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Butterfish
Peprilus triacanthus

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Butterfish is a small, semipelagic schooling species of commercial importance from Southern New England to Cape Hatteras, although it has been reported from Nova Scotia south to deep waters off Florida (Nichols and Breder 1927, Bigelow and Schroeder 1953). Butterfish overwinter along the 183-m (100-fathom) contour of the continental shelf from late autumn through early spring. North of Cape Hatteras, these fish begin to disperse over the shelf in April or May, moving inshore and northward with increasing water temperatures (Horn 1970, Waring 1975). South of Cape Hatteras seasonal inshore/offshore migrations are not thought to be significant (Caldwell 1961, Horn 1970). Spawning occurs from May through October, reaching a peak in July and August (Colton et al. 1979).

Butterfish are fast-growing and short-lived, attaining lengths of up to 24-25 cm (9-10 inches) and a maximum age of 4 although a few fish may reach age 5 or 6. Females are somewhat faster growing than males. Many butterfish are sexually mature by age 1; all are mature by age 2 (DuPaul and McEachran 1973).

Previous investigators (DuPaul and McEachran 1973, Kawahara 1978) have validated hyaline zones as annuli using whole otoliths, but did not describe growth patterns in detail. Although this species is short-lived, growth patterns on some butterfish otoliths are quite complex. Annuli may be very difficult to identify due to formation of checks within opaque zones and split or diffuse hyaline zones.

Whole otoliths are used at the Woods Hole Laboratory and are stored dry because storage in alcohol or glycerin tends to weaken contrast between the hyaline and opaque zones. Otoliths are examined by viewing the distal surface in ethyl alcohol against a dark background using reflected light at a magnification of 15×.

Most butterfish, except those that hatch late, complete at least half of their growth by age 1 (Waring 1975). Therefore, the first annulus, completely formed by the end of the first spring after hatching, is some distance away from the nucleus of the otolith. By convention, a birthdate of 1 January is used. As of this date, the hyaline zone evident on the edge of the otolith until spring growth resumption is interpreted as an annulus. Due to an overgrowth of calcium, the nucleus is seldom visible on the otolith after the fish has attained 4 or 5 cm in length. Larger young-of-the-year (YOY) fish, age 0+, complete seasonal growth by early autumn, judging by the appearance of hyaline material on the edge of the otolith. Smaller late-hatched fish appear to continue growing through autumn and perhaps winter, because opaque edge is still evident by early spring. In general, the time of annulus formation for butterfish is mid-autumn through late spring. This may vary for different age groups as older fish tend to begin and end seasonal growth slightly later in the season.

For butterfish sampled from the waters of the Gulf of Maine to Cape Fear, two types of otolith growth patterns may be identified, though not clearly differentiated. The "offshore" pattern is characteristic of butterfish sampled in waters deeper than 27 m, although such otoliths are also found in specimens taken inshore in summer and autumn. The "inshore" type of otolith growth pattern is characteristic of specimens collected at depths of less than 27 m, especially from the New York Bight south to Cape Fear. Infrequently, otoliths with the inshore pattern will be noted among offshore samples collected during the overwintering period. This distribution of inshore and offshore growth patterns has been stable from year to year among NEFC research and commercial samples.

Otoliths with the offshore growth pattern are predominant in survey and commercial catches, and tend to exhibit clearly defined annular zones. Checks may be prominent on these otoliths but can easily be distinguished from annular zones, and do not normally complicate age interpretation. The otoliths are usually well calcified, with good contrast between the hyaline and opaque zones. They are somewhat elongate in shape and the posterior edge is squared in outline.

Figures 1 to 12 illustrate variations in the offshore pattern. During the summer months, otoliths of young-of-the-year fish exhibit opaque edge, indicating vigorous growth (Fig. 1). By September or October, hyaline edge begins to form, especially on otoliths of age 0+ individuals. The initial deposition of hyaline material often appears as a closely spaced series of thin hyaline rings (Fig. 2); continuous hyaline edge may form during the winter months. If this "split" zone (intermittent deposition of hyaline material) is composed of two apparently distinct but closely spaced hyaline zones, the first zone may be misidentified as a separate annulus, resulting in overestimation of age (Fig. 3).

Checks formed before the first annulus are characteristic of offshore otoliths, but because they contrast with more prominent annular zones they are usually not difficult to differentiate from annuli (Compare Figures 2, 3, and 4). Figure 5 shows an otolith from a 13-cm, age-1 fish with three checks formed before the first annulus on the edge. These are thin, superficial, and/or discontinuous. In Figure 6, however, the hyaline zone near the center of the otolith of a 10-cm fish may represent the first annulus of a late-hatched fish. The zone is narrow but deeply formed and continuous around the periphery of the otolith.

