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Descriptive Key to the Otoliths of Gadid Fishes of the Bering, Chukchi, and Beaufort Seas

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ABSTRACT. An illustrated key with supplementary descriptive material is presented for six species or species groups of gadid fishes which are of trophic importance in the Bering, Chukchi, and Beaufort seas. These species include: *Arctogadus* spp. Drjagin, *Boreogadus saida* (Lepechin), *Eleginus gracilis* (Tilesius), *Gadus macrocephalus* Tilesius, *Microgadus proximus* (Girard), and *Theragra chalcogramma* (Pallas).

RÉSUMÉ. Une clé d'identification illustrée par des figures avec un complément descriptif est ici présentée pour six espèces ou groupes d'espèces de poissons de la famille des gadidés, lesquels ont une importance au point de vue trophique dans les mers de Béring, des Tchouktches et de Beaufort. Ces espèces comprennent: *Arctogadus* spp. Drjagin, *Boreogadus saida* (Lepechin), *Eleginus gracilis* (Tilesius), *Gadus macrocephalus* Tilesius, *Microgadus proximus* (Girard), et *Theragra chalcogramma* (Pallas).

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Key words: otolith, gadid fishes, *Arctogadus*, *Boreogadus*, *Eleginus*, *Gadus*, *Microgadus*, *Theragra*

INTRODUCTION

Investigations of food habits of marine animals almost invariably involve analysis of stomach contents. Successful stomach contents analysis usually requires that prey items be recognized by characteristic fragments. In this respect the sagittal otoliths of bony fishes are very useful (Fitch and Brownell, 1968; Pinkas *et al.*, 1971; Divoky, 1976; Frost and Lowry, 1980). Otoliths of each species of fish have characteristic shapes and features and given adequate comparative material or appropriate keys, identification to species can usually be done provided that the otoliths are not broken or badly digested. The fact that otoliths persist in the stomach, intestines, or feces after soft parts and bones have disappeared increases their utility.

In this paper is presented an illustrated key supplemented by descriptions of otoliths of fishes of the family Gadidae of the Bering, Chukchi, and Beaufort seas. Through numerous studies of food habits and trophic interactions of marine vertebrate consumers in Alaska their importance has become increasingly apparent. Three species in particular, walleye pollock (*Theragra chalcogramma*), saffron cod (*Eleginus gracilis*), and arctic cod (*Boreogadus saida*) are widespread and locally abundant, are major secondary consumers, and are important prey of numerous other species (Klumov, 1937; Andriyashev, 1954; Tomilin, 1957; Frost and Lowry, 1981; Hunt *et al.*, in press; Lowry and Frost, in press). Morrow (1979) published preliminary keys to otoliths of 16 families of fishes found in Alaskan waters including the Gadidae; however, those keys did not include descriptive reports. I have found in my own work with otoliths, particularly those recovered from the digestive tracts of predators, that keys without supporting descriptions are not always adequate for distinguishing similar species. This is particularly true when the surface morphology of an otolith changes with size or when certain features vary such that an otolith of one species closely resembles that of other species. Further, keys are often used by readers who have little familiarity with otoliths and limited access to comparative material, and who therefore require more detailed descriptive material. The comparative descriptive material included with this key should permit more reliable identifications.

METHODS

Samples of fishes were obtained by otter trawling in the Bering, Chukchi, and Beaufort seas. Soon after capture all fishes were identified, weighed to the nearest 0.1 g, and measured to the nearest mm (fork length). The sagittal otoliths were removed, their length and width measured to the nearest 0.1 mm with vernier calipers, and the otoliths stored in 95% alcohol. In the laboratory, otoliths were examined macroscopically and with the aid of a variable magnification dissecting microscope. The key is based on examination of 109 pollock (6-57 cm in length), 104 saffron cod (6-29 cm), 118 arctic cod (5-21 cm), 44 Pacific cod, *Gadus macrocephalus* (13-55 cm), eight Pacific tomcod, *Microgadus proximus* (18-24 cm) and a single whole polar cod (*Arctogadus* spp.) in addition to 24 undigested polar cod otoliths from seal stomachs.

OTOLITH KEY

Several specialized terms are necessary to describe morphological features of the surface of otoliths. Figure 1 diagrams a generalized otolith showing the surface features discussed in the following key and otolith descriptions.

