

A Systematic Study on the Otolith Characters of Sparidae (Pisces) in the Bay of Izmir (Aegean Sea)

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Abstract: The otolith morphologies of 13 species belonging to the Sparidae family collected from the Bay of Izmir (Aegean Sea) were examined separately and the characteristics were drawn. The values obtained from measurements are given in the 95% confidence interval. With discriminant analysis, the groups were formed depending on the data collected. As a result of this analysis, it is possible to identify the species from the Sparidae family by the otolith characters.

Key Words: Sparidae, otolith morphology, discriminant analysis, the Bay of Izmir

İzmir Körfezi'nde (Ege Denizi) Otolit Özelliklerini Kullanarak Sparidae (Pisces) Üzerine Sistematik bir Çalışma

Özet: İzmir Körfezi'nden elde edilen 13 Sparidae türünün otolit morfolojileri ayrı ayrı incelenerek özellikleri çizilmiştir. Ölçümle sağlanan değerler %95 güven aralığında verilmiştir. Toplanan verilere göre Ayrıştırma Analizi (Discriminant Analysis) ile gruplandırma meydana getirilmiştir. Bu analiz sonucunda, Sparidae familyasına ait türlerin otolit özellikleri kullanılarak tanımlanmasının mümkün olduğu görülmüştür.

Anahtar Sözcükler: Sparidae, Otolit morfolojisi, Ayrıştırma Analizi, İzmir Körfezi

Introduction

From the last century until today, many studies have been carried out about different subjects of otolithology. Harkönen (1) remarked that there are otoliths, found by many palaentologists, from the Cenozoic and Palaeozoic periods. Therefore, otoliths are the best evidence for the Teleostoi systematic research.

Every species' otoliths have characteristic shape and features. For that reason otoliths are widely used in the systematic research of the Teleost fishes (2). It is also possible to identify fish species in the form of otoliths through the analysis of the stomach content of the predators.

Akkıran (2) states that the reason to define otoliths is not only for the identification of the species but also for the stomach analysis and the systematic research of fossil fish.

Materials and Methods

Fishes were collected from the Bay of Izmir by using deep trawl and beach seine net. The fork length measurements were made on the measurements board with ± 1 mm class interval and the otolith measurements were made by a digital compass with ± 0.01 mm sensitivity. An electronic balance with 0.0001 g sensitivity was used for the weight measurements. The identification of the species was made according to Bauchot and Hureau (3).

Morphological characteristics of the otoliths were studied under a binocular microscope. The figures of the otoliths were drawn on millimetric paper by enlarging (Figure 1). Morphometric characteristics are given within a 95% confidence interval.

By grouping the morphometric characteristics of otoliths belonging to each species, a statistical

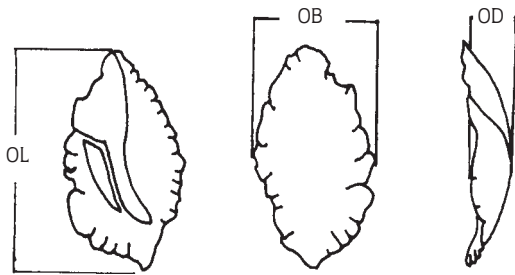


Figure 1. The measurements of an otolith. otolith length (OL), otolith breadth (OB), otolith depth (OD).

determination was made with the help of discriminant analysis. Depending on the discriminant analysis, 4 canonical discriminant functions were attained. In addition, the reliability of the distinguishing force was shown by the χ^2 Test (4). The discriminant function of the analysis was obtained using the SPSS (Statistical Package for the Social Sciences) Program.

Results

Pagellus acarne (Risso, 1826)

Otolith is oval. Rostrum is rounded; antirostrum very small, sharp or round. Sulcus is deep and cristae well-defined. Wide dorsal area lies across the sulcus. Otolith is convex in the medial surface; in the lateral surface, it is concave, almost flat. Sides are lobed (Figure 2). The mean values of the morphometric characteristics of otoliths are shown in Table 1.

Table 1. Morphological presentation of the sagittal otolith taken from *Pagellus acarne* (Risso, 1826).