Subsequent to the first annulus, growth increments (opaque zones) narrow considerably in width. If the first annulus is small, however, growth compensation may result in relatively wide increments (Figs. 6 and 7). In general, growth increments subsequent to the first annulus are larger for more northerly sampled butterfish with faster growth after age 1. Otoliths with very narrow increments between annuli may be difficult to distinguish from otoliths with split annuli (Fig. 3). In addition, individual differences in timing of increment/annulus formation can cause considerable indecision in age interpretation. For example, Figures 8 and 9 show otoliths from fish of similar sizes that were sampled in October. The second summer-growth increment including winter (hyaline) edge is easily recognizable in Figure 8; in Figure 9, however, the growth increment after the first annulus is barely distinguishable, probably due to retarded seasonal growth. In general, a "split" annulus may be distinguished from an annulus close to the edge (due to retarded seasonal growth) by the strength and width of the hyaline zone near the edge. If this zone is thin and/or weak, a split annulus is indicated; if strong and/or wide, the zone may be interpreted as an annulus followed by a narrow growth increment.

Growth patterns become easier to recognize after several annuli have formed. Distinct patterns of check or annulus formation may be repeated on otoliths of individual fish and relative spacing of hyaline zones becomes easier to evaluate. Figure 10, for example, shows an otolith from an 18-cm, age 2+ fish. Both the first and second annuli are weak diffuse zones, but the first annulus can be distinguished laterally on the otolith where the hyaline rings comprising the zone are compacted together.

Figures 4, 7, 11, and 12 show growth patterns characteristic of adult offshore butterfish otoliths. Note especially the otolith in Figure 11. Here, a strong check or split is formed after the first annulus. This is a frequently occurring anomaly and could be confused with an annulus, but the zone is relatively weak in the rostral and subrostral area and closely spaced with the first annulus.

Otoliths exhibiting an inshore growth pattern are typically difficult to age. This pattern involves numerous checks and diffuse annuli. Many of these otoliths have a generally rounder outline than is characteristic of the offshore type, and are often poorly calcified. Figure 13 shows an age 1+ otolith from a 12-cm fish where the increment after the first annulus contains very little opaque material. Otoliths are sometimes so poorly calcified that they are impossible to age, the amount of calcium being insufficient to define annuli (see Figure 14). It is possible that calcification may have been disrupted as these structures were formed, or later resorption removed opaque material. The lack of adequate calcium reduces hyaline/opaque zone contrast making it difficult to distinguish checks from annuli. Otoliths sampled from the shoal waters off Maryland south to Cape Fear are most problematic in this respect.

Figure 15 shows an otolith from a 4-cm YOY fish which has formed a check but is still growing actively in October, judging from the presence of opaque edge. Many larger age 0+ fish are difficult to distinguish from small age 1+ fish if strong checks have formed on the otolith. In Figure 16, numerous checks are present on the otolith, but the obvious contrast of these checks with the stronger first annulus indicates an age-2 individual, since the edge is included in the age. In Figure 17, however, it is difficult to interpret any one of the hyaline zones as an annulus; this 10-cm fish could be age interpreted as 0+ or age 1+.

In addition to problems with checks, annuli of inshore otoliths are frequently split into multiple rings and are not well defined. Figure 18, showing a 9-cm, age 1+ fish, is an extreme example of this type, but the zone of split rings is strong enough to be identified as an annulus.

Figures 19 through 22 are examples of adult inshore butterfish otoliths with complex growth patterns. On such otoliths, it is necessary to search for areas where annular zones are strongest and most condensed, such as the rostrum and lateral edges.

The growth pattern phenomena described for inshore otoliths, involving numerous checks and diffuse annuli, may be correlated with environmental factors. Pannella (1974) has observed that for tropical species the incidence of check formation due to environmental influences tends to increase for fish of shoaler water habitats. These fish are exposed to greater variation and extremes of water temperature, anaerobic conditions, and tidal influences. Pannella has also observed that annular zones may be indistinct or missing due to lack of marked seasonal changes in the environment. Inshore butterfish otoliths, sampled south of the New York Bight, are undoubtedly subject to such influences.

Regarding problems with poor mineralization of inshore butterfish otoliths south from New York Bight, mechanisms controlling otolith calcification in fishes are still poorly understood, although water temperature has been cited as an important factor (Pannella 1980). Poor mineralization of otoliths occurs for a number of tropical and semitropical species. It is possible that high seasonal water temperatures in southern inshore areas are partly responsible for poor calcification. Because poor calcification of fish otoliths can cause serious difficulties with age interpretation, more research is necessary, especially concerning how otolith calcification relates to environmental variables.

