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Feeding structures in the silver pomfret *Pampus argenteus* (Euphrasen) as observed by scanning electron microscopy

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ABSTRACT

The first electron microscopy description of the feeding structures of silver pomfret *Pampus argenteus*, locally called *zobaidy*, from the Kuwaiti waters of the Arabian Gulf, is presented. The mouth is a small, sub-terminal, slit-like transverse opening equipped with a single row of villiform teeth on both the premaxillary and dentary bones. Contrary to past studies suggesting that the back teeth on both jaws are multicuspid, evidence is presented indicating that the teeth on the premaxillary are mostly unicuspid, conical and blunt, and are interspersed with a few tricuspids, while those on the dentary are mostly tricuspid, narrow and sharp, and are interspersed with a few unicuspid teeth. The pharynx extends caudally from the buccal cavity to form a thick-walled sac referred to as the oesophageal sac, a peculiar structure of the stromateids. Pointed and sharp simple conical teeth project from the inner walls of the sac. An attempt has been made to relate the buccal teeth to the diet of the species, reported in our earlier study as consisting of copepods and their eggs, Bacillariophyta, other crustaceans, Mollusca, fish scales, fish larvae and their eggs, and other phytoplankton, in that order of abundance. The tricuspid teeth with pointed middle cusps are efficient for masticating the "soft-bodied" crustaceans (e.g. copepods and their eggs), and fish larvae and their eggs. The conical unicuspid teeth with blunt ends are most likely used in dealing with the shelled crustaceans. The pointed, conical, sharp teeth and the blunt ones would be useful for grabbing, tearing and grinding the seized victims. The sharp, pointed, blade-like tricuspid teeth are adapted for breaking diatoms and other phytoplankton, such as filamentous algae.

Keywords: oesophageal sac; *Pampus argenteus*; scanning electron microscopy; silver pomfret; teeth.

INTRODUCTION

Fish exhibit a spectacular diversity of dentition where tooth structure and arrangement are intimately related to the nature of the diet and the method employed for its acquisition (Trewavas 1935, Dadzie & Opiyo in press). In some cases, tooth structure not only varies from species to species but also through an individual's life time. As a consequence, the dentition of adults can be strikingly different from

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that of juveniles. In *Chilotilapia rhoadesii*, for example, a change in dentition with size of fish is even accompanied by a change in the jaws as the fish increase in size (Trewavas 1935, Fryer & Iles 1972).

There is a dearth of information on the dentition of *Pampus argenteus* (Euphrasen) (Family: Stromateidae). Based on gross morphological observations, Haedrich (1967) described the jaw teeth as minute, uniserial, flattened, with a large rounded central cusp and two shorter auxiliary cusps, close set laterally by a membrane. A single row of minute teeth are borne by both the jaws (Khanna & Mehrotra 1970). Finally, Shamsul Hoda (1974) described the upper jaw teeth as villiform, arranged in a single row, the front teeth slightly smaller than the back teeth which are cusped (2–3 small cusps); while the lower jaw bears a single row of villiform teeth extending over its whole length, the front teeth also slightly smaller than the middle and back teeth which are cusped (2–5 cusps). Despite the obvious limitations imposed by this technique, none of the above studies relate the feeding structures with diet.

Due to its wide area of distribution from the Arabian Sea (Mohamed & Ali 1992, Ali & Mahmood 1993) through the coast of India (Pati 1980), extending eastwards to China (Kim & Lee 1992) and Japan (Haedrich 1967), it could be expected that the pomfrets have become adapted to a wide range of food and feeding habits which could result in the evolution of structural and physiological specializations of feeding structures and organs.

