A Guide to the Use of Otoliths in the Study of Predators at South Georgia

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Natural Environment Research Council

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Cover Photograph: Antarctic fur seal *Arctocephalus gazella* with a nototheniid fish, an illustration of the role of fish in the diet of higher predators at South Georgia. (Photo. T.S. McCann/BAS).

Contents

Introduction

The monitoring of the diet of higher predators in the marine environment is a crucial aspect of research in the Antarctic. In much of this work there is a requirement to identify fish species in highly digested remains which often depends on the use of fish otoliths. The characteristics of the otoliths of some fish species may vary geographically and the varying amounts of partial digestion act to compound this variability. Since the size of fish can be estimated from otolith size, using species specific regression equations, the correct identification of fish from their otoliths is essential. The aim of this guide is to describe the otoliths of fish species found in the diet of predators at Bird Island, South Georgia using specimen otoliths from fish caught in the vicinity of South Georgia, to minimise the effects of geographical variation, alongside otoliths recovered from predator samples, to illustrate the effects of partial digestion (the source of the otolith is shown in the header of the photograph). In addition, the regression equations provided to allow fish length and mass to be estimated from otolith length are taken, where possible, from fish caught in the vicinity of South Georgia.

Methods for the retrieval of otoliths

Otoliths are composed mainly of calcium carbonate and organic proteinaceous material and are relatively resistant to digestion, thus they are often found in regurgitate samples or pass into the faeces of predators. In some instances otoliths can be retrieved by simply by sieving samples in a continuos flow of water, however, where the supply of water is limited or with samples containing large amounts of krill exoskeletons sieving is not practicable (krill exoskeletons form a mat and clog the sieve). One of the easiest ways to retrieve otoliths in these situations is by suspending the sample in a solution of detergent (approx 1% of commercial concentrated detergent) and disinfectant (approx 1% of a commercial disinfectant) in a glass

beaker and gently disintegrating. The differential settling rates of components in the sample allows denser, objects such as otoliths, to settle out. The supernatant fluid can then be decanted, usually into a sorting tray, and the beaker topped up with the solution. This process of gentle agitation, partial decanting and re-suspension is continued until no further remains passed over into the sorting tray. The residue in the beaker is then poured into a petri dish and sorted under a binocular microscope (x6). The use of a petri-dish with a black base and illuminating from an oblique angle makes otoliths easier to see. Once the otoliths have been retrieved they are cleaned as much as possible and stored dry, (medial sculpturing is usually easier to see when the otolith is dry).

The Identification of otoliths.

There are three otoliths on either side of the neuro-cranium of teleost fish, in most cases the sagittal otolith is the largest and has species specific features that can be used to identify fish species (reference to 'otoliths' is assumed to refer to the sagittal otolith). Generally the inner (medial) surface of the otolith has well developed sculpturing, whereas the outer (lateral) face is usually smooth. The identification of otoliths is usually based on a combination of the geometric shape and the pattern of sculpturing on the medial surface. As a general rule geometric shape is most useful in identifying otoliths to family level while the medial sculpturing is more important at the species level.

The first step in identifying otoliths is to group them into families, and in general the main families found in the diets of predators at South Georgia have distinctive otoliths. The three main families are the Myctophidae (the myctophids or lantern fish), the Nototheniidae (the notothens or Antarctic cod) and the Channichthyidae (the icefish). Characteristics of otolith structure that are useful for identification are shown in Fig. 1. for further discussion on the

terminology used to describe the characteristics of otoliths see Hecht (1987). The general characteristics of the otoliths of these three families are shown in Fig. 2. In view of the large foraging range of predators at South Georgia, especially albatrosses, it is recommended that this guide is used in conjunction with material covering otoliths from a wider range of species covering a wider geographical area (e.g. Hecht 1987, Williams & McEldowney 1990, Smale et al. 1995). Additional useful information on geographical and vertical distribution as well descriptions of the fish species can be found in Gon & Heemstra (1990).

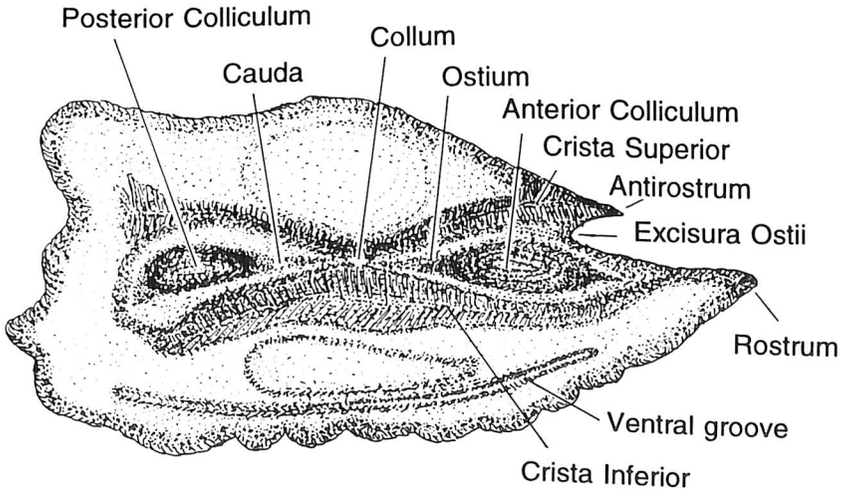

Figure 1. Terminology used in the descriptions of otoliths (after Hecht 1987).

Myctophidae - Generally oval or discoid, thin with little medial relief. Often have noticeable pseudo-colliculum below cauda (appears as small ridge below cauda).

Nototheniidae - Ovoid shape (often half-pear like), usually with distinct rostrum and well defined medial relief.

Channichthyidae - Discoid or square, ventral portion distinctly thicker than dorsal portion. Postero-anteriorly symmetrical.

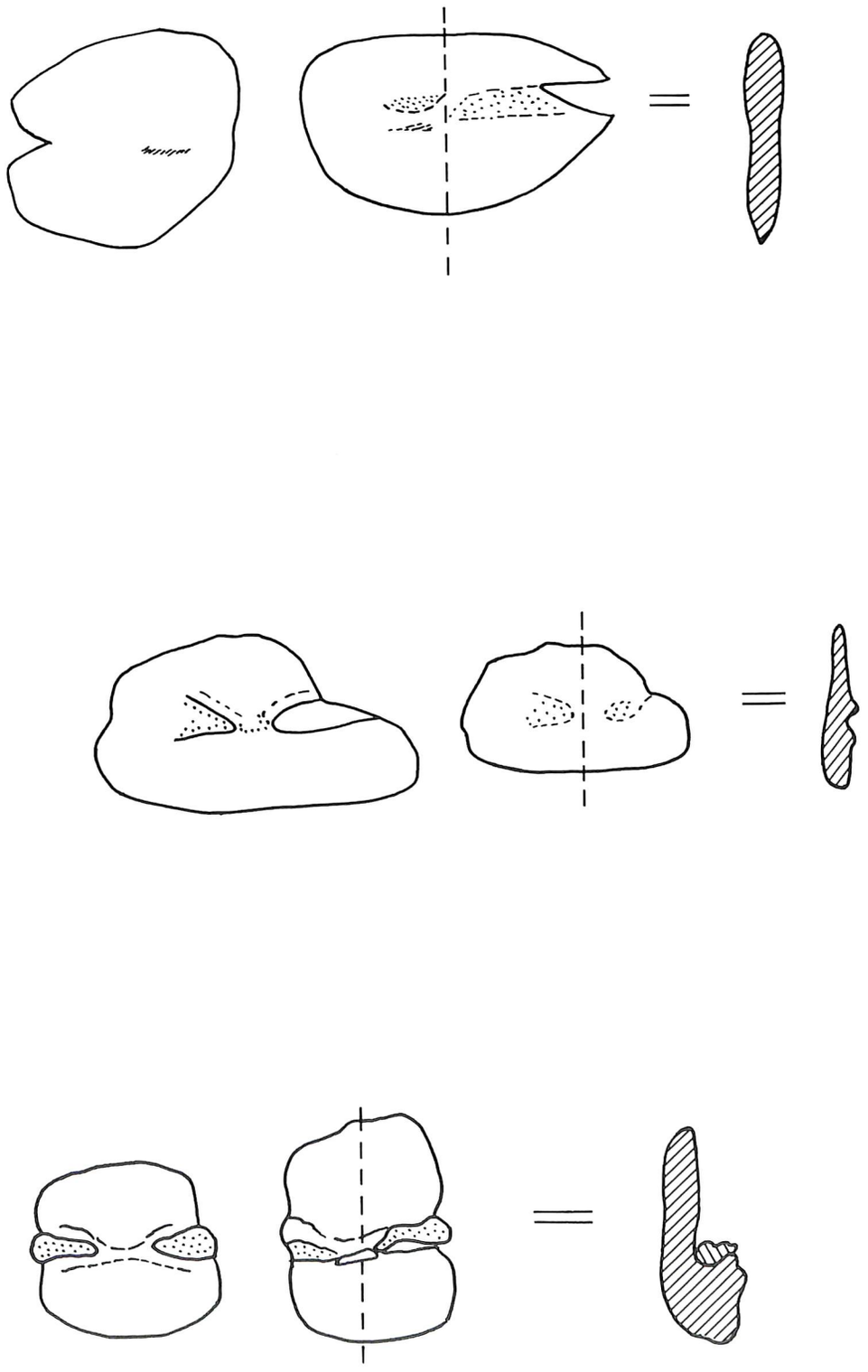

Figure 2. Otoliths showing the characteristics of the three most important fish families.