Although observations of differences in growth patterns are useful in describing ageing methods used for butterfish, a more systematic study is in order before inferences can be made about their significance, especially for stock separation. Thus far, existing meristic and morphometric studies by Caldwell (1961) and Horn (1970) indicate a separate stock of butterfish, possibly a *P. triacanthus*/*P. burti* hybrid, distributed in shallow water (to 20 m) from Cape Hatteras south to Florida. No comment can be made concerning the appearance of these otoliths, since no such fish have been identified during the Cape Hatteras to Cape Fear component of our bottom trawl surveys. Waring (1986) identified five subregions of butterfish distribution based on length-frequency data and trends in abundance. Two inshore groups, north and south of Delaware Bay, were differentiated from offshore groups. However, no inferences were drawn concerning the existence of separate subpopulations in those regions.

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1986. An analysis of spatial differences in size composition and abundance of butterfish, *Peprilus triacanthus*, off the Northeast United States. Ref. Doc. 86-04, Woods Hole Lab., Natl. Mar. Fish. Serv., NOAA, Woods Hole, MA 02543, 23 p.

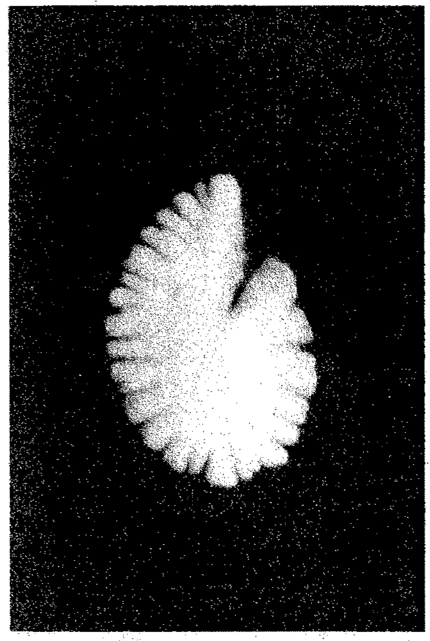

Figure 1
Whole otolith of a 6-cm age 0+ butterfish collected offshore in August showing opaque edge.

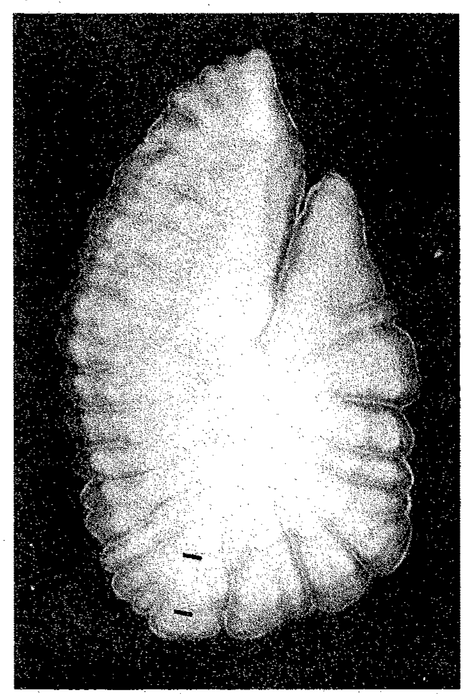

Figure 2
Whole otolith of a 10-cm age 0+ butterfish collected offshore in October showing a first summer check and split hyaline edge forming.

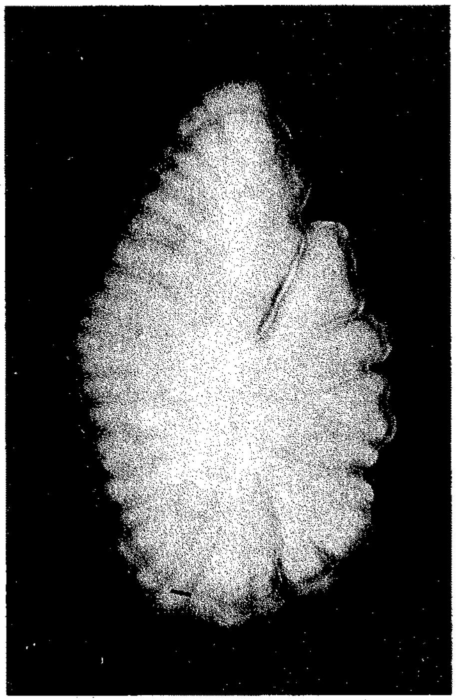

Figure 3
Whole otolith of an 8-cm age 0+ butterfish collected offshore in October showing a check or split formed just inside the (hyaline) edge.