A part of the oesophagus of *P. argenteus* contains an outgrowth called the oesophageal sac (Isokawa *et al.* 1965) or pharyngeal sac (Haedrich 1967) or pharyngeal bulb (Kharma & Mehrotra 1970), containing tiny teeth. Using conventional anatomical and histological methods, Isokawa *et al.* (1965) described the sac as elliptical and the teeth consisting of homogeneous calcified tissue and pulp tissue, while Khanna & Mehrotra (1970), using gross morphological methods described the structure as a simple thick-walled muscular sac bearing internally numerous pharyngeal papillae or teeth. The thick-walled oesophageal sac with teeth-like structures suggest it to be an organ for trituration of food (Khanna & Mehrotra 1970). Hence, it is a feeding structure and therefore needs a closer description. The latter is an important area to address given the fact that *P. argenteus* is not only of great economic importance in Kuwait (Ministry of Planning 1995), but also a candidate for mariculture in areas of occurrence, especially in the Arabian Gulf region, particularly Kuwait. As part of an ecological project on the food and feeding habits of the species inhabiting Kuwait waters, the feeding structures of *P. argenteus* are described using scanning electron microscopy. The buccal feeding structures of the fish are also related to the diet of this species described in our earlier study (Dadzie *et al.* in press).

MATERIALS AND METHODS

Fresh samples of *P. argenteus* were collected monthly from commercial gill-net catches from the northern part of Kuwaiti waters of the Arablan Gulf (Fig. 1). The nets measured 1000–2500 m long, with a 13.8 cm mesh size, and were laid at depths ranging from 7 to 15 m. The sampling lasted 12 months, from May 1996 to April 1997. The standard length (cm), body weight (g) and gut weight (g) were recorded for each specimen sampled.

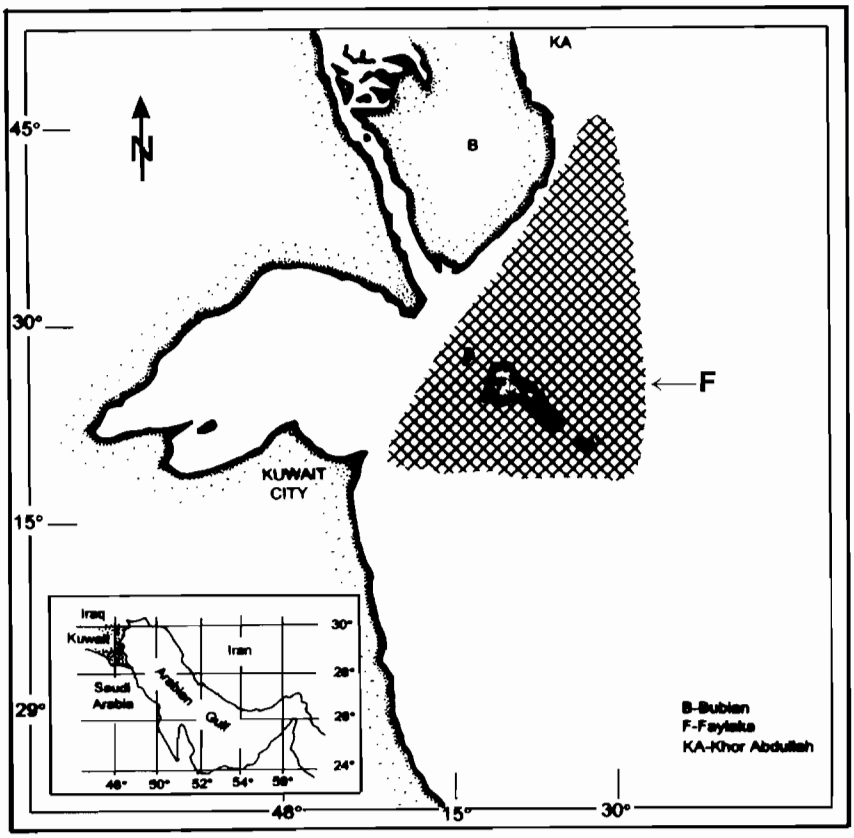

Fig. 1. Map of Kuwait waters of the Arabian Gulf, showing the fishing areas (hatched).

Scanning electron microscopy

After gross morphological observation, parts of the jaws and oesophageal sacs were carefully dissected, cleaned in distilled water and fixed individually in 2.5% glutaraldehyde solution made up in 0.1 M phosphate buffer (pH 7.4) at 37°C. Following fixation overnight, the tissues were washed with several changes of 0.1 M phosphate buffer (pH 7.4), after which 2% osmium tetraoxide was then added to the specimens which were washed again with the same buffer. The specimens were dehydrated in ascending concentrations of acetone (30%–100%) and subjected to critical point drying using liquid CO_2 (BAL-TEC CPD 030). They were then mounted on silver-painted aluminium stubs coated with a thin layer of gold palladium complex in a sputter coater (BAL-TEC SCD 050), and then inspected using a JEOL JSM 6300 scanning electron microscope at an accelerating voltage of 20 KV. Photomicrographs were taken on Polaroid films (Polaroid Corp., U.S.A.).