Species Catalogue

Petromyzontidae - Lampreys

Geotria australis - (not illustrated) This species does not have otoliths, but the distinctive eel-like skeletal structure and the unusually shaped cranium and mouth-parts make it readily identifiable (Ivano-Berg 1968, Gon and Heemtstra 1990). Lampreys are a characteristic part of the diet of grey-headed and, to a lesser extent, black-browed albatrosses (Potter et al. 1979, Prince 1980, Reid et al. 1996).

Rajidae - Skates

Raja georgiana -The dorsal spines of this species (which does not have otoliths) are distinctive, only recorded from a single occurrence in diet of fur seals (Reid 1995)

Paralepididae - Barracudinas

Notolepis coatsi - The ventral portion of this otolith is distinctly larger than central dorsal section and the medial relief is poorly defined. This species occurs in the diet of penguins, usually associated myctophids (Olsson and North 1996, BAS unpublished data).

TL = 187.82 OL - 151.31 $r^2 = 0.868$ $n = 15$
M = 6.19 lgOL - 0.80 $r^2 = 0.980$ $n = 15$ (4)

Magnisudis prionosa - very distinctive otolith, unlikely to be confused, ventral portion much larger than dorsal portion with prominent, well-separated colliculi, found in diet of albatrosses (Reid et al. 1996). No relationships available.

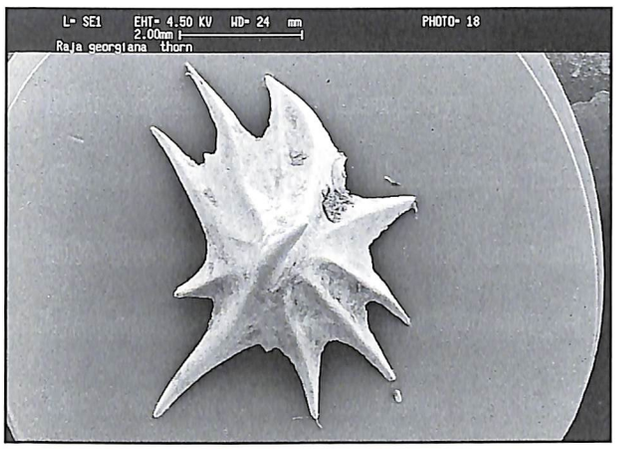

Plate 1. *Raja georgiana* (dorsal spine)

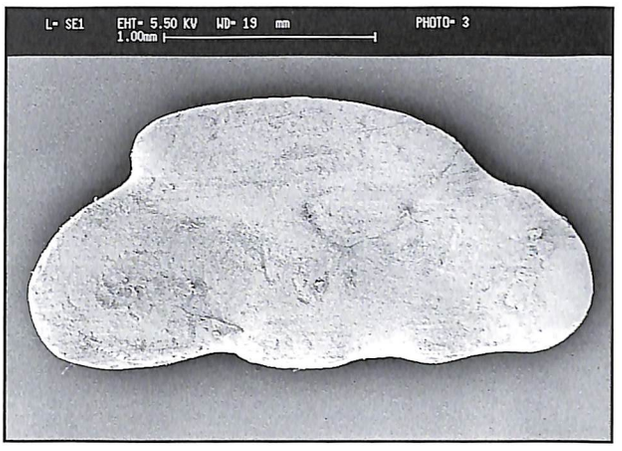

Plate 2. *Notolepis coatsi* (eroded)

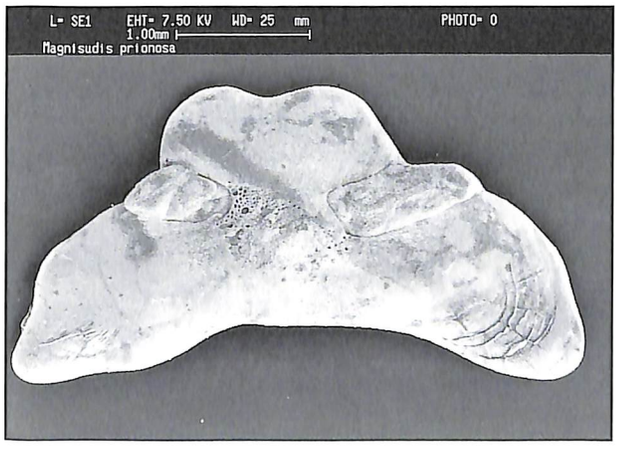

Plate 3. *Magnisudis prionosa* (eroded)

Plate 4. Anotopterus pharao (eroded)

Anotopteridae - Daggertooths

Anotopterus pharao - This square otolith has very little medial relief or sculpturing of the margins, the most distinctive features are the very prominent colliculi. Has occurred in a single sample from grey-headed albatross (Reid et al. 1996). No relationships available.

Myctophidae - Lanternfish

Electrona antarctica - A 'comma' shaped otolith with generally smooth margins, a generally flat medial surface and a convex lateral face which has distinctive concentric circles rising to central point. Occurs in the diet of Antarctic fur seal (Reid and Arnould 1996), king penguins (Olsson and North 1996), gentoo and macaroni penguin (Croxall et al. in press), black-browed and grey-headed albatrosses (Reid et al. 1996) and white-chinned petrel (Croxall et al. 1995).

$SL = 42.96686 OL + 0.278033$ $r^2 = 0.984$ $n = 86$ (SL range 20-96 mm)
$M = 9.53 \times 10^{-6} SL^{3.08}$ $r^2 = 0.976$ $n = 227$ (1)

E. carlsbergi - A fairly large, thin, distinctively discoid otolith with small excisura ostii. Occurs mainly in the diet of king penguins (Olsson and North 1996) and Antarctic fur seal (Reid and Arnould 1996).

$SL = (OL - 0.254)/0.042$ $r^2 = 0.91$ $n = 90$
$M = 7.43 \times 10^{-6} SL^{3.159}$ $r^2 = 0.90$ $n = 60$ (2)

E. subaspera - (not illustrated) This otolith is very similar to *E. carlsbergi* except: 1. it has notch in posterior margin, 2. the central line of excisura ostii is level with crista superior and not the centre of the ostium as in *E .carlsbergi.* Uncommon in the diet of Antarctic fur seal (Reid and Arnould 1996).

$SL = 29.0 OL - 9.04$ $r^2 = 0.98$ $n = 17$
$M = 7.98 \times 10^{-6} SL^{3.19}$ $r^2 = 0.98$ $n = 21$ (1)

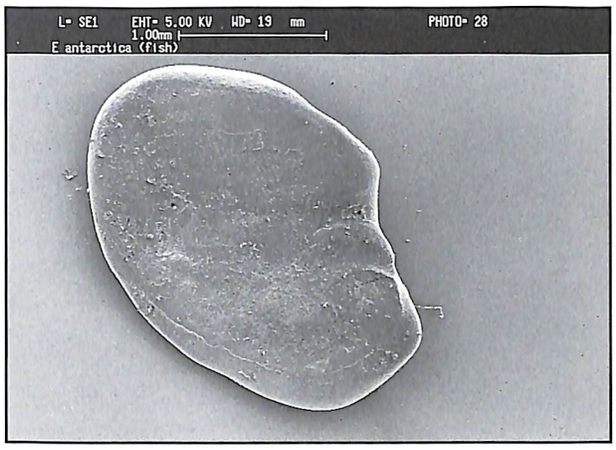

Plate 5. *Electrona antarctica* (fish)

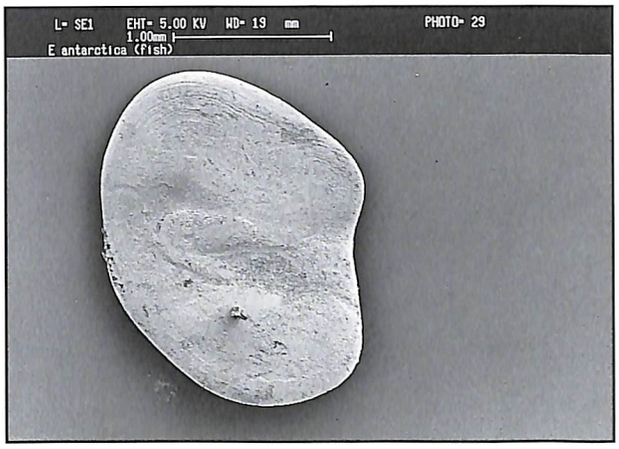

Plate 6. *Electrona antarctica* (eroded)

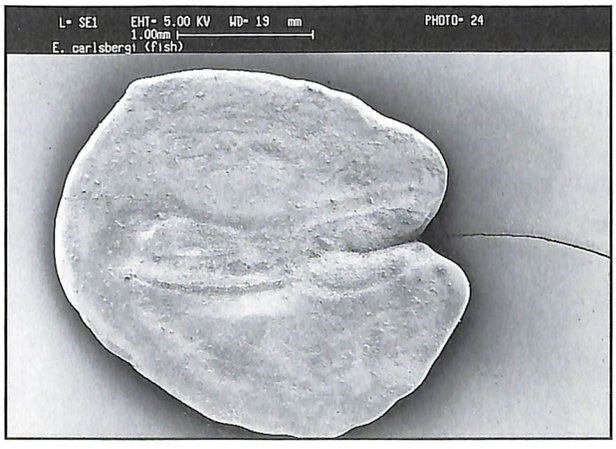

Plate 7. *Electrona carlsbergi* (fish)

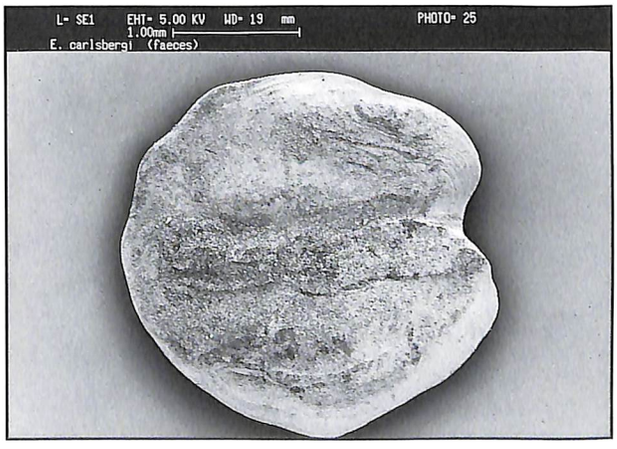

Plate 8. *Electrona calsbergi* (eroded)

Gymnoscopelus bolini - The otolith shown is from a fish of SL 270 mm, considerably larger than attained by other myctophids with similar otoliths (*G. nicholsi* and *G. fraseri*). The serrated ventral margin is not present in fish up to 64 mm SL (Williams and McEldowney 1990) making separation from *G. fraseri* apparently impossible, although the dorsal margin appears more rounded in *G. bolini*. Larger otoliths, with the serrated ventral margin, can be separated from *G. nicholsi* by their size and the notch in the dorsal margin. Has occurred in the diet of black-browed albatross (Reid et al. 1996).