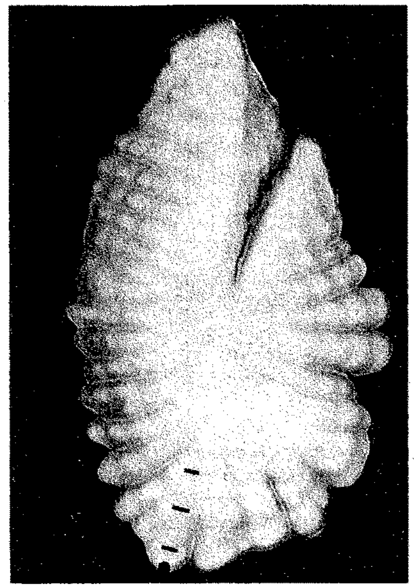

Figure 5
Whole otolith of a 13-cm age-1 butterfish collected offshore in April showing three weak superficial checks formed before the first annulus (hyaline zone) on the edge.

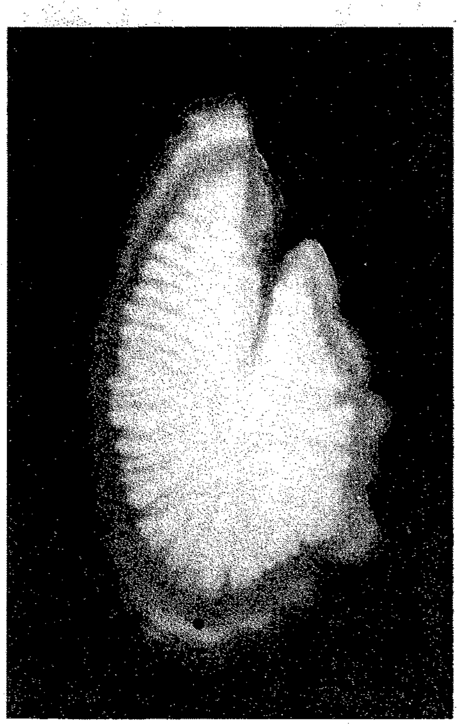

Figure 4
Whole otolith of a 14-cm age 1+ butterfish collected offshore in September showing strong wide annuli and a thin check between the first and second annuli.

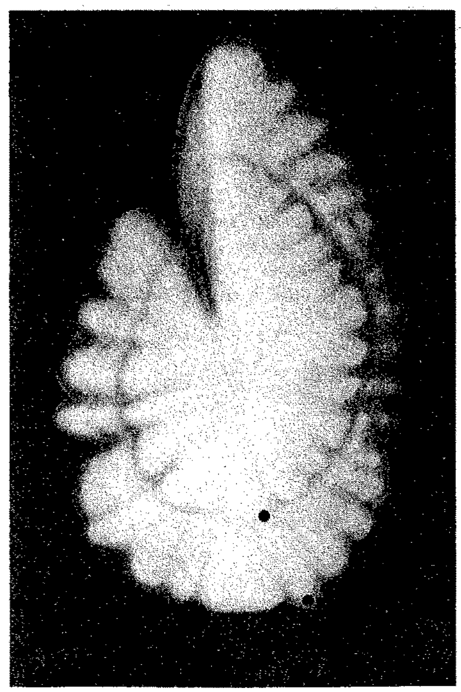

Figure 6
Whole otolith of a 10-cm age-2? butterfish collected offshore in May showing a possible small first annulus.

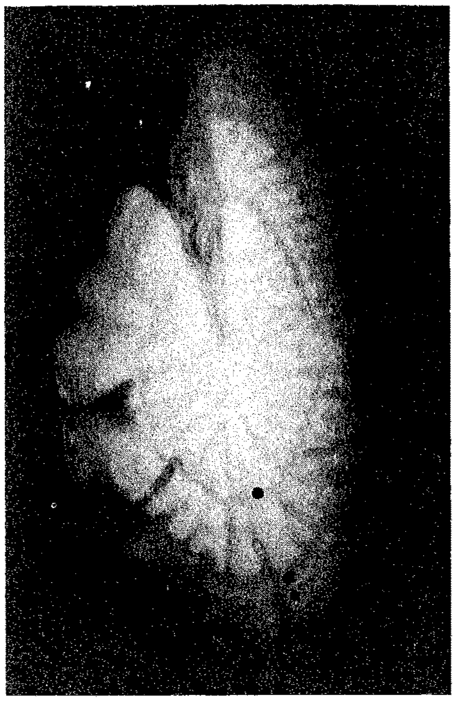

Figure 7
Whole otolith of a 21-cm age-4 butterfish collected offshore in April showing a small first annulus and weak checks between successive annuli.