N=38	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	123.29	5.24	3.05	1.07	0.0139
Min.	103	4.33	2.73	0.89	0.01
Max.	151	6.4	3.92	1.38	0.0209
Std.	8.75	0.379	0.224	0.098	0.0019
95% C.I.	2.88	0.13	0.07	0.03	0.00006

Oblada melanura (Linnaeus, 1758)

Otolith is oval. Rostrum is rounded; antirostrum sharp or round. Sulcus is deep. The posterior extension of cauda is slightly sloped. Dorsal area is wide. Otolith is convex in the medial surface; lateral surface well concave (Figure

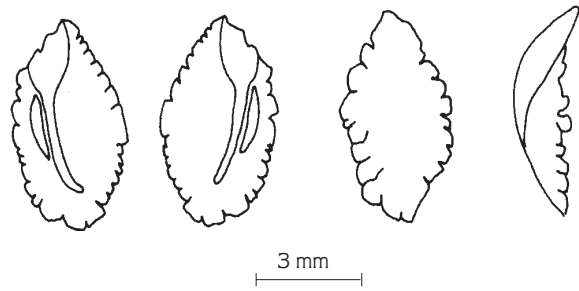


Figure 2. Sagittae of *Pagellus acarne* (Risso, 1826).

3). The mean values of the morphometric characteristics of otoliths are shown in Table 2.

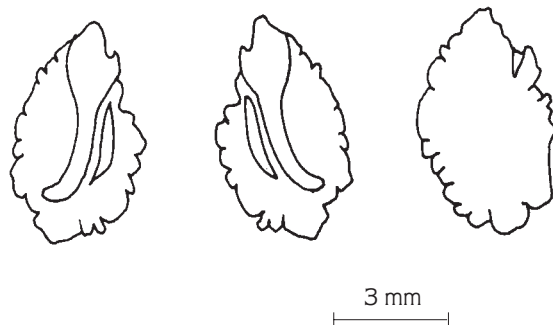


Figure 3. Sagittae of *Oblada melanura* (Linnaeus, 1758).

Table 2. Morphological presentation of the sagittal otolith taken from *Oblada melanura* (Linnaeus, 1758).

N=35	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	109.74	4.94	3.16	1.05	0.0147
Min.	95	4.49	2.84	0.93	0.0113
Max.	122	5.56	3.64	1.24	0.0199
Std.	6.963	0.25	0.19	0.06	0.0018
95% C.I.	2.4	0.09	0.07	0.02	0.00006

Boops boops (Linnaeus, 1758)

Otolith of this species is oval. Rostrum is prominent and pointed; antirostrum pointed or flat. Sulcus is very deep. Ostium is hollow-shaped. Posterior of cauda makes a strong curve to the postero-ventrale. Cristae are well-defined. Dorsal area is wide and long. Medial surface is convex; in the lateral surface, it is concave almost flat. Sides are lobed (Figure 4). The mean values of the morphometric characteristics of otoliths are shown in Table 3.

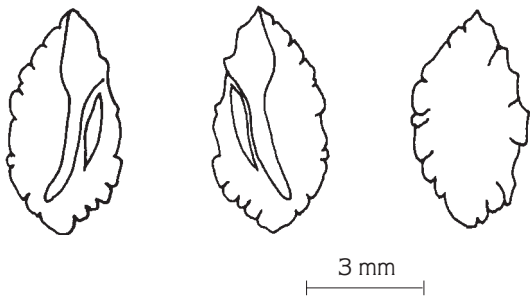


Figure 4. Sagittae of *Boops boops* (Linnaeus, 1758).

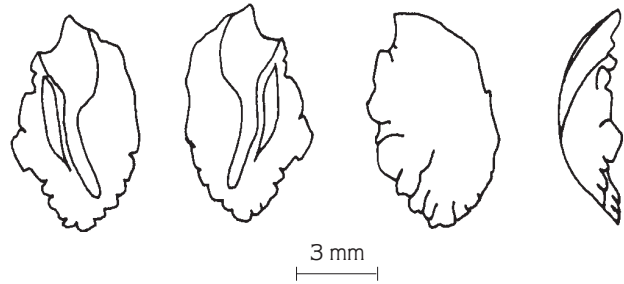


Figure 5. Sagittae of *Diplodus annularis* (Linnaeus, 1758).

Table 3. Morphological presentation of the sagittal otolith taken from *Boops boops* (Linnaeus, 1758).