RESULTS

Morphology and dentition

The mouth of *P. argenteus* is a small, sub-terminal, slit-like transverse opening. The lips are fleshy and both the maxillary and mandibular valves are present. A single row of minute, oral, villiform teeth are borne on both the premaxillary and the dentary (Figs. 2 & 3). The teeth are of two types, unicuspid and tricuspid. The premaxillary bears mainly unicuspid teeth that are interspersed, in no specific pattern, with few tricuspid ones (Fig. 4). The dentary, in the opposite fashion, bears mainly tricuspid teeth interspersed with unicuspid teeth (Fig. 5). The unicuspid teeth are of two types: conical with blunt ends and conical with sharp ends (Fig. 6). The tricuspid teeth are pointed and sharp, the lateral ones having sharp, blade-like edges. The central cusp is the largest while the other two are forked (Fig. 7). There was no evidence of changes in dentition with increase in size of *P. argenteus*.

Oesophageal sac

The pharynx extends behind to form a simple thick-walled muscular sac called the oesophageal sac, a peculiar structure of stromateids. The sac is elliptical in shape and, internally, the cavity is divided by elevations of mucosa into four cup-like

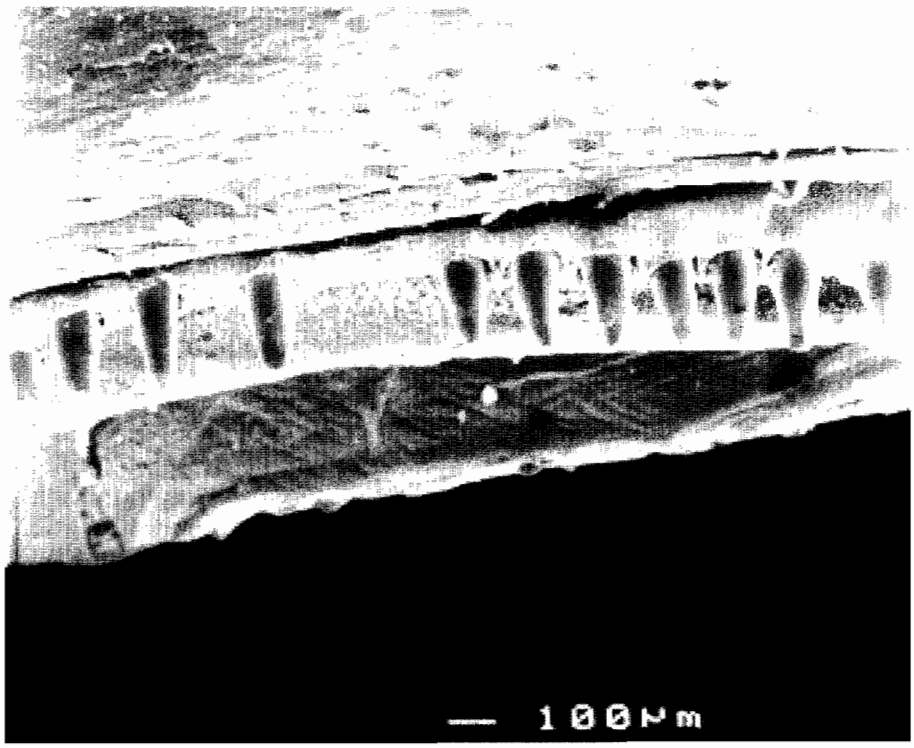

Fig. 2. Scanning electron micrograph of the premaxillary bone of *P. argenteus*, showing a single row of unicuspid teeth.