In general, gadid otoliths have no true exisura (opening of the sulcus on the margin) although shallow anterior or

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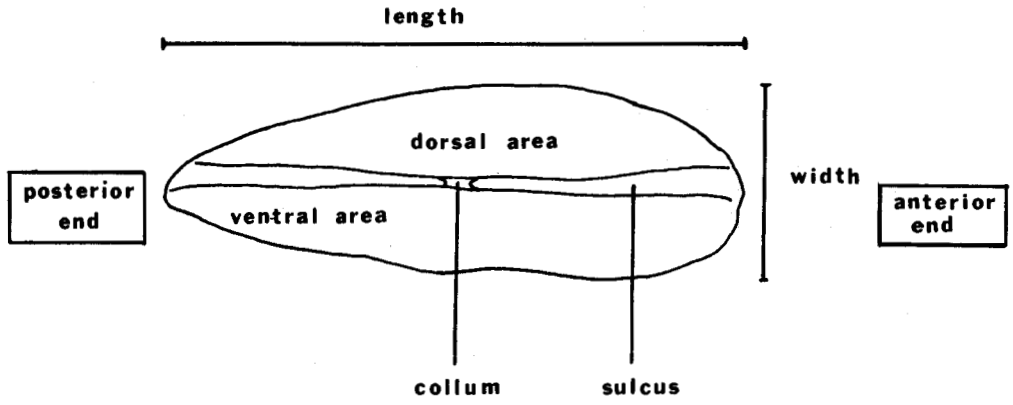

FIG. 1. Diagram of the medial surface of a generalized gadid otolith showing major features and measurements.

posterior notches are sometimes present. The sulcus is shallow and poorly defined, constricted at approximately the midpoint of its length, and broad at each end. Otolith length is twice or nearly twice its width. Otolith width is usually greatest at the anterior end. Otoliths taper at both ends but more so posteriorly. Lobular margins may be present at all ages. (See also Morrow, 1979).

1a) Lateral surface (side opposite the sulcus) distinctly concave 2

1b) Lateral surface flat or almost flat 3

2a) Otolith width less than 44% of otolith length, usually less than 40%. Lobulations on ventral margin not extending up to the longitudinal midline.
Theragra chalcogramma
(Walleye pollock)

2b) Otolith width usually greater than 44% of otolith length. Lobulations on ventral margin extend up to midline forming a thickened lower half of the otolith.
Gadus macrocephalus
(Pacific cod)

3a) Margin distinctly lobular. Lateral surface with elevated bumps. Anterior margin without notches 4

3b) Margins less distinctly lobular; if lobulated, dorsal margin only. Lateral surface without elevated bumps. Anterior margin notched once or twice, rarely unnotched 5

4a) Posterodorsal margin with a slightly concave "shelf," forms angle of 25°-30° with long axis. Dorsal portion thin without well-developed sculpturing. (See description of otoliths for further comments on *Microgadus* and *Eleginus*.) *Microgadus proximus*
(Pacific tomcod)

4b) Posterodorsal margin forms angle of about 20° with long axis, generally without a defined shelf, but when shelf is present it is usually flat or convex. Dorsal margin usually somewhat thickened with well-defined and somewhat swollen lobulations. (See description of otoliths for this species.)
Eleginus gracilis
(Saffron cod)

5a) Otolith width usually less than 47% of otolith length. In otoliths less than 4.0 mm long, width is sometimes 50% of length. Anterior end with one, rarely two or no notches. Posterior end tapered and thickened.
Boreogadus saida
(Arctic cod)

5b) Otolith width usually 50% or more of otolith length. Anterior end with one, sometimes two or no notches, generally flattened. Posterior end broadly rounded to somewhat pointed. *Arctogadus* spp.
(Polar cod)

DESCRIPTION OF OTOLITHS

Theragra chalcogramma (Fig. 2)