N=52	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	141.56	5.25	3.09	1.01	0.0146
Min.	118	4.47	2.65	0.86	0.0111
Max.	195	6.87	4.04	1.29	0.0273
Std.	13.15	0.44	0.26	0.09	0.0031
95% C.I.	3.65	0.12	0.08	0.18	0.006

Diplodus annularis (Linnaeus, 1758)

Otolith is in the form of cubiceps, slightly long and pentagonal. Rostrum is wide, antirostrum is flat. Sulcus is deep. Cauda lies with a slight slope to the postero-ventrale. Cristae are well-defined. Dorsal area is wide. Otolith is convex in the medial surface; in the lateral surface, it is concave, almost flat. Postrostrum and posterior sides are lobed (Figure 5). The mean values of the morphometric characteristics of otoliths are shown in Table 4.

Table 4. Morphological presentation of the sagittal otolith taken from *Diplodus annularis* (Linnaeus, 1758).

N=42	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	105.6	4.88	3.04	1.05	0.0162
Min.	84	3.57	2.54	0.73	0.0096
Max.	156	6.83	3.88	1.66	0.0396
Std.	13.31	0.55	0.28	0.17	0.0052
95% C.I.	4.14	0.17	0.09	0.05	0.00016

Dentex dentex (Linnaeus, 1758)

Otolith is in the form of cubiceps and irregularly pentagonal. Rostrum and antirostrum are prominent and pointed. Sulcus is not very deep. Dorsal area is wide and lies between the antirostrum base and the caudal end. Otolith is very convex in the medial surface; in the lateral surface, it is very concave, almost flat and striated. Postrostrum is sharp pointed, sides are highly denticulated (Figure 6). The mean values of the morphometric characteristics of otoliths are shown in Table 5.

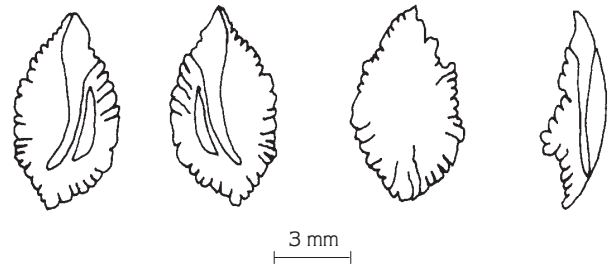


Figure 6. Sagittae of *Dentex dentex* (Linnaeus, 1758).

Table 5. Morphological presentation of the sagittal otolith taken from *Dentex dentex* (Linnaeus, 1758).

N=11	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	176.82	6.25	3.6	1.29	0.0207
Min.	159	5.13	3.24	1.08	0.0143
Max.	220	7.44	4.16	1.58	0.0308
Std.	17.03	0.635	0.267	0.14	0.0044
95% C.I.	11.43	0.43	0.18	0.1	0.0029

Diplodus vulgaris (E. Geoffroy St-Hilaire, 1817)

Otolith is in the form of cubiceps, slightly long and irregularly pentagonal. Dorsal side is projected. Rostrum protruded, antirostrum flat or absent. Sulcus is deep and well-defined. Dorsal area is wide. Otolith is convex in the medial surface and concave in the lateral surface. Postrostrum is lobed, sides are denticulated (Figure 7). The mean values of the morphometric characteristics of otoliths are shown in Table 6.

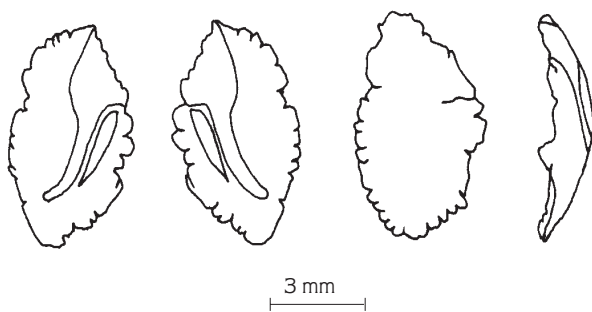


Figure 7. Sagittae of *Diplodus vulgaris* (E. Geoffroy St-Hilaire, 1817).

Table 6. Morphological presentation of the sagittal otolith taken from *Diplodus vulgaris* (E. Geoffroy St-Hilaire, 1817).