$SL = 33.2\ OL - 18.3$ $\quad r^2 = 0.98 \quad n = 10$ (1 & M.G. White unpublished data)

G. braueri - The open angle of excisura ostii and dorso-ventrally rectangular shape distinguish this species. Recorded in small numbers in the diets of white-chinned petrel (Croxall et al. 1995) and Antarctic fur seal (Reid and Arnould 1996).

$SL = 44.84\ OL^{0.85}$ $\quad r^2 = 0.94 \quad n = 10$
$M = 4.59 \times 10^{-5}\ SL^{3.68}$ $\quad r^2 = 0.96 \quad n = 9$ (3)

G. nicholsi - This distinctive otolith, is distinguished by its size, 'oval' shape, deep narrow excisura ostii and serrated ventral margin. It is commonly found in the diet of Antarctic fur seal (Reid and Arnould 1996), King Penguin (Olsson and North 1996) and white-chinned petrel (Croxall et al. 1995).

$SL = -20.63 + 34.991\ OL$ $\quad r^2 = 0.75 \quad n = 12$ (SL range 126-188mm)
$\lg M = 0.3419 + 0.34039\ OL$ $\quad r^2 = 0.91 \quad n = 12$ (4)

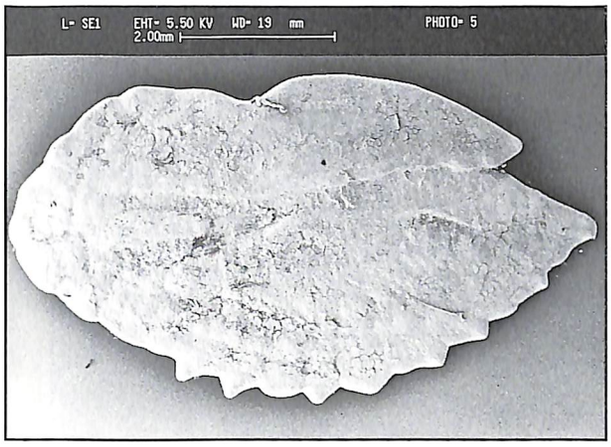

Plate 9. *Gymnoscopelus bolini* (eroded)

Plate 10. *Gymnoscopelus braueri* (fish)

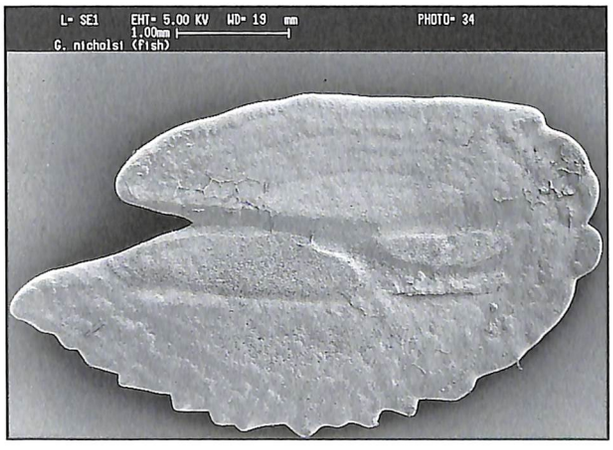

Plate 11. *Gymnoscopelus nicholsi* (fish)

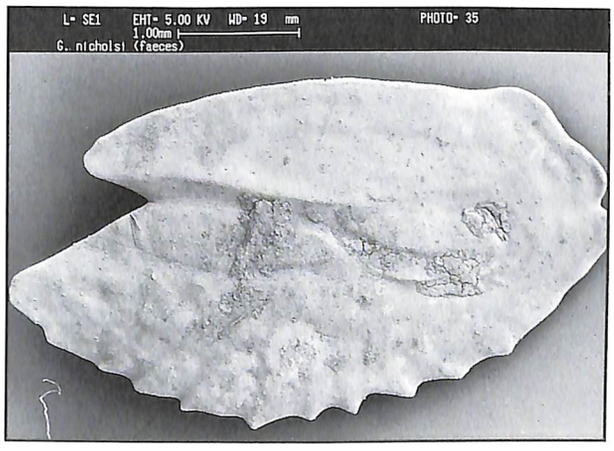

Plate 12. *Gymnoscopelus nicholsi* (eroded)

G. fraseri - Although similar to *G. nicholsi* this otolith is generally dorsally 'squarer' and lacks serrations on ventral margin. However, eroded examples of *G. nicholsi* may also lack serrations and separation of eroded *Gymnoscopelus* otoliths is sometimes not possible. Found, usually along with other myctophid species, in the diet of Antarctic fur seal (Reid and Arnould 1996), grey-headed albatross (Reid et al. 1996) and Antarctic prion (Reid et al. in press).

$SL = 21.845\ OL + 1.73$ $\quad r^2 = 0.895 \quad n = 17$ (SL range 57-84 mm)
$M = 7.29 \times 10^{-6}\ SL^{3.101}$ $\quad r^2 = 0.946 \quad n = 17$ (1)

Krefftichthys anderssoni - The dorsal margin of this small, square otolith has a characteristic slope toward the excisura ostii. It is often found in the diet of king penguins (Olsson and North 1996), Antarctic fur seal (Reid and Arnould 1996) and macaroni penguin (Croxall et al. in press).

$TL = -17.627\ OL + 58.108$ $\quad r^2 = 0.88 \quad n = 76$ (TL range 36-83 mm)
$LgM = -1.65 + 1.356\ OL$ $\quad r^2 = 0.79 \quad n = 72$ (4)

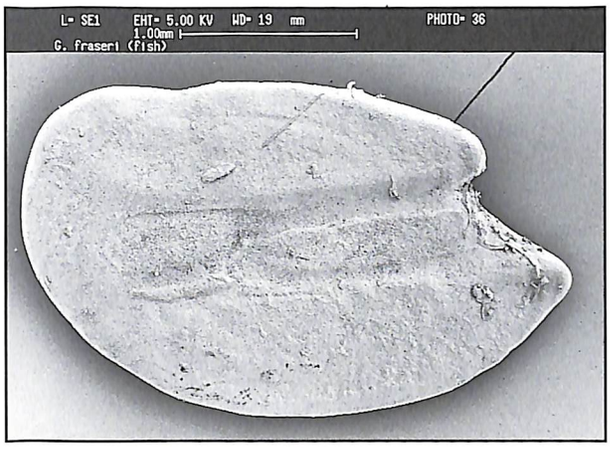

Plate 13. *Gymnoscopelus fraseri* (fish)

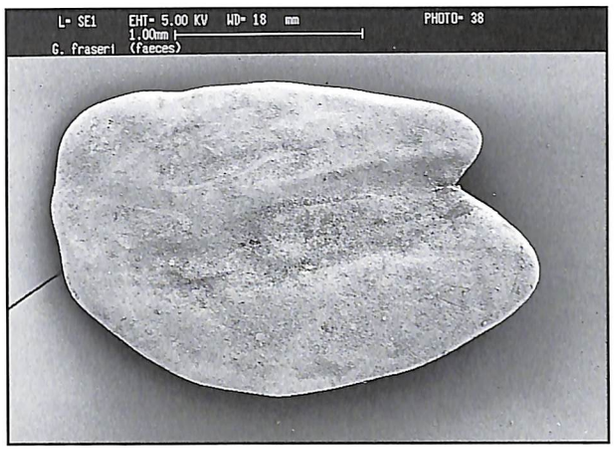

Plate 14. *Gymnoscopelus fraseri* (eroded)

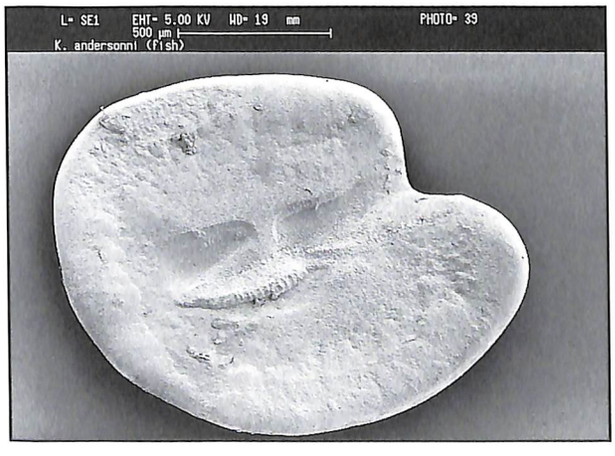

Plate 15. *Krefftichthys anderssoni* (fish)

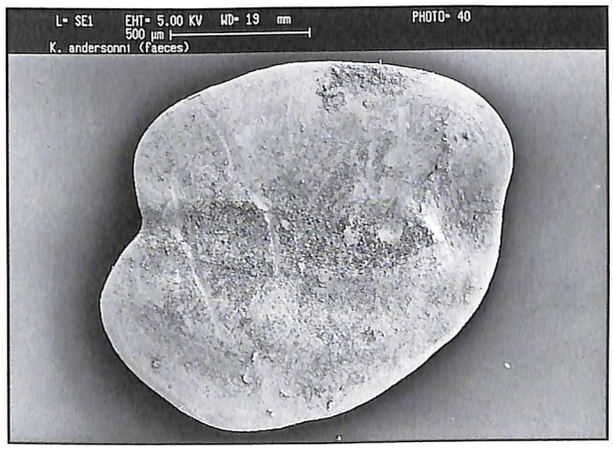

Plate 16. *Krefftichthys anderssoni* (eroded)

Protomyctophum bolini - The otoliths of this species are similar to *E. antarctica* but have a less uniform 'comma' shape and typically show a notch in the posterior margin, opposite the excisura ostii, which combine to make the dorsal and ventral portions distinct. Common. although never numerous, in the diets of grey-headed albatross (Reid et al. 1996), white-chinned petrel (Croxall et al. 1995) and Antarctic fur seal (Reid and Arnould 1996).