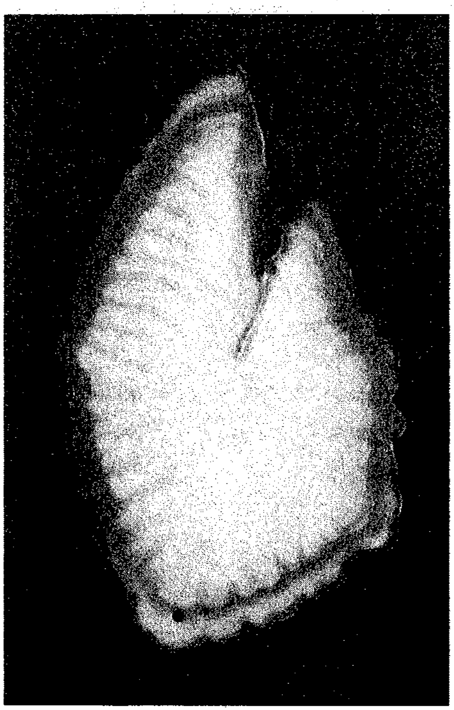

Figure 8
Whole otolith of a 15-cm age 1+ butterfish collected offshore in October showing a strong first annulus and hyaline edge.

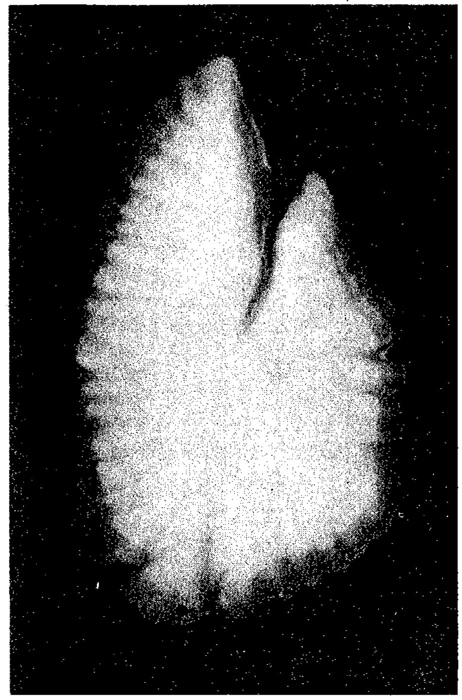

Figure 9
Whole otolith of a 14-cm age 1+ butterfish collected offshore in October showing a diffuse first annulus and unusually narrow seasonal growth increment (opaque zone) on the edge.

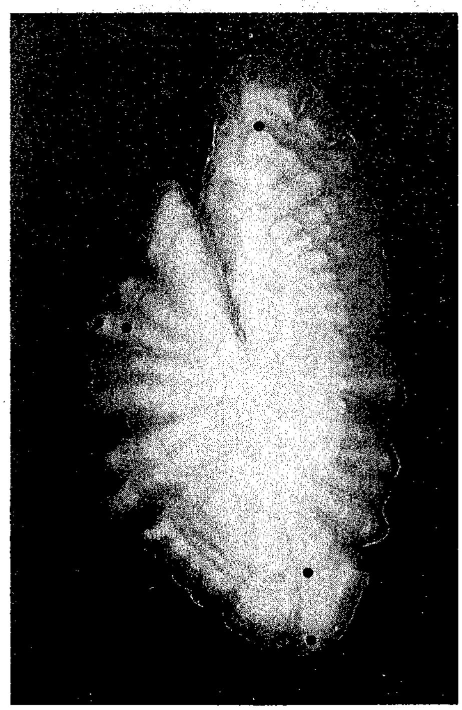

Figure 10
Whole otolith of an 18-cm age 2+ butterfish collected offshore in November showing thin first summer checks and weak, split first and second annuli.

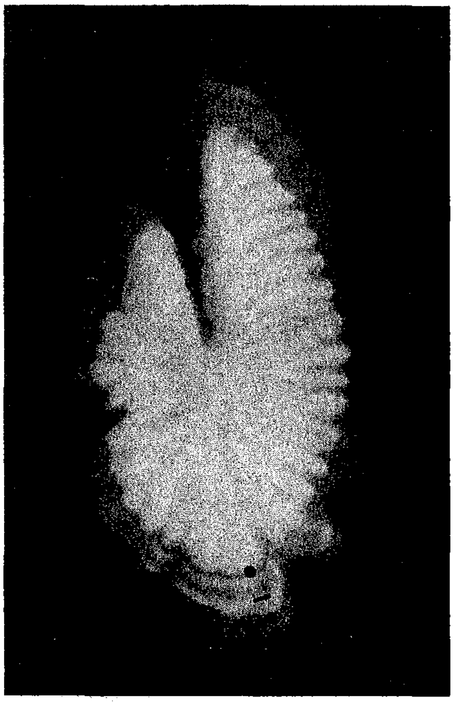

Figure 11
Whole otolith of a 19-cm age-3 butterfish collected offshore in April showing a strong check (or split) formed after the first annulus.