N=69	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	115.71	4.84	3	1.104	0.015
Min.	85	3.93	2.38	0.093	0.0076
Max.	160	6.27	3.71	1.46	0.0305
Std.	15.69	0.49	0.268	0.19	0.0044
95% C.I.	3.78	0.12	0.06	0.05	0.0001

Pagellus erythrinus (Linnaeus, 1758)

Otolith is in the form of cubiceps and irregularly pentagonal. Rostrum is short and rounded. Antirostrum is small and sharp pointed. Sulcus is deep. The posterior of cauda turns to the ventral side with a strong curve. Dorsal area is wide. Otolith is very convex in the medial surface; in the lateral surface, it is very concave and in the ventral is almost flat. Sides are lobed (Figure 8). The mean values of the morphometric characteristics of otoliths are shown in Table 7.

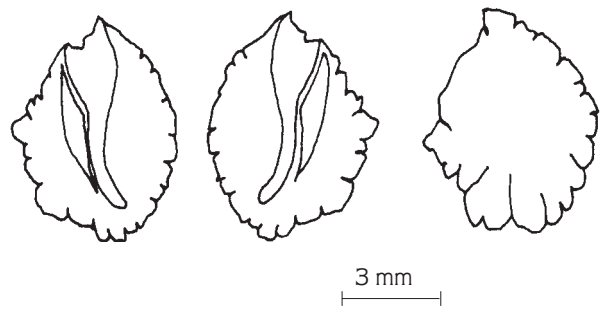


Figure 8. Sagittae of *Pagellus erythrinus* (Linnaeus, 1758).

Table 7. Morphological presentation of the sagittal otolith taken from *Pagellus erythrinus* (Linnaeus, 1758).

N=133	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	119.9	5.76	4.27	1.32	0.0338
Min.	71	3.51	2.59	0.83	0.0075
Max.	190	8.88	6.79	1.96	0.1086
Std.	24.19	1.07	0.85	0.22	0.018
95% C.I.	4.14	0.18	0.14	0.038	0.003

Dentex macrophthalmus (Bloch, 1791)

Otolith is in the form of cubiceps and irregularly pentagonal. Rostrum is protruded and sharp pointed; antirostrum is projected. Sulcus deep and well-defined. Cauda declines towards the postero-ventrale with a strong slope. Dorsal area is wide. Otolith is convex in the medial surface, in the lateral surface concave. Postrostrum is wide, sides are lobed (Figure 9). The mean values of the morphometric characteristics of otoliths are shown in Table 8.

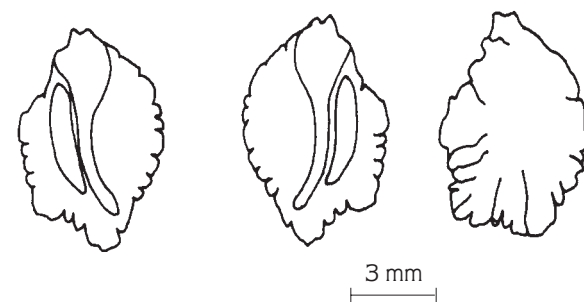


Figure 9. Sagittae of *Dentex macrophthalmus* (Bloch, 1791).

Table 8. Morphological presentation of the sagittal otolith taken from *Dentex macrophthalmus* (Bloch, 1791).

N=8	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	161.75	7.23	5.07	1.75	0.0537
Min.	147	6.02	4.44	1.5	0.0353
Max.	184	9.07	6.27	2.05	0.1004
Std.	12.04	0.98	0.72	0.18	0.028
95% C.I.	10.07	0.83	0.59	0.15	0.02

Pagrus pagrus (Linnaeus, 1758)

Otolith is in the form of cubiceps and irregularly pentagonal. Rostrum is protruded and tipped; antirostrum is tied to the rostrum with a projection. Sulcus is very deep. Cristae are well-defined. Cauda descends to the postero-ventrale with a strong slope. Otolith is convex and concave in the medial and lateral surfaces respectively. Sides are denticulated (Figure 10). The mean values of the morphometric characteristics of otoliths are shown in Table 9.

