks) Caudal rings of trachea 2. Tympanic membrane 3. Extra pulmonary primary bronchi.

bronchial half rings both on the right and left sides as against to eight (Warner, 1971, Lockner and Youngner, 1976) or ten (Frank *et al.*, 2007) in singing birds. This variation in the number of the rings depends on the fusion of the cartilages. At early ages, these cartilages can easily be counted; however, with the advancement of age, these become fused and difficult to be counted.

The pessulus in Kuttanad ducks is a wedge-shaped cartilaginous structure up to 10 week of age and showed ossification with the progress of age (Figure 13). The pessulus in the mallard is composed of a bony tissue similar to that in singing birds (Frank *et al.*, 2007; Taşbaş *et al.*, 1994; Warner, 1972), yet different from that in ostriches (Yıldız *et al.*, 2003) and chicken (King, 1989). The syrinx did not present any bulla formation in female Kuttanad ducks; Khaksar *et al.* (2012) observed the same in relation to turkeys.

The length and width of the syrinx are shown in Table 3; they are significantly and positively correlated with age (r= 0.958 and 0.757), body weight (r=0.956 and 0.958) and weight of the respiratory tract (r= 0.956 and 0.854) respectively. As observed from this study, the length of the syrinx increased linearly from day one to the twenty-fourth week of age recording a maximum length by week twenty-four. The width of the syrinx also increased with age and a slight decrease was observed in twenty-week-old birds followed by an increase in the succeeding groups.

The syrinx is lined with a pseudostratified, ciliated columnar epithelium with a few mucous glands (Figure 14). The basal cells have round to irregular nuclei, whereas the nuclei of ciliated cells were seen to be oval to elongate. The lamina propria was continuous with dense submucosa underneath forming the propria-submucosa, made of dense irregular connective tissue containing collagen and many elastic fibres with plenty of blood vessels and nerves. Lymphoid cells were also seen at the second week of age onwards. The next layer was the cartilaginous rings surrounded by perichondrium followed by the adventitial connective tissue.

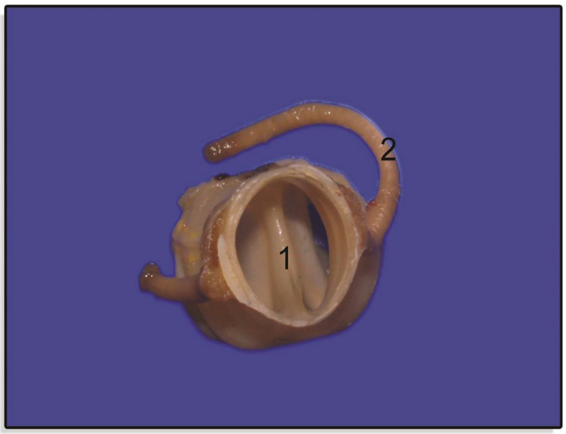

Figure 13. Syrinx showing pessulus (12 weeks) 1 Pessulus 2. Sterno-trachealis muscle

The dilated part of the syrinx is formed by the bronchial cartilages and is lined by the low columnar ciliated pseudo-stratified epithelium with plenty of the goblet cell groups. The paired lateral and medial tympaniform membranes of the tympanum present similar histological structures. Internally, the mucosa of the tympanic membranes consists of cuboidal or flattened cells with a few goblet cells scattered amongst them.

The density of the goblet and ciliated cells was lesser than those in the trachea. Underlying this layer, was the propria-submucosa, containing a connective tissue layer of coarse elastic fibres followed by a layer of loose, fine collagen and elastic fibres, various blood vessels, adipose cells, nerves, and scattered smooth muscle cells. The final layer consists of coarse collagen fibres interspersed with elastic fibres. The whole is bounded by the serosa formed by a single layer of squamous epithelium. Hodges

Figure 14. Cross section of syrinx showing lining epithelium (20 weeks) Gomori's one step trichrome method x 400 1 Lining epithelium 2. Lamina propria 3. Cartilage.

(1974) reported the same in domestic fowls, and Khaksar *et al.* (2012) in male and female turkeys; however, Bayram and Liman (2000) reported that lateral and medial tympaniform membranes were covered by stratified cuboidal epithelium in quails.