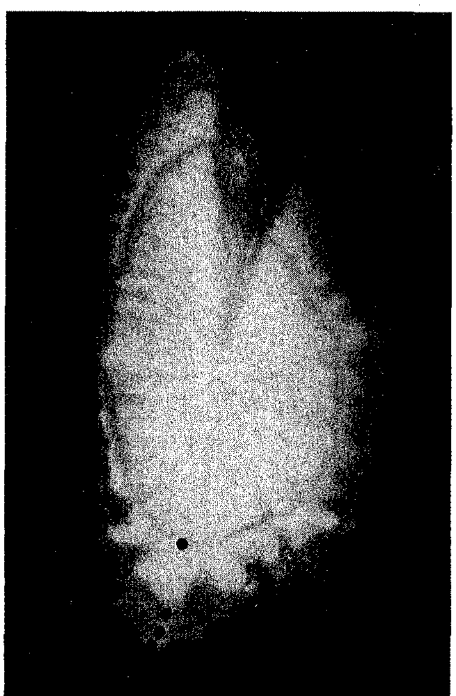

Figure 12
Whole otolith of an 18-cm age-4 butterfish collected offshore in March showing clear annuli.

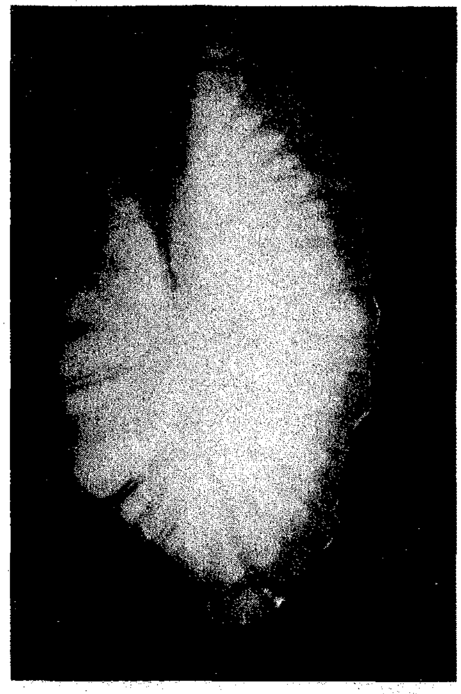

Figure 13
Whole otolith of a 12-cm age 1+ butterfish collected inshore in October showing poor calcification subsequent to the first annulus.

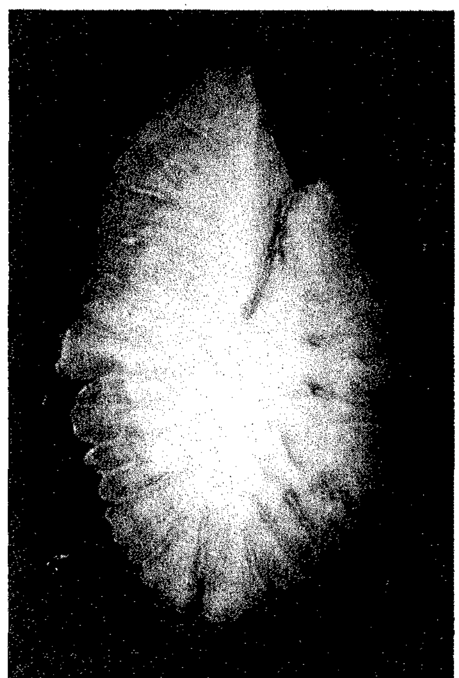

Figure 14
Whole otolith of a 16-cm age? butterfish collected inshore in October showing indistinct zones due to poor calcification.