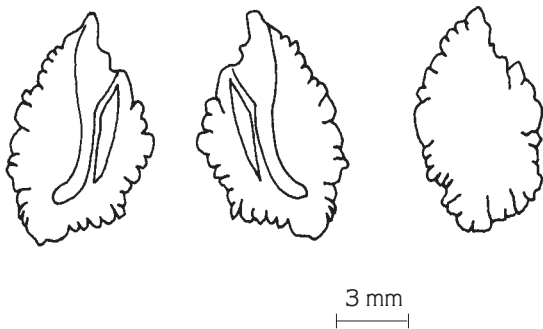


Figure 10. Sagittae of *Pagrus pagrus* (Linnaeus, 1758).

Table 9. Morphological presentation of the sagittal otolith taken from *Pagrus pagrus* (Linnaeus, 1758).

N=32	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	163.53	7.04	4.64	1.67	0.0407
Min.	120	5.44	3.48	1.2	0.0202
Max.	258	10.73	6.29	2.54	0.1126
Std.	27.53	0.97	0.54	0.26	0.016
95% C.I.	9.92	0.35	0.19	0.09	0.006

Diplodus puntazzo (Cetti, 1777)

Otolith is irregular and oval. Rostrum is protruded; antirostrum is flat. Sulcus is very deep. Ostium is hollow-shaped. Cristae are well-defined. Cauda is deep, posterior side of cauda is curved on the ventral. Otolith is very convex in the medial, and concave in the lateral surfaces. Sides are lobed, postrostrum is slightly lengthened (Figure 11). The mean values of the morphometric characteristics of otoliths are shown in Table 10.

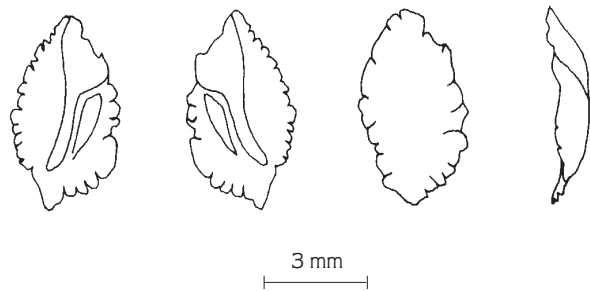


Figure 11. Sagittae of *Diplodus puntazzo* (Cetti, 1777).

Table 10. Morphological presentation of the sagittal otolith taken from *Diplodus puntazzo* (Cetti, 1777).

N=17	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	203.65	6.45	3.73	1.38	0.022
Min.	174	5.87	3.27	1.22	0.0178
Max.	248	7.04	4.01	1.56	0.0256
Std.	17.22	0.283	0.214	0.092	0.0024
95% C.I.	8.86	0.15	0.11	0.05	0.00011

Sarpa salpa (Linnaeus, 1758)

Otolith is irregular and oval, but it is lengthened in the part of postrostrum. Rostrum is protruded, antirostrum is flat and rounded. Sulcus is deep. Ostium is hollow-shaped. Cristae are well-defined. Dorsal area is wide. Cauda extends to postero-ventrale with a curve. Otolith is convex in the medial surface, and in the lateral surface is concave. Sides are lobed on the dorsal and the posterior and it is denticulated on the other sides (Figure 12). The mean values of the morphometric characteristics of otoliths are shown in Table 11.

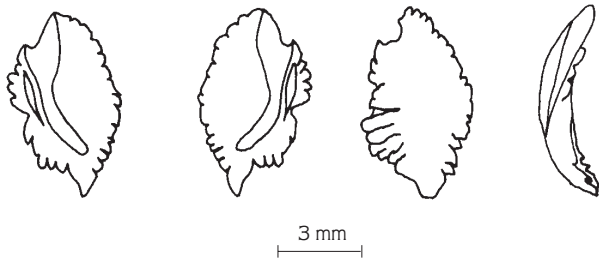


Figure 12. Sagittae of *Sarpa salpa* (Linnaeus, 1758).

Table 11. Morphological presentation of the sagittal otolith taken from *Sarpa salpa* (Linnaeus, 1758).