TL = -7.767 + 39.323 OL $r^2 = 0.75$ $n = 51$ (TL range 46-63 mm)
LgM = -0.9558 + 0.6653 OL $r^2 = 0.66$ $n = 51$ (4)

P. choriodon - This otolith is rather flat dorsally with a more rounded ventral margin, the rostrum and antirostrum are usually about same length. Separation of this species from *P. normani* appears to be very difficult by comparison with image in Smale et al. (1995). This is the most numerous myctophid in the diet of Antarctic fur seal (Reid and Arnould 1996) , and king penguins (Olsson and North 1996).

TL = -21.95 + 53.753 OL $r^2 = 0.80$ $n = 16$ (TL range 64-90 mm)
LgM = -1.3849 + 1.01631 OL $r^2 = 0.98$ $n = 6$ (4)

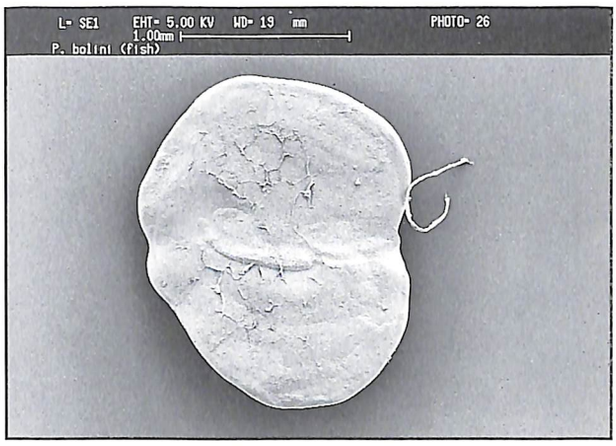

Plate 17. *Protomyctophum bolini* (fish)

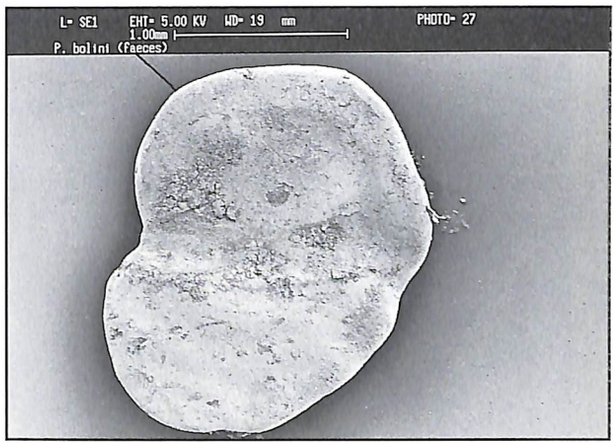

Plate 18.*Protomyctophum bolini* (eroded)

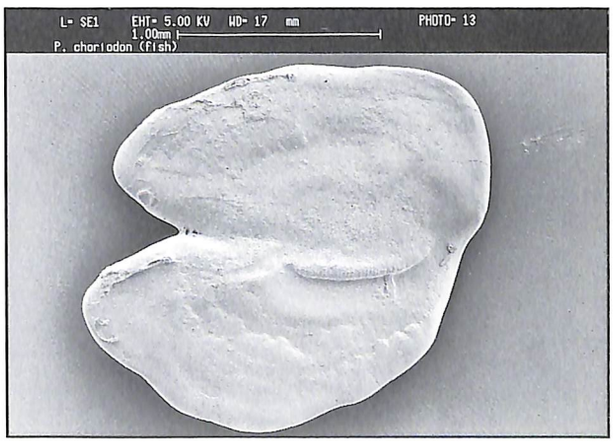

Plate 19. *Protomyctophum choriodon* (fish)

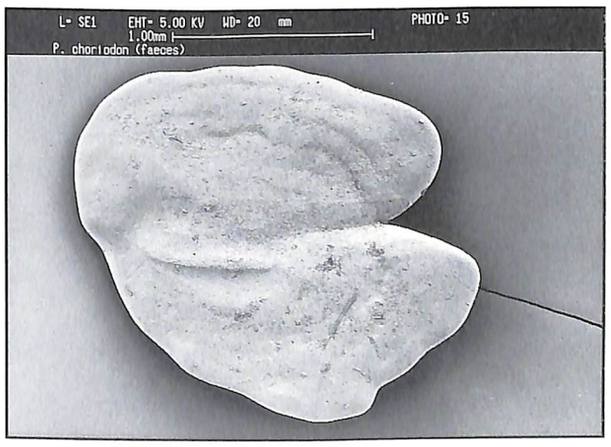

Plate 20. *Protomyctophum choriodon* (eroded)

P. tenisoni - Although similar to *G. braueri* in overall shape this otolith has a more distinct pseudo-rostrum and excisura ostii, as well as a notch in the posterior margin. Rare in the diet of Antarctic fur seal (Reid and Arnould 1996).

$SL = (OL - 0.416)/0.022$ $r^2 = 0.88$ $n = 27$
$M = 5.36 \times 10^{-6} SL^{3.082}$ $r^2 = 0.90$ $n = 16$ (2*)

Muraenolepididae - Eel Cods

Muraenolepis microps - This otolith is generally thin and has very little medial sculpturing. The ostium and cauda form a central groove with distinctive spot formed by collum which is particularly distinctive in eroded specimens. Occurs in the diet of Antarctic fur seal (Reid 1995, Reid and Arnould 1996) , wandering albatross (Croxall et al. 1988), grey-headed albatross (Reid et al. 1996) and blue-eyed shag (BAS unpublished data).

$LgTL = 1.59 + 1.35\ lgOL$ $r^2 = 0.92$ $n = 43$
$LgM = -0.396 + 4.15\ LgOL$ $r^2 = 0.98$ $n = 43$ (5)

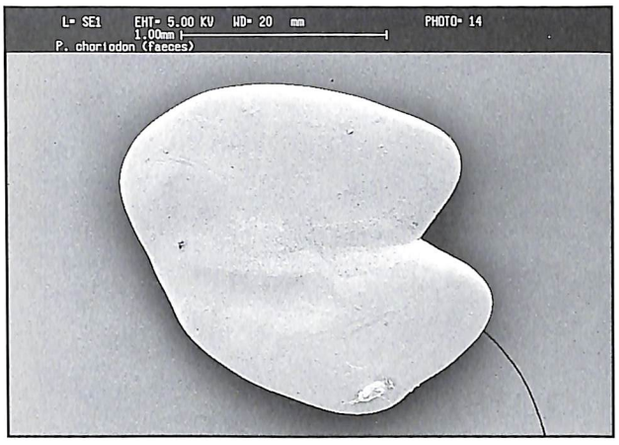

Plate 21. *Protomyctophum choriodon* (eroded)

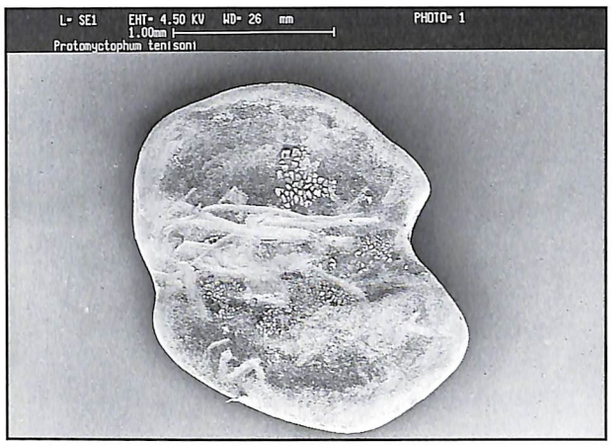

Plate 22. *Protomyctophum tenisoni* (eroded)

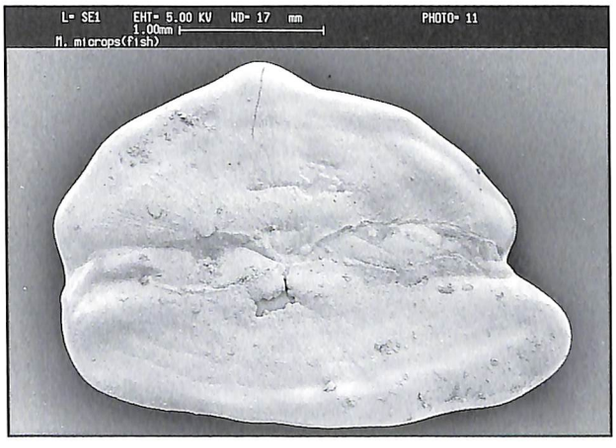

Plate 23. *Muraenolepis microps* (fish)