The principal change in the syrinx observed through the present study is the deposition of the cartilaginous matrix. From day one of age onwards, the perichondrium was composed of inner vascular and outer fibrous layers. With the progress of age, the number of chondrocytes per lacunae increased and by the sixth week, two to four cells occupied each lacunae forming an isogenous group of cells. At an older age in the post-hatch period, the proportion of intercellular matrix also increased. Each chondrocyte was surrounded by the pericellular matrix and each lacuna by a territorial matrix. The inter territorial matrix between lacunae, was stained lighter than the territorial matrix. From the tenth week onwards, the cartilages of the syrinx showed signs of ossification, but for a comparatively less degree than those in the trachea and larynx. The pessulus was highly ossified by week twenty-four of age.

The main function of the syrinx is voice production. However, in the present study, no bulla was observed in female Kuttanad ducks; hence voice production will be comparatively lower in males, which have the bulla. The syrinx may probably also help in minimizing the collapse or compression of the exchange tissue and pulmonary air ways during expiration by its valve-like action at the beginning. The syrinx is held in the clavicular air sac; therefore, when the pressure rises inside the clavicular air sac during expiration, a transient pressure gradient will be created from the sac to the interior of the syrinx which causes the bulging of lateral and medial tympanic membranes to bulge into the syrinx and obstruct it. Such a transient closure of the syrinx can reduce the pressure gradient across the lung during expiration and thus limits the compression. This valve-like action may be much pronounced in waterfowls including Kuttanad ducks because before going deep into the water, they expel maximum air from the air sacs to reduce resistance by the water.

Ossification of Larynx and Syrinx

In this study signs of ossification were absent in the larynx, trachea, and syrinx up to the sixth week of post-hatch life in Kuttanad ducks. Small, scattered foci of ossification started to appear at week eight of age in the laryngeal cartilages (Figure 15). The cricoid was the first to show signs of ossification followed by the arytenoid at its body and then the procricoid. Bradley and Grahame (1960) found that the cricoid and the arytenoid cartilages become ossified as age advances in fowls. Hogg (1982) reported mineralization in birds aged 105 days, specifically in the bodies of the arytenoid cartilages and only in domestic fowls .

The syrinx exhibited signs of ossification from the tenth week onwards. Compared to the trachea and larynx, the syrinx showed lesser degrees of ossification. Hogg (1982) reported mineralization in the syrinx of domestic fowls on the ninety-eighth day after hatching. In all cases, it was present only in the pessulus and the bases of the left and right first bronchial syringeal cartilages. However, Khaksar *et al* (2012) observed that the pessulus in female and male turkeys did not contain any ossified or cartilaginous tissues and was made up of a double folded mucous membrane. While holding the ducks by neck, this ventral ossification of the cartilages of the trachea acts as a kind of adaptation meant to reduce the damage of the deeper tissues resulting from pressing and may also keep the trachea firm without any damage to itself.

Conclusion

Structural variations may occur in the respiratory system components among residing in a particular area. Variations may be due to the living habitat, nature of feeding, or extent of the flight. The variation both in the development and structure, documented in present paper, can be very helpful in providing future information on the sequential developmental pattern of different structural components including the larynx and syrinx of the respiratory system in water birds.