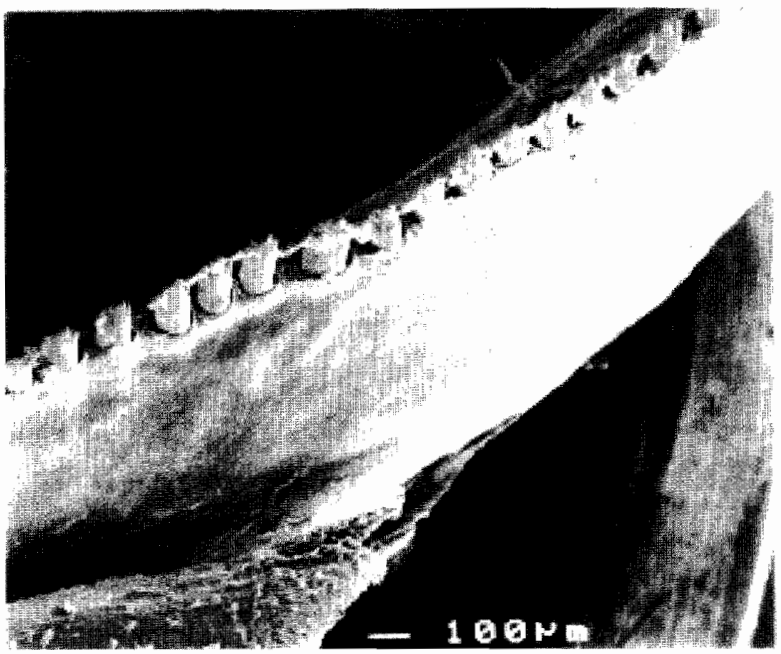

Fig. 3. Scanning electron micrograph of the dentary bone of *P. argenteus*, showing a single row of tricuspid teeth,

Fig. 4. Scanning electron micrograph of the premaxillary bone of *P. argenteus*, showing unicuspid teeth interspersed with one triscuspid.

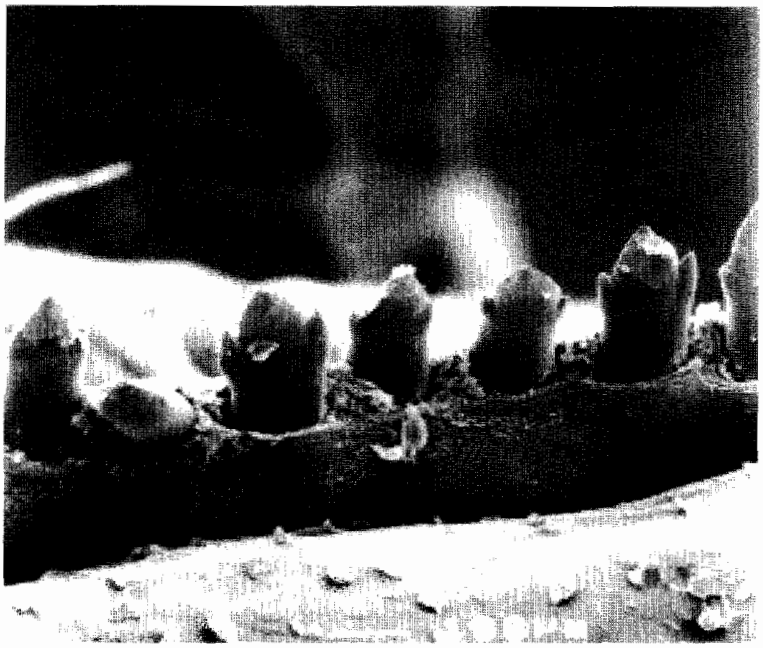

Fig. 5. Scanning electron micrograph of the dentary bone of *P. argenteus*, showing tricuspid teeth interspersed with a unicuspid.