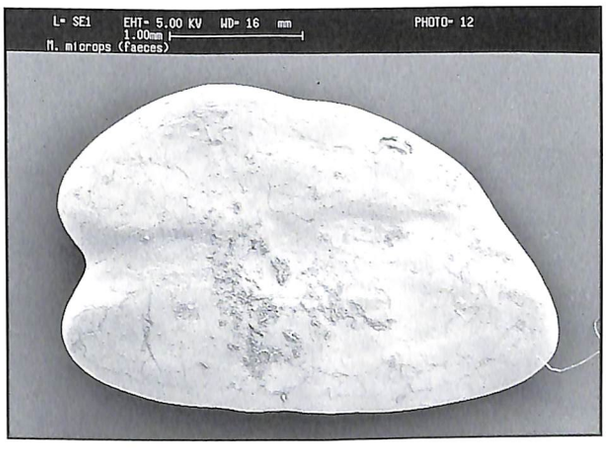

Plate 24. *Muraenolepis microps* (eroded)

Melamphaidae - Bigscale fishes

Sio nordenskjöldii - this rectangular shaped otolith has an irregular (and apparently variable) margin and very little medial sculpturing. The overall shape and the single, prominent anterior colliculi (the posterior colliculi is absent) are distinctive. Found in a single sample from grey-headed albatross (Reid et al. 1996)

TL = 49.6 +12.9 OL
Lg M = 0.265 OL - 0.087 (A.W. North unpublished data).

Nototheniidae - Antarctic cod

Dissostichus eleginoides - The high level of sculpturing and crenellations on margins and the deep sulcus acusticus with continuous crista superior distinguish this otolith. Only small fish are taken by land-based predators since this species attains up to 2 m TL, has been recorded in small numbers of the diet of Antarctic fur seal (Reid 1995).

SL = 73.863 OL -191.414 $r^2 = 0.839$ $n = 160$ (SL range 218-960 mm)
$M = 4.59 \times 10^{-6}\ SL^{3.187}$ r^2 0.970 $n = 159$ (1)

Gobionotothen gibberfrons - The otoliths of this species are highly variable, especially those from larger fish, however they generally have very distinct medial relief , in particular the crista superior above the ostium is very prominent. The dorsal margin is generally notched and rising to highest point just above, or anterior to, the collum. An important component on the diet of male Antarctic fur seal in winter (Reid 1995) and also found in the diet of wandering albatross (Croxall et al. 1988) and blue-eyed shag (BAS unpublished data).

LgTL = 1.39 + 1.28 LgOL $r^2 = 0.98$ $n = 60$
LgM = -1.28 + 4.30 LgOL $r^2 = 0.98$ $n = 59$ (5)

Plate 25. *Sio nordenskjöldii* (eroded)

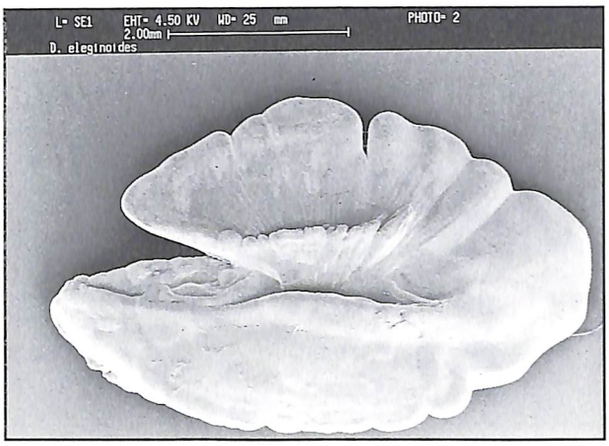

Plate 26. *Dissostichus eleginoides* (fish)

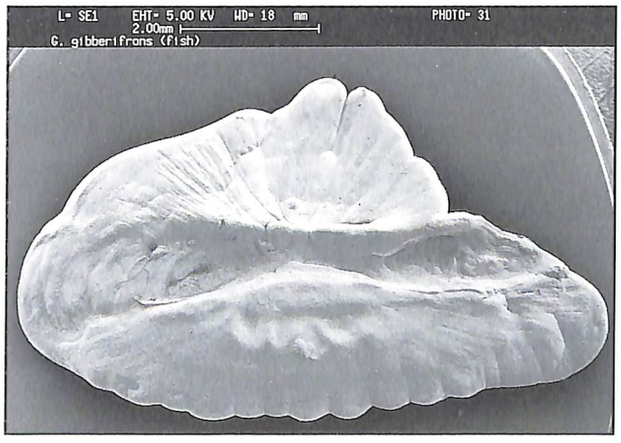

Plate 27. *Gobionotothen gibberifrons* (fish)

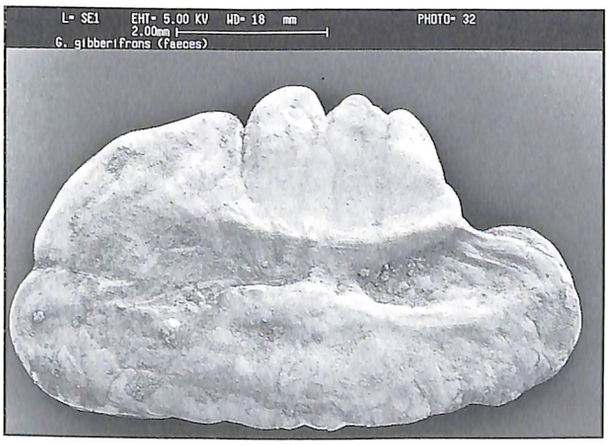

Plate 28. *Gobionotothen gibberifrons* (eroded)

G. marionensis - The large angle of the excisura ostii gives this otolith an antero-posteriorly symmetrical appearance, although the highest point on the dorsal margin in generally above the cauda. Occurs particularly in the diet of blue-eyed shag (BAS unpublished data) with small numbers in Antarctic fur seal (Reid 1995) and gentoo penguin (Croxall et al. in press).

$TL = 41.42\ OL^{0.768}$ $r^2 = 0.91$ $n = 22$
$M = 3.73 \times 10^{-6}\ SL^{3.16}$ $r^2 = 0.98$ $n = 24$ (3)

Lepidonotothen squamifrons - The long rounded rostrum and very prominent crista superior over the ostium, often protruding into the pseudo-rostrum, of this otolith are distinctive. Occurs in small numbers in the diet of Antarctic fur seal (Reid 1995).

$SL = 56.02584OL - 86.2886$ $r^2 = 0.906$ $n = 155$
$M = 1.1 \times 10^{-5}\ SL^{3.097}$ $r^2 = 0.992$ $n = 839$ (1)

L. larseni - Although somewhat variable this otoliths generally has a distinctive notch in postero-dorsal margin, except in very small specimens. The rostrum becomes relatively longer with size of otolith. Other similar species (such as *L. nudifrons* and *L. kempi*) are very difficult to separate from *L. larseni* when eroded and are often grouped simply as *L. larseni* agg. This species is an abundant component of the diet of Antarctic fur seal (Reid 1995, Reid and Arnould 1996) and gentoo penguin (Williams 1991).

$TL = 21.432 + 33.3971\ OL$ $r^2 = 0.97$ $n = 40$ (TL range 57-215mm)
$M = -0.41914 + 0.42581\ OL$ $r^2 = 0.96$ $n = 39$ (4)

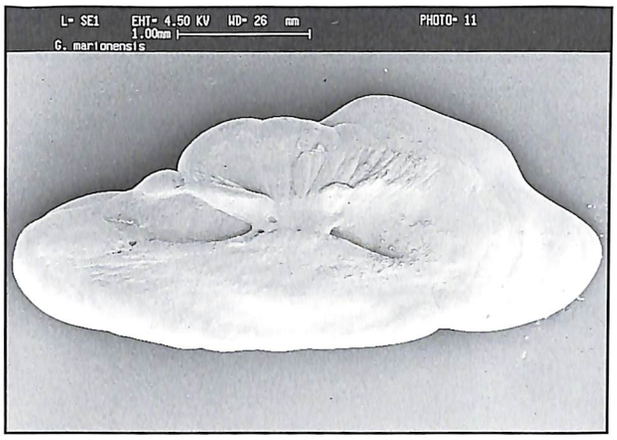

Plate 29. *Gobionotothen marionensis* (fish)

Plate 30. Lepidonotothen squamifrons (fish)

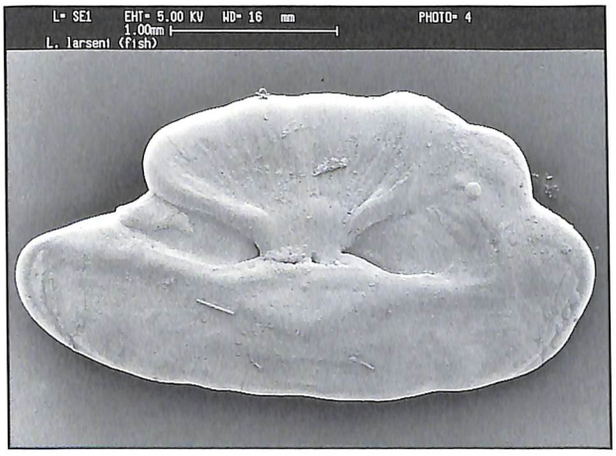

Plate 31. *Lepidonotothen larseni* (fish)