N=9	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	243.67	6.73	3.15	1.44	0.021
Min.	201	6.22	2.88	1.24	0.0169
Max.	286	7.81	3.66	1.8	0.0318
Std.	23.19	0.47	0.25	0.16	0.0044
95% C.I.	17.83	0.37	0.19	0.12	0.002

Sparus aurata Linnaeus, 1758

Otolith is in the form of cubiceps and is irregularly pentagonal and elongated. Rostrum is wide and elongated; antirostrum is small and sharp-tipped. Sulcus is deep and wide. Cristae can be well-defined. Cauda is slightly tied to the ventral area with a slope. Dorsal area is wide. Otolith is convex and concave in the medial and lateral surfaces respectively. Sides are indented. Especially postrostrum is denticulated like a saw (Figure 13). The mean values of the morphometric characteristics of otoliths are shown in Table 12.

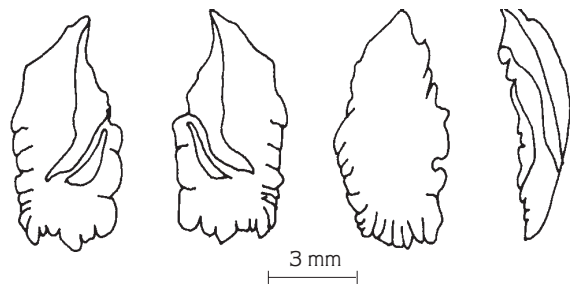


Figure 13. Sagittae of *Sparus aurata* Linnaeus, 1758.

Table 12. Morphological presentation of the sagittal otolith taken from *Sparus aurata* Linnaeus, 1758.

N=39	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	200.67	6.54	3.97	1.51	0.031
Min.	147	5.48	3.47	1.05	0.0157
Max.	279	8.93	4.8	2.17	0.0787
Std.	28.93	0.84	0.3	0.28	0.0138
95% C.I.	9.38	0.27	0.09	0.09	0.0044

Lithognathus mormyrus (Linnaeus, 1758)

Otolith is in the form of cubiceps, oval and slightly elongated. Rostrum is protruded and rounded; antirostrum is flat or very slightly round. Sulcus is deep and cauda is tied to the side with a trace. Cristae are well-defined. Dorsal area is deep and it lies along the cauda. Otolith is convex and quite concave in the medial and lateral surfaces respectively. Postrostrum is lobed, other sides are denticulated (Figure 14). The mean values of the morphometric characteristics of otoliths are shown in Table 13.

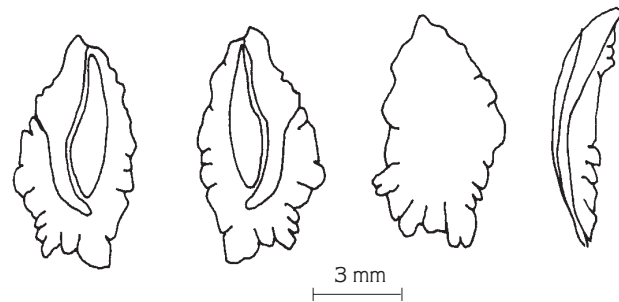


Figure 14. Sagittae of *Lithognathus mormyrus* (Linnaeus, 1758).

Table 13. Morphological presentation of the sagittal otolith taken from *Lithognathus mormyrus* (Linnaeus, 1758).

N=34	Fork Length	Otolith Length	Otolith Breadth	Otolith Depth	Otolith Weight
Mean	188.23	7.35	3.51	1.64	0.0366
Min.	155	6.37	3.15	1.39	0.0276
Max.	220	8.57	3.9	1.82	0.0468
Std.	17.59	0.55	0.21	0.13	0.0059
95% C.I.	6.12	0.19	0.07	0.04	0.002

Discrimination of the Species

By using discriminant analysis, 4 canonical discriminant functions were obtained as given below:

Function 1: $y_1 = -2.44 (OL) + 0.33 (OD) + 1.99(OB) + 0.29 (OW)$

Function 2: $y_2 = -0.18 (OL) + 1.26 (OD) + 0.18 (OB) - 1.29 (OW)$

Function 3: $y_3 = 1.73 (OL) - 1.66 (OD) + 0.74 (OB) - 0.61 (OW)$

Function 4: $y_4 = 0.17 (OL) - 0.68 (OD) - 0.43 (OB) + 1.52 (OW)$

As a result:

Function	Wilks' Lambda Values
1	1.256
2	2.669
3	3.931

Among the Wilks' lambda values, the two smallest values show the best functions in discrimination, because of this depending on the 1st and 2nd values, the graphic of the canonical discriminant function is sketched in Figure 15.