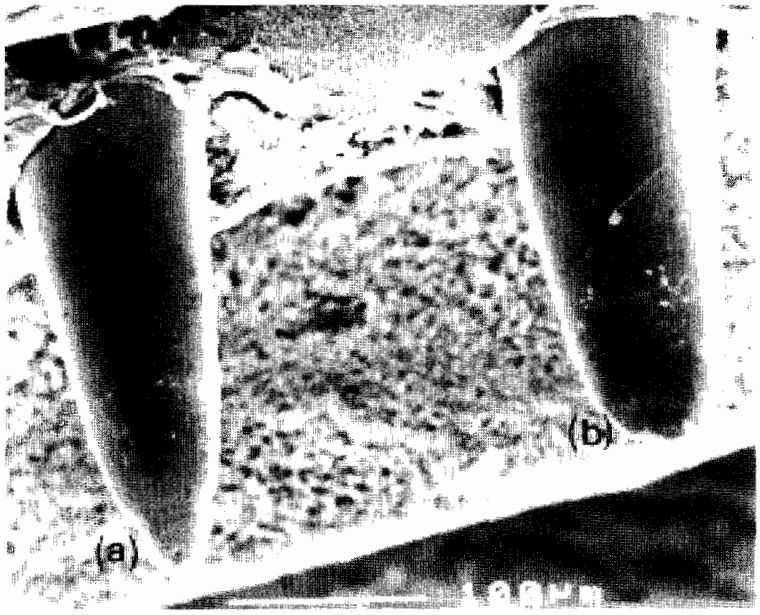

Fig. 6. Scanning electron micrograph of the premaxillary bone of *P. argenteus*, showing conical teeth with (a) sharp end, (b) blunt end.

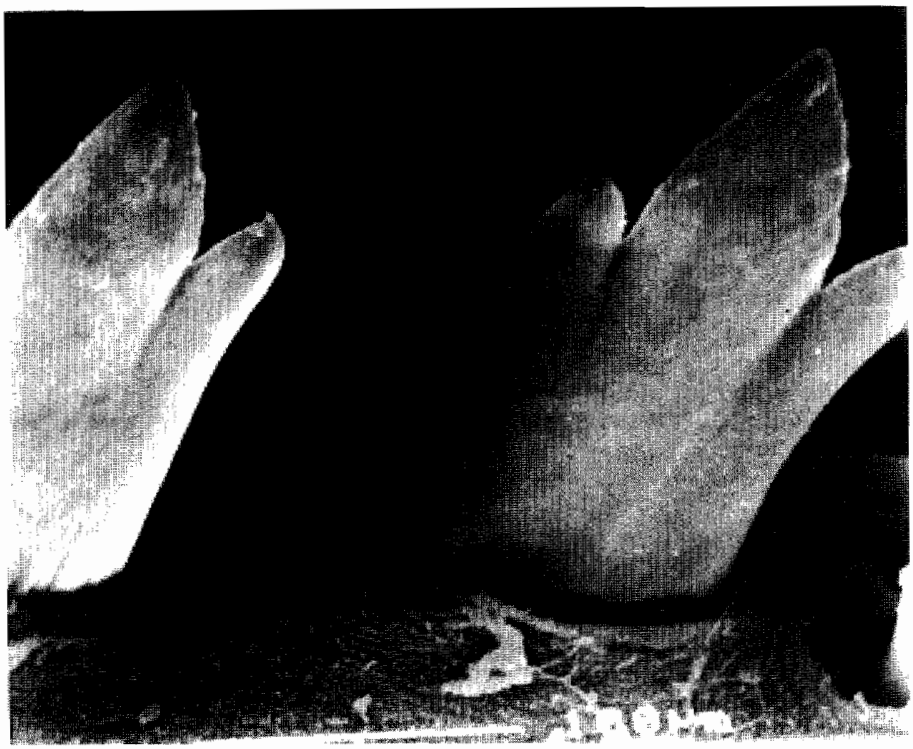

Fig. 7. Scanning electron micrograph of the dentary bone of *P. argenteus*, showing tricuspid teeth with large, sharp-edged central cusps.

separate parts. Irregularly-shaped papillae are seated in the mucosal walls arranged in longitudinal bands. These papillae bear numerous simple conical teeth projecting from the wall of the oesophageal sac. Each tooth is long with a broad base, and a narrow, sharp, and pointed apical region (Fig. 8).

DISCUSSION

There are very few reports on the buccal anatomy of *P. argenteus*. The limited information on the morphology of the buccal region is unequivocal that the mouth is transverse and subterminal and that villiform teeth are borne on both the premaxillary and dentary bones (Haedrich 1967, Khanna & Mehrotra 1970, Shamsul Hoda 1974). Similar observations were made in the present study. Shamsul Hoda (*op. cit*) provided the only available description of the buccal teeth in the species from the northern Arabian Gulf population. According to the author, the premaxillary bears a single row of villiform teeth, the front teeth being slightly smaller than the back ones, while the dentary also bears a single row of villiform teeth, the front ones being smaller than the middle and back ones. The present study has yielded results in support of these observations. Shamsul Hoda (*op. cit*), however, reported that the back teeth on the premaxillary have 2–3 cusps, while the back teeth on the dentary have 2–5 cusps. Such multicusped teeth, confined