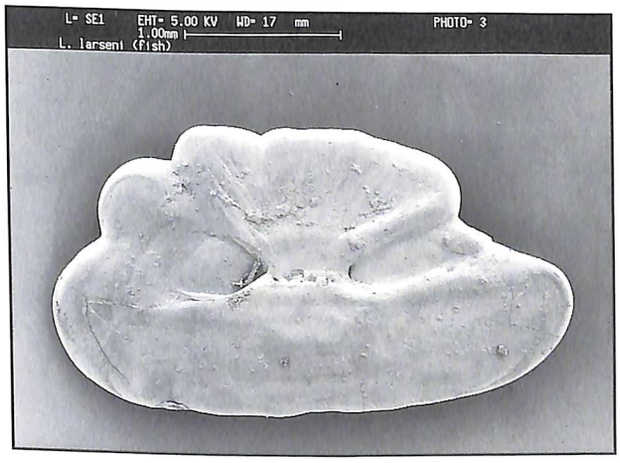

Plate 32. *Lepidonotothen larseni* (fish)

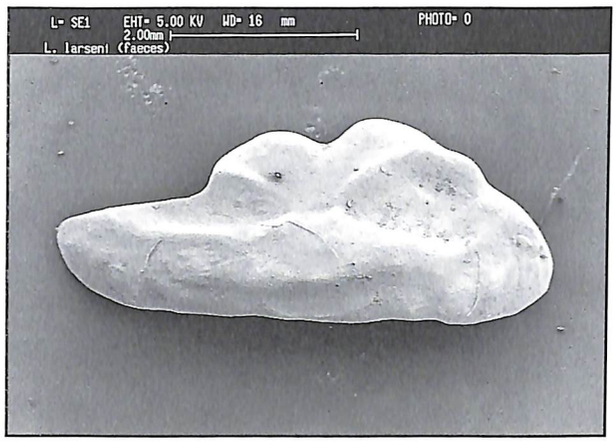

Plate 33. *Lepidonotothen larseni* (eroded)

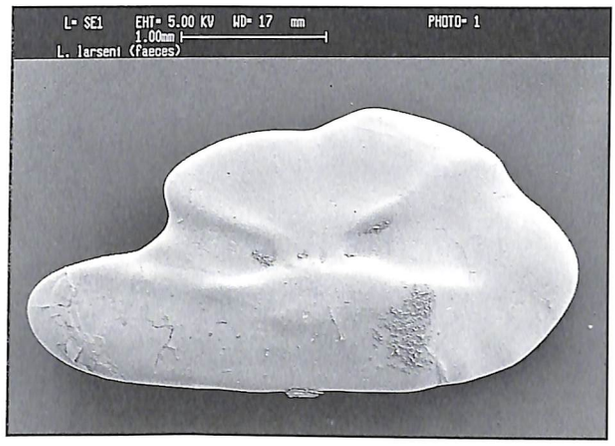

Plate 34. *Lepidonotothen larseni* (eroded)

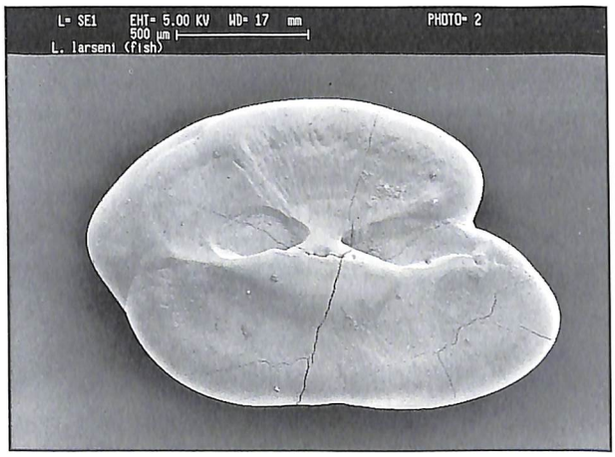

Plate 35. *Lepidonotothen larseni* (eroded)

Notothenia coriiceps -The otoliths of this species are similar to but generally more rounded than *G. gibberifrons* with more sinuate margins and with the cristae superior split over the collum. Occurs in the diet of Antarctic fur seal (Reid 1995) with smaller individuals in the diet of blue-eyed shag (BAS unpublished data).

$TL = 66.47\ OL^{1.181}$ $r^2 = 0.92$ $n = 66$
$M = 4.25\ OL^{3.549}$ $r^2 = 0.99$ $n = 28\ (3)$

Notothenia rossii - The highly crenellate margins, particularly the concave dorsal margin, are usually distinctive. The ostium and cauda are deep and pit like although the structure of the collum appears variable. Formerly a common component of the diet of range of species now found uncommonly in the diet of Antarctic fur seal (Reid 1995) and blue-eyed shag (BAS unpublished data).

$TL = 66.14\ OL^{1.20}$ $r^2 = 0.94$ $n = 34\ (3)$
$M = 4.25\ OL^{3.549}$ $r^2 = 0.97$ $n = 28\ (6)$

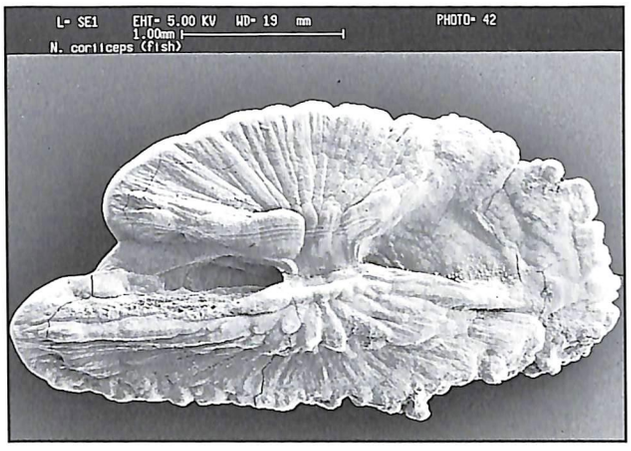

Plate 36. *Notothenia coriiceps* (fish)

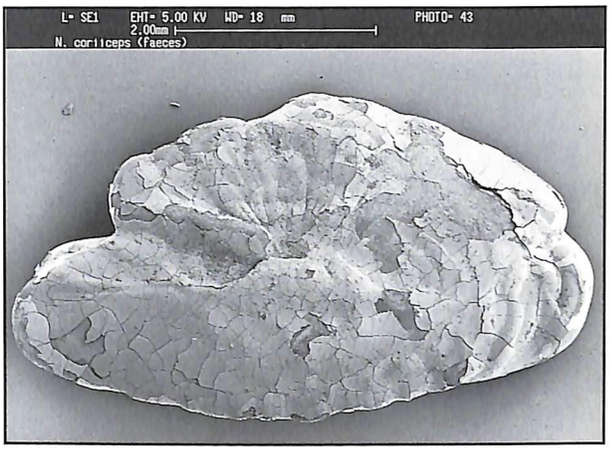

Plate 37. *Notothenia coriiceps* (eroded)

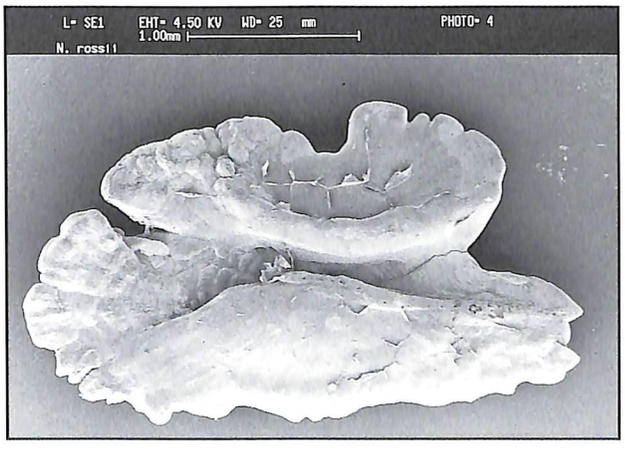

Plate 38. *Notothenia rossii* (fish)

Plate 39. *Notothenia rossii* (eroded)

Patagonotothen guntheri - This otolith is somewhat similar to *L. larseni* although generally lacks the postero-dorsal notch, has a more rounded posterior and the highest point on dorsal margin is usually above ostium. In smaller specimens there appears to be a notch in the dorsal margin that extends into the cauda. Occurred in the diet of black-browed and grey-headed albatrosses (Reid et al. 1996) and white-chinned petrel (Croxall et al. 1995) during 1986, probably taken in association with fishing operations.

Lg TL = 1.862 + 0.608 lg OL $r^2 = 0.67$ $n = 20$
M = 0.0044 $OL^{3.22}$ $r^2 = 0.99$ $n = 132$ (8)

Trematomus hansoni -The excisura ostii of this otolith is generally greater then 90° with a particularly high pseudo-rostrum. In addition the crista superior is indistinct or absent and the ostium and cauda are distinct and pit like. An uncommon component of the diet of Antarctic fur seal (Reid 1995).