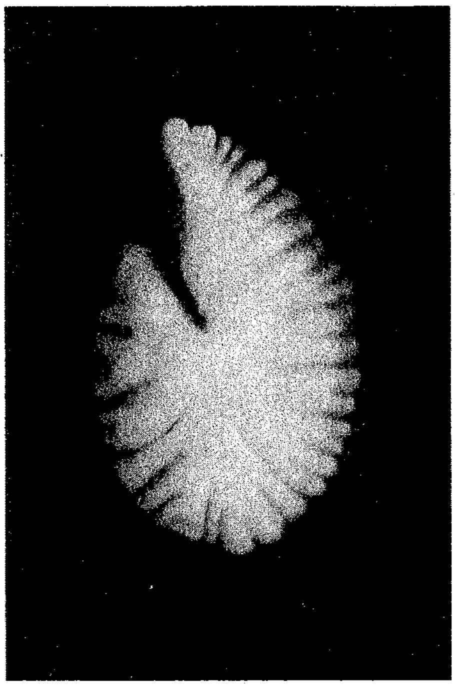

Figure 15
Whole otolith of a 7-cm age 0+ butterfish collected inshore in October showing a thin check formed inside opaque edge.

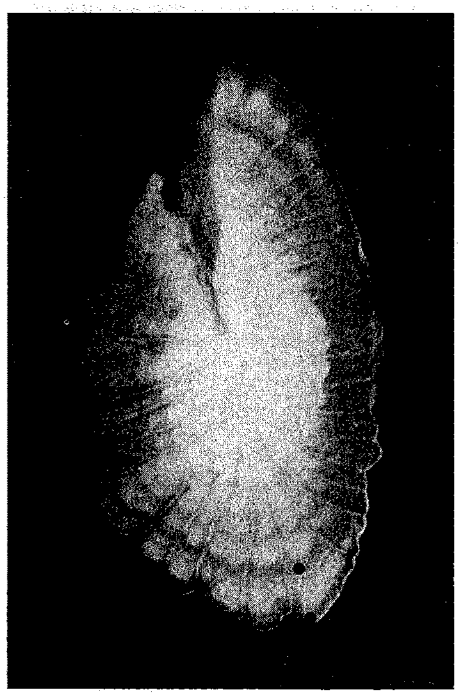

Figure 16
Whole otolith of a 15-cm age-2 butterfish collected inshore in April showing numerous first summer checks and hyaline edge.

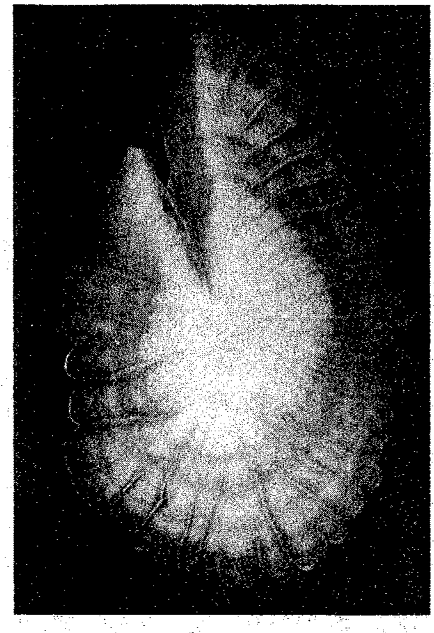

Figure 17
Whole otolith of a 10-cm age 0(1)+ butterfish collected inshore in October showing a complex growth pattern with a possible small first annulus.

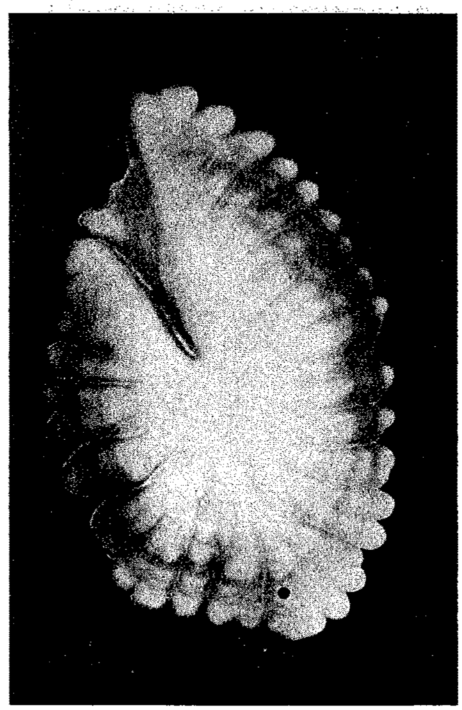

Figure 18
Whole otolith of a 9-cm age 1+ butterfish collected inshore in October showing a split first annulus.