The lateral surface is quite concave and lobulations are distinct around the entire perimeter of the otolith. The posteroventral lateral surface (more pointed end of otolith) has a definite lateral twist, most pronounced in large otoliths, but also present in small ones. The posterodorsal margin forms an angle of about 45° with the longitudinal axis. There is a somewhat thickened ridge down the center of most otoliths with no elevated bumps on this ridge. The width of otoliths is less than 44% of length, usually less than 40%. Length of otolith reaches at least 22 mm. When compared to *Gadus macrocephalus*, the lateral surface in *Theragra* is generally more dished, somewhat less thickened, and the central ridge when present is more pronounced. The otolith is less rectangular and the ends are more pointed and narrower. Some overlap in length-to-width ratios does occur, especially in the 8- to 13-mm length range, but only in a very small percentage of all otoliths examined. When overlap occurs, the angle of the posterodorsal (more pointed) margin is the best differentiating character. When compared to *Eleginus graci-*

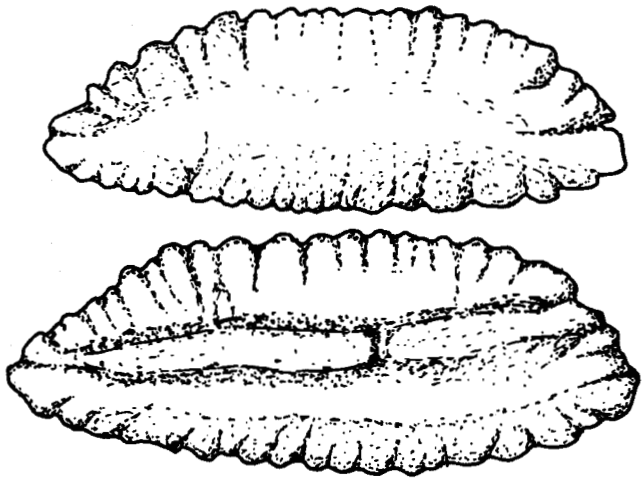

FIG. 2. Drawing of sagittal otoliths of *Theragra chalcogramma* — walleye pollock. Top: Lateral surface of right otolith 9.6 mm long. Bottom: Medial surface of left otolith 11.4 mm long.

lis, *Theragra* otoliths larger than 7 mm are distinct, whereas those 5-7 mm in length appear more similar. Lateral curvature in *Theragra* is sometimes hard to see, but is most evident when the otolith is held with the ventral surface up. *Eleginus* in this view is straight; the ventral lobulations are distinct and sometimes exaggerated.

Gadus macrocephalus (Fig. 3)

The medial surface is convex; the lateral surface is concave. Lobulations are present and well defined around the entire margin. The otolith is quite thick, especially the ventral half. Otolith width is usually greater than 44% of length. General appearance is almost rectangular. The posterodorsal (most pointed) margin forms an angle of about 60° with the longitudinal axis. *Gadus* otoliths can be differentiated from *Eleginus* by the concave lateral surface and from *Theragra* by the greater width and by the angle of the posterodorsal margin. The possibility exists for confusion of some of the narrow *Gadus* otoliths with wide *Theragra* otoliths.

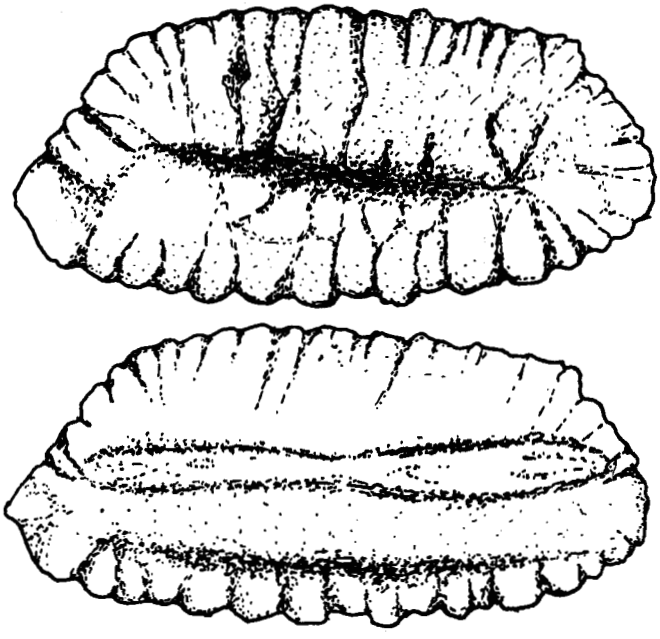

FIG. 3. Drawing of sagittal otoliths of *Gadus macrocephalus* — Pacific cod. Top: Lateral surface of right otolith 13.2 mm long. Bottom: Medial surface of left otolith 13.3 mm long.