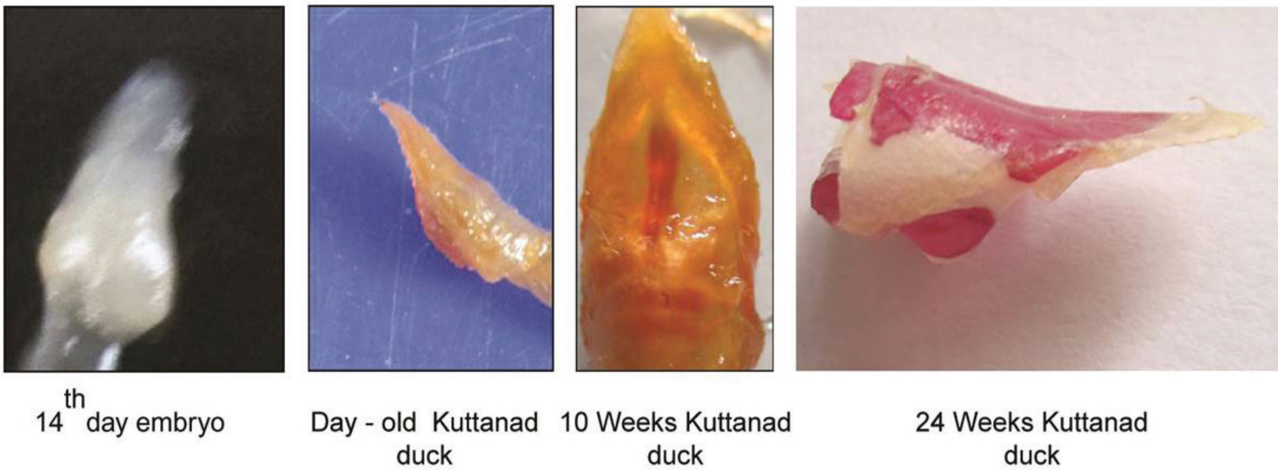

Figure 15. Alizarin staining of laryngeal cartilages at different ages

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Notes on the Pigeons and Doves (Family Columbidae) Occurring in the Gaza Strip – Palestine

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Abstract: Birds are the commonest terrestrial vertebrates among the fauna of the Gaza Strip. Hundreds of bird species have been recorded and more records are being added continually. Columbids (pigeon and doves), constitute a prominent component of birds, yet they have never been separately studied in the Gaza Strip. The current study aims at giving useful notes on the doves and pigeons occurring in the Gaza Strip. Field visits, observations, photography, and discussions with stakeholders were carried out to reach the goals of the study. Seven species of pigeons and doves were recorded in the Gaza Strip. The Rock Pigeon (*Columba livia*) was found to be the commonest while the African Collared Dove (*Streptopelia roseogrisea*) was the rarest. Different plumage colors of the Barbary Dove (*Streptopelia risoria*) are easily reared and traded in local zoos and pet shops. All pigeon and dove species are subject to poaching and hunting for different purposes including meat and pet trade. Finally, the study recommends raising ecological awareness among Gazans and the implemtation of protection measures in order to sustainably conserve bird fauna in the Gaza Strip.

Keywords: Bird fauna, pigeons, doves, Streptopelia, hunting, Gaza Strip.

Introduction

Bird fauna are among the best known creatures characterized by biodiversity around the globe (Pomeroy, 1992 and Bibby *et al.*, 1998). In Palestine, which has a total area of about 27,000 km^2, 540 avifaunal species are known to inhabit all types of landscapes and ecosystems (Perlman and Meyrav, 2009). The strategic geographic location of Palestine along with its major migration routes contributes to the diversity of bird fauna (UNEP, 2003). The arid to semi-arid Gaza Strip, which covers an area of about 365 km^2 (1.5% of the total area of Palestine), has a diversity of bird fauna occurring in its diverse ecosystems and habitats. Hundreds of bird species have been recorded, and new more records are being added continually (Project for the Conservation of Wetland and Coastal Ecosystems in the Mediterranean Region – MedWetCoast, 2002; Abd Rabou, 2005; Yassin *et al.*, 2006; Abd Rabou *et al.*, 2007 and Abd Rabou 2011a and b; 2019a and b). Urbanization constitutes a major threat to vertebrate fauna; particularly birds, in Palestine and hence the Gaza Strip (Qumsiyeh *et al.*, 2014). Different groups of bird fauna are commonly hunted and trapped for different purposes in the Gaza Strip (Abd Rabou 2005 and 2020). In the fall season of each year, many Gazans erect fishing nets along the Mediterranean coast in order to catch the Middle Eastern migratory Common Quail (*Coturnix coturnix*), because of its delicious meat (UNEP, 2003; Abd Rabou *et al.*, 2007 and Abd Rabou, 2011a and b; 2019a and b and Marwat *et al.*, 2014).

Columbidae is a worldwide family of birds containing pigeons and doves. It is the only family in the order Columbiformes. It is one of the most threatened bird families in the world (Walker, 2007). Pigeons and doves primarily feed on seeds, fruits, and plants (Gutiérrez-Galán and Alonso, 2016). Their nests are commonly built on trees, ledges, or on the ground, depending on the species. Several species of pigeons and doves are commonly trapped or shot to be used

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