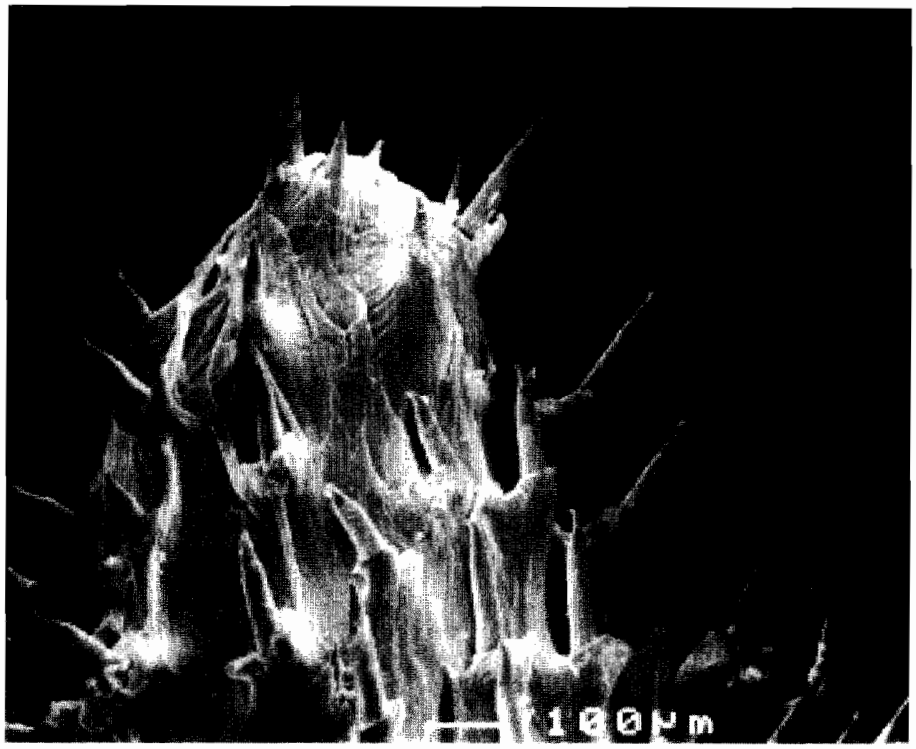

Fig. 8. Scanning electron micrograph of the oesophageal sac of *P. argenteus*, showing conical teeth projecting upwards.

strictly to the back of the premaxillary and dentary bones, were not observed in the present study based on the southern Arabian Gulf population. Instead, as evident in Fig. 4, the premaxillary teeth, as revealed by scanning electron microscopy, were mostly unicuspid, interspersed with a few tricuspid ones, while the teeth on the dentary, as revealed by the same technique (see Fig. 5), were mostly tricuspid, interspersed with a few unicuspid ones. Furthermore, Shamsul Hoda (1974) reported the presence of small teeth borne on two rounded elevations on the roof of the buccopharyngeal cavity. Our examination of these structures in the buccopharyngeal cavity did not reveal the presence of teeth. Indeed, no other teeth were observed in the buccopharyngeal region apart from those on the premaxillaries and dentaries.

The differences in teeth anatomy of the two different Arabian Gulf populations of *P. argenteus*, i.e. the multicusped teeth on the back of the premaxillary and dentary bones reported by Shamsul Hoda (1974), and their absence in the present observation, are quite remarkable. Since the species are sympatric, it cannot be argued that compared to our southern specimens from Kuwait waters, the northern specimens studied by Shamsul Hoda (*op. cit.*) from Iraqi waters were from populations adapted to a range of food and feeding habits which could have resulted

in the evolution of structural specializations of feeding structures. Unfortunately, the diet of the species was not reported by Shamsul Hoda (1974) to determine whether dramatic changes in the diet have occurred or not.