LgTL = 1.7 + 1.01 LgOL $r^2 = 0.96$ $n = 32$
LgM = -0.228 + 3.54 LgOL $r^2 = 0.95$ $n = 32$ (5)

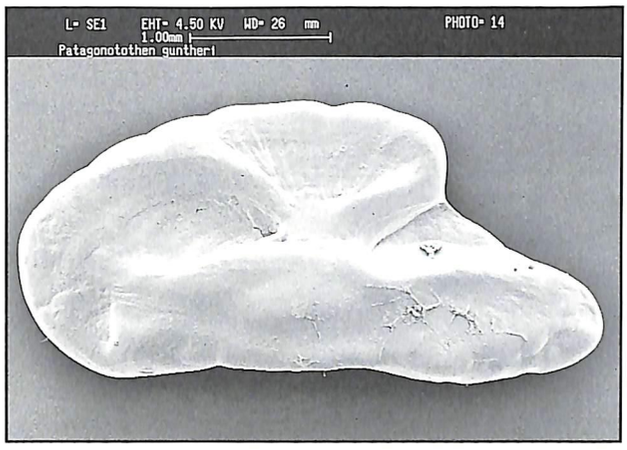

Plate 40. *Patagonotothen guntheri* (eroded)

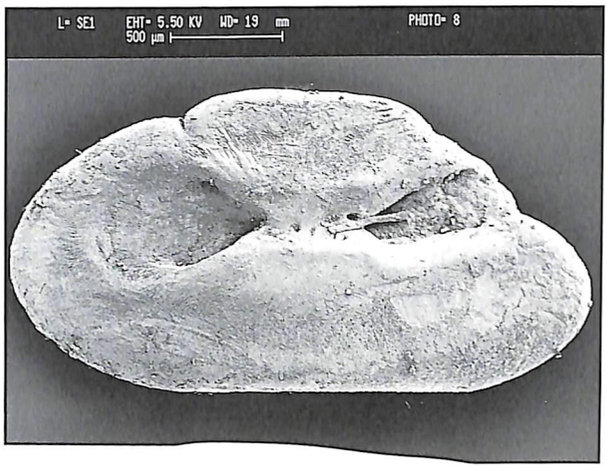

Plate 41. *Patagonotothen guntheri* (eroded)

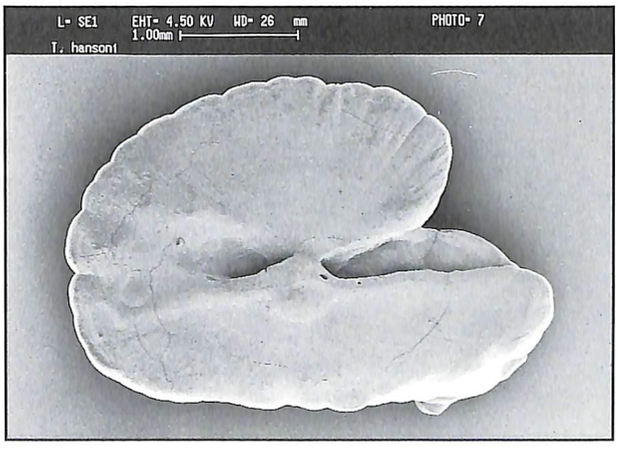

Plate 42. *Trematomus hansoni* (fish)

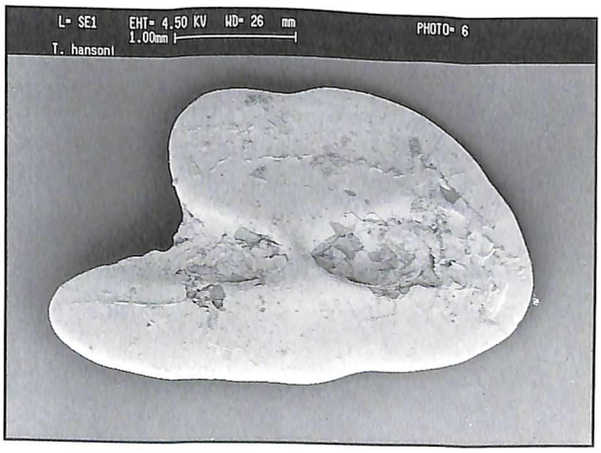

Plate 43. *Trematomus hansoni* (eroded)

Harpagiferidae - Spiny plunderfish

Harpagifer georgianus - This generally ovate otolith has a rounded posterior section and a well developed dorsal area, particularly above the ostium. The pit like ostium and cauda are separated by a well developed collum formed by the crista inferior. An inshore species found in the diet of blue-eyed shag (BAS unpublished data).

$TL = 40.74\ OL^{0.698}$ $r^2 = 0.99$ $n = 8$

$M = 8.13 \times 10^{-7}\ TL^{3.70}$ $r^2 = 0.98$ $n = 5\ (3)$

Bathydraconidae - Dragonfish

Parachaenichthys georgianus- The otoliths of this species is similar to *Trematomus* sp. however the rostrum is more rounded and there is usually a notch in the antero-dorsal margin and in the mid-ventral margin.

$TL = 84.28\ OL$ $n = 32$ (1)
$LgM = -3.32 + 2.261\ LgTL$ (7**)

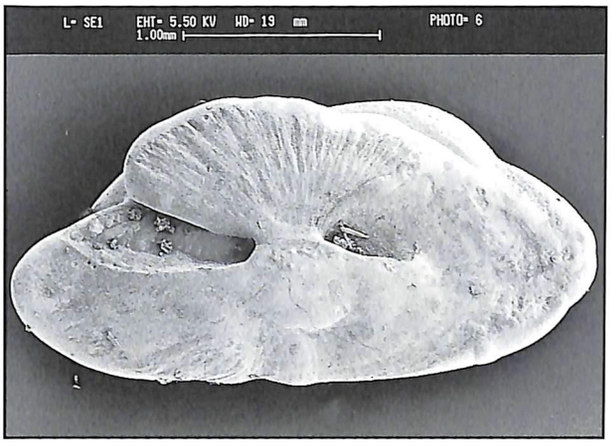

Plate 44. *Harpagifer georgianus* (fish)

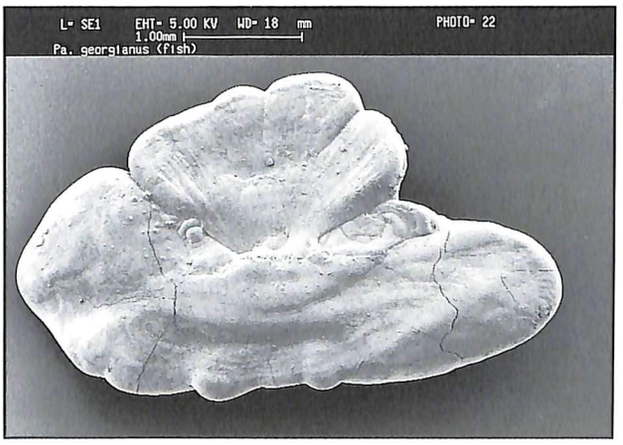

Plate 45. *Parachaenichthys georgianus* (fish)

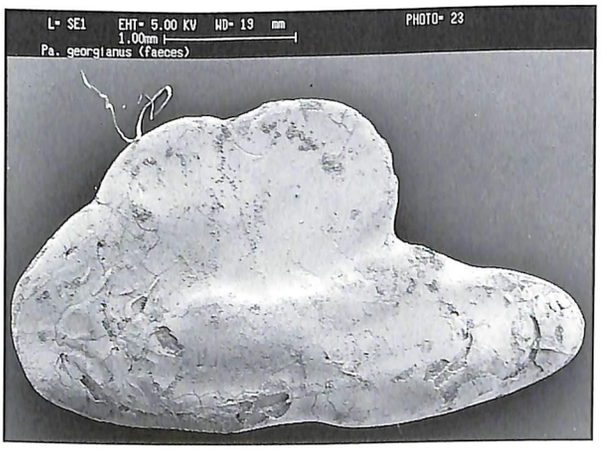

Plate 46. *Parachaenichthys georgianus* (eroded)

Channichthyidae - Icefish

Chaenocephalus aceratus - The otoliths of this species are more rounded than those of the similar *Champsocephalus gunnari*, in particular the 'scallop shell' dorsal area. The crista superior is only prominent over the ostium which is larger than the cauda. This species has been found in the diet of Antarctic fur seal (Reid 1995) and wandering albatross (Croxall et al. 1988, K. Reid pers obs.).

$TL = 76.59\ OL^{1.22}$ $r^2 = 0.87$ $n = 49$
$M = 4.33x10^{-7}\ SL^{3.44}$ $r^2 = 0.99$ $n = 52$ (3)

Champsocephalus gunnari - This otolith is generally square and antero-posterially symmetrical with the dorsal half much thicker than the ventral portion (typical of the channichthyidae). The projections of the colliculi are distinctive, especially in larger fish. However these projections are prone to breaking off during digestion and this may lead to an under-estimate of otolith size. This species is the most important fish in the diet of Antarctic fur seal (Reid 1995, Reid and Arnould 1996) and also occurs in the diet of gentoo and macaroni penguins (Croxall et al . in press), king penguin (Olsson and North 1996), wandering albatross (Croxall et al. 1988) and blue-eyed shag (BAS unpublished data).

$TL = -64.06 + 138.574\ OL$ $r^2 = 0.92$ $n = 30$ (TL range 144-480 mm)
$LgM = 0.1296 + 0.74596\ OL$ $r^2 = 0.92$ $n = 29$ (4)

Plate 47. *Chaenocephalus aceratus* (fish)

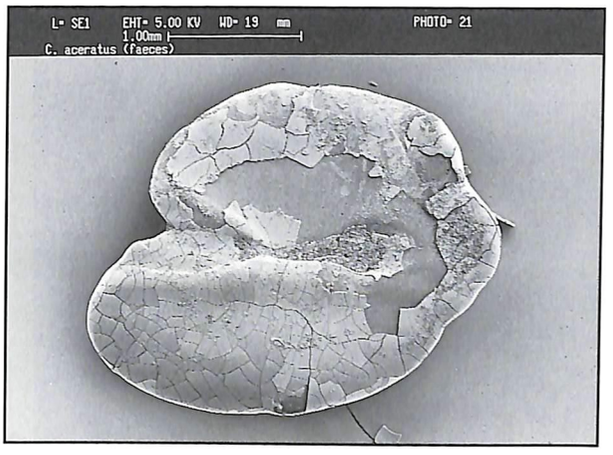

Plate 48. *Chaenocephalus aceratus* (eroded)