Eleginus gracilis (Fig. 4)

The medial surface is somewhat convex; the lateral surface is straight below the midline and straight or slightly concave above. The bottom half of the otolith is thickened, lobulations are distinct, and elevated bumps are present on the lateral surface especially near the center. Dorsal lobulations are also distinct, may be somewhat thickened, and the grooves are well defined. Individual bumps are most distinct in small otoliths; later they appear as part of a general ventral thickening and raised lobulations. The anterior end is bluntly rounded in small otoliths. The anteroventral margin may be slightly pointed in larger ones. The posterior margin is tapered to a gradual point. Even when somewhat digested the lateral bumps and overall shape remain characteristic. *Eleginus* otoliths are quite readily distinguished from all other gadid otoliths, except those of *Microgadus proximus*. It is the author's opinion that the otoliths of these two species are easily confused, especially when they are small or if they have undergone digestive degeneration. The posterodorsal, slightly concave shelf characteristic of *Microgadus* is sometimes also present in *Eleginus*. The angle of the posterodorsal margin used by Morrow (1979) to differentiate these species appears to be quite variable. For the most part, however, their geographic distribution does not overlap. *Microgadus* is found from the Aleutian Islands and the Gulf of Alaska south to California (rarely in southern Bering Sea) whereas *Eleginus* is found from the Gulf of Alaska and the Aleutian Islands north to arctic Alaska (Wilimovsky, 1958; Quast and Hall, 1972).

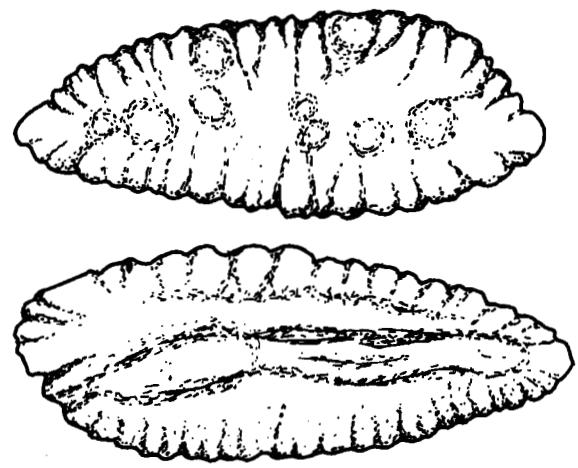

FIG. 4. Drawing of sagittal otoliths of *Eleginus gracilis* — saffron cod. Top: Lateral surface of right otolith 10.5 mm long. Bottom: Medial surface of left otolith 10.8 mm long.

Microgadus proximus (Fig. 5)

The medial surface is somewhat convex; the lateral surface is straight. The bottom half of the otolith is thickened, lobulations are distinct, and elevated bumps are

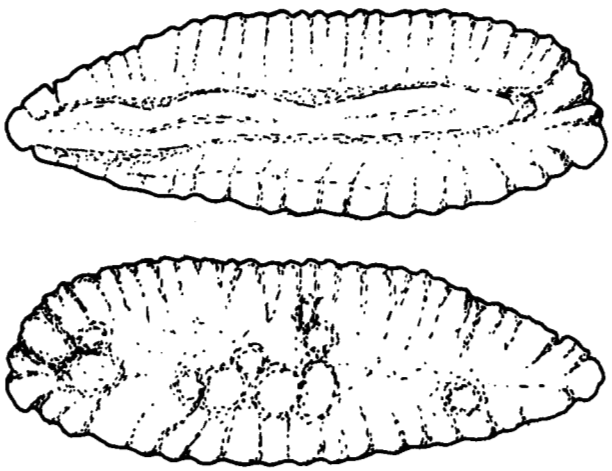

FIG. 5. Drawing of sagittal otolith of *Microgadus proximus* — Pacific tomcod. Top: Lateral surface of left otolith 11.6 mm long. Bottom: Medial surface of same otolith.

present on the lateral surface, especially on the ventral half. The anterior end is bluntly rounded, with a slight corner or point on the anteroventral margin. The posterior margin is tapered to a gradual point. The posterodorsal margin is flattened or slightly concave, forming a shelf of sorts. These otoliths are very difficult to distinguish from *Eleginus gracilis*. In some instances the posteroventral margin of *Eleginus*, when viewed from the ventral surface, is slightly twisted toward the lateral surface. The ventral surface of *Microgadus* is very straight. The dorsal portion of *Microgadus* otoliths is usually quite thin. Dorsal lobulations are not thickened and associated grooves are shallow and generally less distinct than those in *Eleginus*.