Reliability of the discriminant analysis was checked using the χ^2 Test, and according to this, H_0 , the discriminant feature of the discriminant analysis, is not significant,

H_1 ; starting from the point of the hypothesis that the discrimination feature of the discriminant analysis is significant, Q value was calculated as 2945.59 and H_0 was rejected, because, since $\chi^2_{(1;0.05)}=3.841$, the discriminational feature of the discriminant function was found to be significant. Examining according to the otolith features, it can be tested with 95% reliability that the correct discriminating force is 71.24%.

Discussion

In the Bay of Izmir, 13 species' otolith characteristics belonging the Sparidae family were evaluated using discriminant analysis and it was found that the greatest similarity was among *P. acarne*, *O. melanura*, *B. boops*, *D. annularis* and *D. vulgaris*. Similarities were also found in three other groups: (a) *S. salpa* and *L. mormyrus*, (b) *D. dentex*, *D. puntazzo* and *S. aurata*, (c) *P. pagrus* and *D. macrophthalmus*.

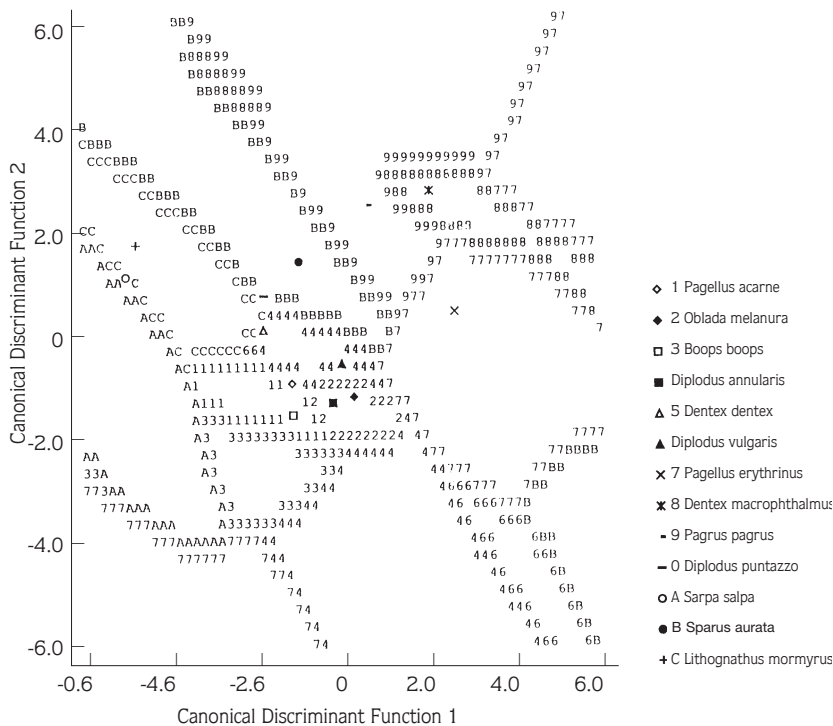


Figure 15. The species otolith discrimination depending on the canonical discriminant function.

According to Akkiran (2), who examined the otolith morphologies of the same species in the north-eastern Mediterranean, the greatest similarity was observed between *P. erythrinus* and 3 species belonging to the Pagrus genus (*P. caeruleosticus*, *P. ehrenbergi* and *P. pagrus*). Akkiran (2) also reported similarities in three other groups: (a) *B. boops* and *P. acarne*, (b) *L. mormyrus* and *S. salpa* and (c) 4 species of the Sparus genus (*O. melanura*, *D. cervinus*, *D. puntazzo*, *D. vulgaris*). Although otoliths obtained from the species studied by Akkiran (2) had features similar to those in the present findings, there were also some differences because of several possible reasons. Hopkins (5), after his study on horse mackerel, stated that the morphology of

otoliths from the same species could show differences between the stocks of different locations. Moreover, Campana and Casselman (6) reported that the size of otoliths varied depending on the area where the samples were collected from. However, the differences between the results of the present study and those obtained by Akkiran (2) may also have been caused by the differences between the analysis methods used in the studies.

As a result, although the otoliths of the Sparidae family have a general similarity, it is possible to make a definite differentiation of species from the special otolith morphologies.

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