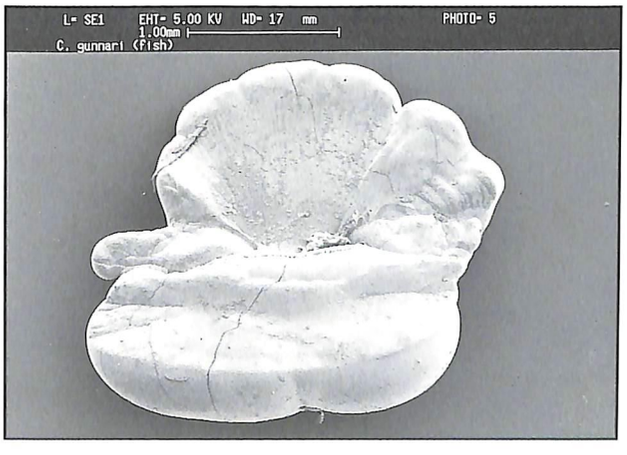

Plate 49. *Champsocephalus gunnari* (fish)

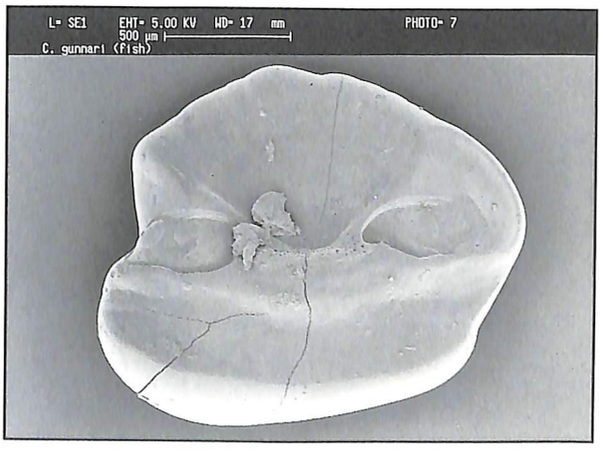

Plate 50.*Champsocephalus gunnari* (fish)

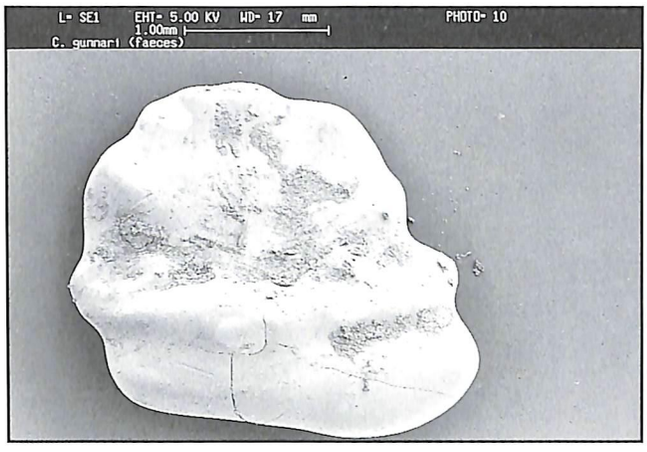

Plate 51.*Champsocpehalus gunnari* (eroded)

Plate 52.*Champsocpehalus gunnari* (eroded)

Plate 53. *Champsocephalus gunnari* (eroded)

Pseudochaenichthys georgianus - This otolith has particularly thick and rounded dorsal section and is more rectangular (greater height in relation to length) than *C. gunnari*. There are pronounced collicular projections , particularly the anterior colliculum. Occurs in the diet of Antarctic fur seal (Reid 1995), wandering albatross (Croxall et al. 1988), grey-headed albatross (Reid et al. 1996) and macaroni penguin (Croxall et al. in press).

LgTL = 1.57 + 1.64 LgOL $r^2 = 0.9$ $n = 36$
LgM = -0.93 + 5.87 LgOL $r^2 = 0.9$ $n = 36$ (5)

Gempylidae - Snake mackerels

Paradiplospinus gracilis - The unusual leaf shape of this otolith and the lack of distinctive sculpturing are distinctive. The ostium and cauda are not separated and the cristae are weakly defined hence the sulcus acusticus appears as an enclosed trough. Recorded as single specimens in the diet of Antarctic fur seal (Reid and Arnould 1996) and black-browed albatross (Reid et al. 1996).

SL = 33. 2 OL - 18.3 $r^2 = 0.94$ $n = 110$

$M = 2.412 \times 10^{-8} SL^{3\,67}$ $r^2 = 0.99$ $n = 110$ (1)

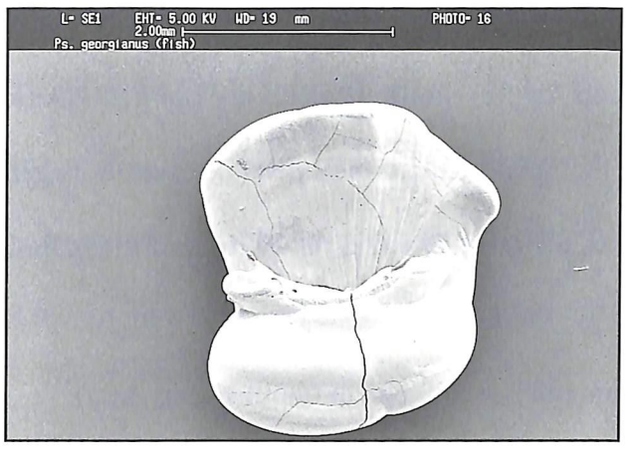

Plate 54. *Pseudochaenichthys georgianus* (fish)

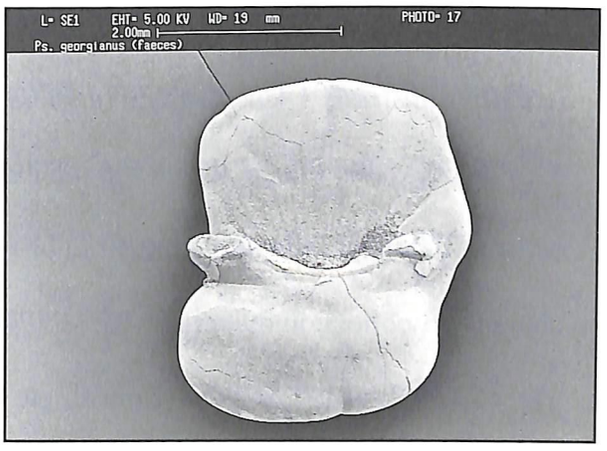

Plate 55. *Pseudochaenichthys georgianus* (eroded)

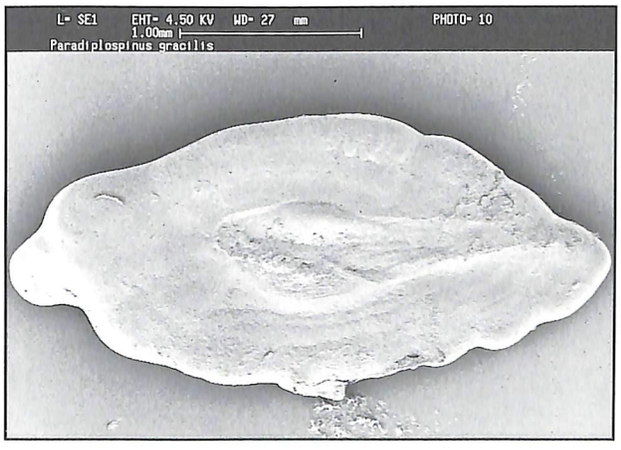

Plate 56. *Paradiplospinus gracilis* (fish)

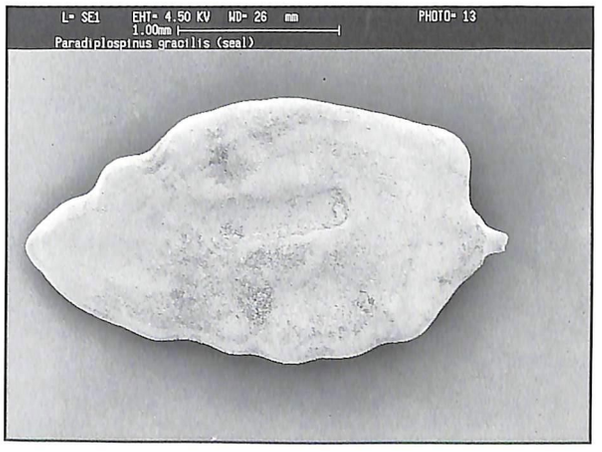

Plate 57. *Paradiplospinus gracilis* (eroded)

Centrolophidae - Driftfish

Icichthys australis - This distinctive, elongated (and fragile) otoliths has a very open excisura ostii, a ridge like cristae which are parallel over the small cauda and open out over a larger ostium. Found in a single sample from black-browed albatross (Reid et al. 1996) and identified using BAS collection material.

TL = 53.6 OL ; M = 79.2 OL (from single specimen only, A. W. North unpublished data).

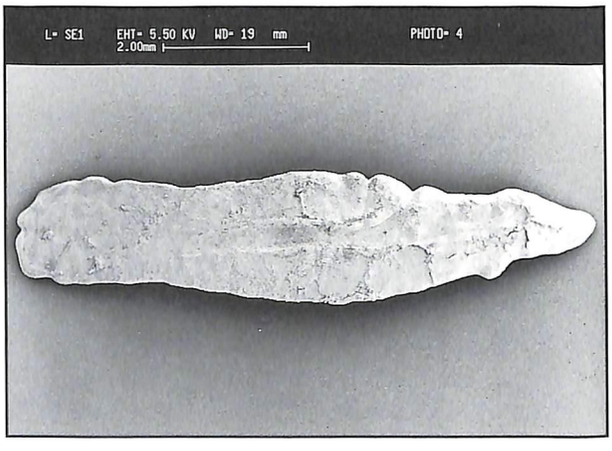

Plate 58. *Icichthys australis* (eroded)

Acknowledgements

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