Fishes that have an oesophageal sac are apparently uncommon. These fishes and their sacs have been little known, for very few authors have made detailed observations on oesophageal sacs and their teeth (Isokawa *et al.* 1965, Khanna & Mehrotra 1970). Apart from the stromateids, the pharynx of some clupeids have developed a pocket-like structure (Khanna 1962), resembling the oesophageal sac of *P. argenteus*. The thick muscular walls with stiff, spiny, teeth-like structures of the oesophageal sac suggest that it is an organ for trituration of food (Khanna & Mehrotra 1970, Shamsul Hoda 1974). In some reports, the oesophageal sac has been referred to as a pharyngeal bulb (Khanna & Mehrotra *op. cit.*) or pharyngeal sac (Haedrich 1967). Gilchrist (1922) pointed out that the sacs are not strictly oesophageal, but are derived from the pharyngeal epithelium. In the present work, the term oesophageal sac is used in conformity with the term popularly used (Isokawa *et al.* 1965, Shamsul Hoda 1974). Isokawa *et al.* (*op. cit.*) and Shamsul Hoda (*op. cit.*) pointed out that the radial processes of the different papillae are not in contact with each other and that they occupy different levels in the muscles of the sac. Such an arrangement of the processes and papillae appear well adapted for the storage of food in the sac.

All the previous documented reports on the oesophageal sacs and their teeth in *P. argenteus* were based either on gross anatomy alone (Haedrich 1967, Shamsul Hoda 1974) or on gross anatomy coupled with histomorphological techniques (Isokawa *et al.* 1965, Khanna &Mehrotra 1970). The limitations imposed by these methods on the structures in question cannot be overemphasized. In the present study, however, using fine scanning electron microscopy, it has been possible to provide, again for the first time, a more detailed description of some of the internal structures of the sac hitherto not described in the species, especially the simple, broad-based conical teeth in the oesophageal sac.

Prior to our ecological study on the food and feeding habits of *P. argenteus*, the only existing report which attempted to relate feeding structures to the diet of the species was that of Khanna & Mehrotra (1970). The authors, however, abandoned their attempts after observing merely that the buccal cavity was edentulous and that the teeth were minute, Consequently, an exact and detailed relationship could not be established between the extent of development of the dentition and feeding habits.

Our recent report (Dadzie *et al.* in press) has revealed that the major component of the diet of *P. argenteus* in Kuwaiti waters are copepods and their eggs, contributing 39% of the major food types eaten by the species. Bacillariophyta, other crustaceans, Mollusca and fish scales accounted for 21%, 16%, 11% and 10% respectively. Fish eggs and larvae were the least common item and accounted for 3% of the major food types. The frequency of occurrence study confirmed that of the crustaceans, copepods were the major food items, followed by *Euconchoecia* sp., *Carcinus* sp. Cypris of barnacle, *Evadne* sp., *Cypridina* sp., in that order. Of the invertebrates, Lamellibranchia registered the highest percentage frequency of occurrence, while *Coscinodiscus* spp. and *Rhizosolenia* sp. registered the highest frequencies of occurrence among the Bacillariophyceae.

The overwhelmingly planktonic nature of the food of *P. argenteus* as revealed by our study (Dadzie *et al.* in press) establishes the species as a plankton feeder, with the zoo-planktonic members constituting the greater majority. Among the latter, bodies covered with carapace and shells (both internal and external) were not uncommon, such as ostracods (e.g. Cypris of barnacle and *Cypridina* sp), decapods (e.g. *Ebalia* sp.), Mollusca (e.g. Lamelibranch veliger) and malacostracans (e.g. *Carcinus* sp). The tricuspid teeth with pointed middle cusps described in this study would be efficient for masticating the "soft-bodied" crustaceans such as copepods and their eggs as well as fish eggs and larvae. The conical, unicuspid buccal teeth with blunt ends would be useful in dealing with the shelled organisms mentioned and, as reported by Lin & Lee (1991), a series of strong conical teeth on jaws enable the fish to seize victims more easily. The sharp, pointed conical teeth, together with the blunt ones, would be useful for grabbing, tearing and grinding the seized victims. For the phytoplankton members, the sharp, pointed, blade-like tricuspid teeth could similarly be adapted for breaking the diatoms and filamentous algae into finer fragments as suggested by Dadzle & Opiyo (in press), Fryer & lles (1972) and Lanzing & Higginbotham (1976), for tilapias.