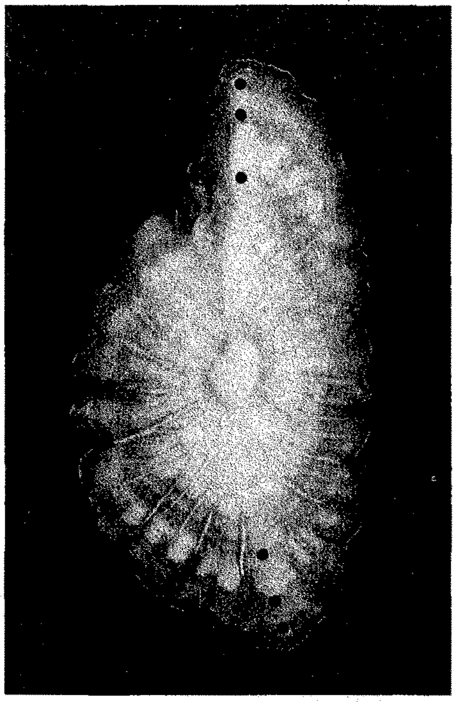

Figure 19
Whole otolith of a 17-cm age 3+(?) butterfish collected inshore in November showing a tiny check close to the nucleus and split, diffuse hyaline zones.

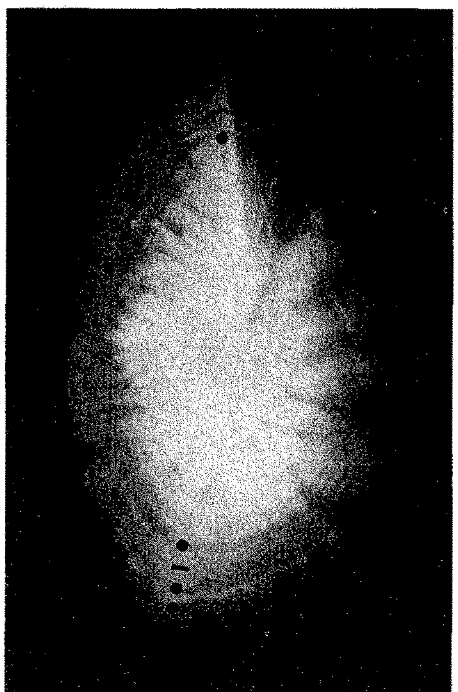

Figure 20
Whole otolith of a 15-cm age 3+ butterfish collected inshore in October showing strong checks and split zones.

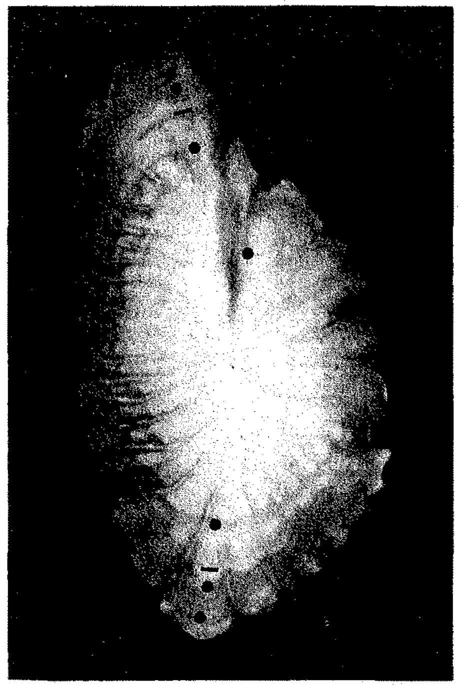

Figure 21
Whole otolith of an 18-cm age 3(4)+ butterfish collected inshore in October showing poorly differentiated annuli.

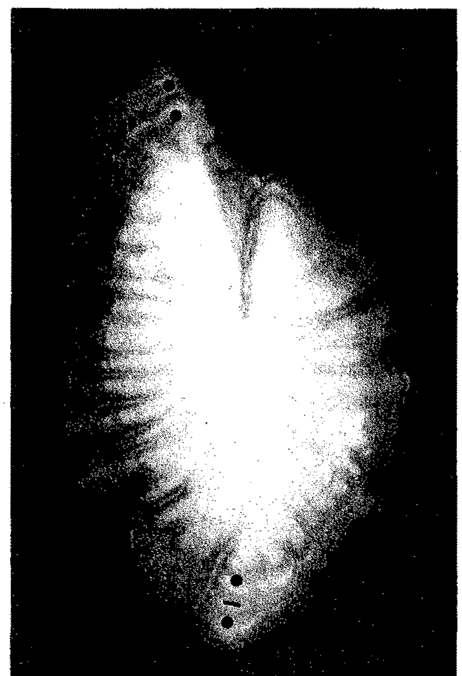

Figure 22
Whole otolith of a 16-cm age 2+ butterfish collected in October showing a complex pattern with two annuli apparent inside the dorsal (lateral) edge.