Boreogadus saida (Fig. 6)

Medial and lateral surfaces are straight or nearly so. Lobulations are present but are generally less distinct than

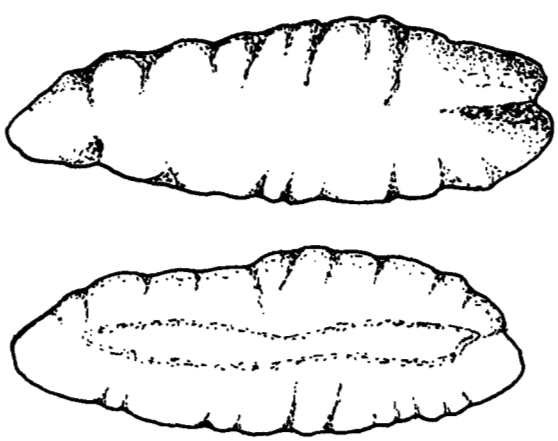

FIG. 6. Drawing of sagittal otoliths of *Boreogadus saida* — arctic cod. Top: Lateral surface of right otolith 8.2 mm long. Bottom: Medial surface of left otolith 7.7 mm long.

in *Theragra* or *Eleginus*. They are usually not continuous around the entire margin. There are no medio-lateral bumps. The anterior (deepest) end is almost always notched, with the ventral lobe the largest. This notch is not always visible in digested otoliths. The posterior end is thickened and lobulations are absent. This posterior thickening is evident even in digested specimens. A notch is sometimes also present in the posterior margin. The posteroventral

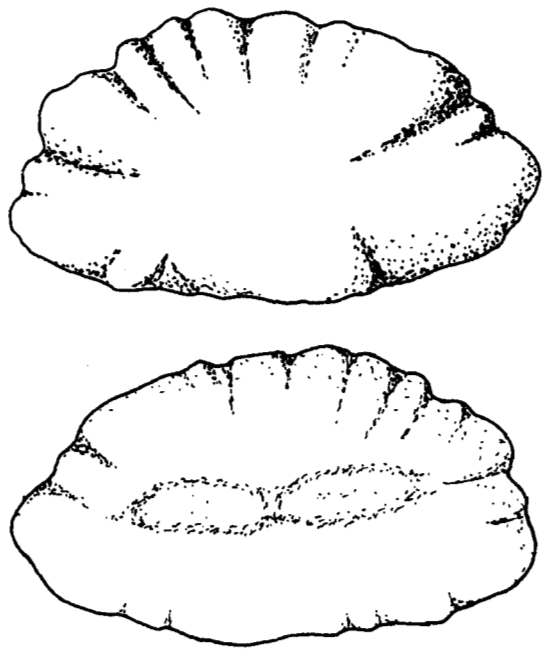

FIG. 7. Drawing of sagittal otolith of *Arctogadus* spp. — polar cod. Top: Lateral surface of left otolith 8.9 mm long. Bottom: Medial surface of same otolith.

(thickened) end twists slightly up and out. In a digested state, *Boreogadus* otoliths can be distinguished from *Eleginus* by the notched anterior end, thickened posterior end, and overall smooth appearance.

Arctogadus spp. (Fig. 7)

Lateral and medial surfaces are flat or nearly so. Lobulations are present as in *Boreogadus*. The anterior end has one, sometimes two or no notches. The dorsal notch is the deepest and most defined. The posterior margin is round to squarish. The width of the otolith is at least 44% and usually 50% or more of the otolith length. *Arctogadus* otoliths look similar to those of *Boreogadus* but can usually be distinguished by proportionately greater widths.

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