Mastication of the food probably starts in the buccal cavity using the single rows of teeth on the premaxillary and dentary bones. Upon arrival of the food in the oesophageal sac, further trituration probably takes place using the numerous sharp and pointed oesophageal teeth. Indeed, Haedrich (1967) pointed out that the oesophageal sac and papillae in *P. argenteus* make a very efficient shredding organ. The advantages of reduced particle size include a greatly increased surface to volume ratio that facilitates enzyme-substrate interaction and reduced resistance to peristaltic mixing. In addition, the further trituration of the food in the oesophageal sac increases the efficiency with which the food is digested, as pointed out by Caulton (1976).

Recently, Howe (1993) reported some pomacanthids (*Genicanthus personatus*) possessing a relatively large and thick-walled oesophagus with papillae arranged radially and filling the entire lumen, similar to the oesophageal sac in *P, argenteus*. These papillae are pointed posteriorly to keep the food items moving down the oesophagus and reducing food loss by regurgitation.

From the present study, it may be concluded that contrary to the pioneer study undertaken a quarter of a century ago (Shamsul Hoda 1974), the buccal teeth of *P. argenteus* inhabiting Kuwaiti waters exhibit structural types enabling the species to cope with its present simple diet composed mainly of Crustacea and Bacillariophyceae. Single rows of villiform teeth borne on the premaxillary bone are unicuspid, interspersed with a few tricuspid teeth, while those on the dentary are tricuspid, interspersed with a few unicuspid teeth. The oesophageal sac contains numerous simple conical teeth, each with a broad base and a narrow pointed apical region.

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التراكيب الإغتذائية في سمكة السلفر بامفرت
كما بينها المجهر الإلكتروني الماسح

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خلاصة

يعرض هذا البحث لأول مرة وصف التراكيب الإغتذائية لسمكة سلفر بامفرت ، والمعروفة محلياً بالزبيدي من مياه الكويت للخليج العربي . الفم في هذا النوع من الأسماك صغير ، وتحت طرفي كشق مفتوح عرضياً ، ومزود بصف واحد من الأسنان الزغبية على كل من عظام الفك العلوي ، والسفلي . وعلى عكس بعض الاستنتاجات للدراسات السابقة أن الأسنان الخلفية متعددة النتوءات ، فقد أظهرت الدراسة الحالية أن أسنان الفك العلوي في معظمها أحادية النتوءات ، مخروطية الشكل ، وغير مدببة ويتخللها قليل من الأسنان ثلاثية النتوءات . على حين أن أسنان الفك السفلي في معظمها ثلاثية النتوءات ، ضيقة وحادة يتخللها أحيانا القليل من الأسنان أحادية النتوءات . ويمتد البلعوم من التجويف الفموي إلى الخلف مكوناً كيساً سميك الجدار يطلق عليه اسم الكيس المريئي وهي تركيب فريد للستروماتدي. وينتيء من الجدار الداخلي للكيس المريئي أسنان حادة مخروطية بسيطة . وهناك محاولات أجريت للربط بين نوع الغذاء وأسنان التجويف الفموي ، وتم إدراجها في دراسة سابقة لنا حيث يتكون الغذاء بالترتيب من حيث الكثافة من مجدافيات الأقدام وبيضها ، باسلاريوفيتا ، وقشريات أخرى ، رخويات ، قشور أسماك يرقات أسماك وبيضها ، وهوائم نباتية أخرى . فالأسنان ثلاثية النتوءات ذات نتوء وسطي حاد تكون قادرة على تفتيت الطعام المكون من الأجسام الطرية من القشريات (مثل مجدافيات الأرجل وبيضها) ، ويرقات الأسماك وبيضها . أما الأسنان المخروطية ذات النتوء الواحد نهايته غير حادة ممكن أن يستخدم للتعامل مع القشريات ذوات الغطاء . والأسنان المخروطية المدببة الحادة وكذلك الغير حادة منها يمكن الاستفادة منها بالإمساك ، وتمزيق ، وطحن الضحية التي تم افتراسها . والأسنان الثلاثية النتوءات كالشفرة الحادة ملائمة لتفتيت الدياتوم ، والهوائم النباتية الأخرى ، مثل الطحالب الشريطية.