

smallest, innermost rings. Electron and light microscopy techniques give similar results, suggesting that optical and sample preparation artifacts are not a problem.

By examining the otoliths of *N.gibberifrons* captured in mid-January 1989 at South Georgia, a preliminary estimation of the age of each individual was made. Using the average of three independent readings of each otolith from a sample 23 fish, the average age was found to be 71 days (± 8 , 95 percent confidence intervals); therefore they hatched sometime between mid-October and late November. By the time they were caught, they had grown to 21.7 millimeters (± 2.8). If these fish hatched at the smallest reported size of 8.5-11.5mm (Efremenko 1979), then they grew at a rate of .14 to .19 millimeters per day. Loeb (1991) reports a growth rate of .12 mm/day for *N. gibberifrons* from the peninsula area.

Estimation of the ages of *N.larseni* captured from the same cruise (18.8 mm \pm 5.6 mm) must await SEM analysis to determine the number of smallest rings adjacent to the core. However, counts of the outer visible rings (n= 6) show that these fish are at least 50 days old (± 14) and therefore hatched before late November to late December.

N.larseni develop slowly. Pelvic fin-buds have not appeared and rays in other fins are still not fully developed nearly two months after hatching. In comparison, at a little more than two months from hatching, *N.gibberifrons* are relatively well developed and have a complete set of fully developed fins.

Description of the growth history of individual fish awaits an understanding of the relationship between fish size and otolith size over a range of sizes. When this is achieved, the description of growth and development rates through different season, stages of development, and between two different re-

gions will be possible along with a better understanding of the two different life-history strategies.

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References

- Efremenko, V. N. 1979. The larvae of six species of the family Nototheniidae from the Scotia Sea. *Journal of Ichthyology*, 19:95-104.
- Everson, J. 1984. Fish Biology. In R.M. Laws (Ed.), *Antarctic Ecology*. London: Academic Press, 2:491-532.
- Kellermann, A. and S. Schadwinkel. 1991. Winter aspects of the ichthyoplankton community in Antarctic Peninsula water. *Polar Biology*, 11:117-127.
- Kock, K. H. and A. Kellermann. 1991. Reproduction in antarctic Notothenioid fish. *Antarctic Science*, 3(2):125-150.
- Loeb, V. J. 1991. Distribution and abundance of larval fishes collected in the western Bransfield Strait region, 1986-87. *Deep-Sea Research*, 38 (8/9):1,251-1,260.
- Marshall, N. B. 1953. Egg size in arctic, antarctic and deep-sea fishes. *Evolution*, 7:328-341.
- Pannella, G. 1971. Fish otoliths: Daily growth layers and periodical patterns. *Science*, 173:1,124-1,127.
- Radtke, R. L. and T. Hourigan. 1990. Age and growth of the antarctic fish *Nototheniops nudifrons*. *Fishery Bulletin*, 88:557-571.
- Thorson, G. 1950. Reproduction and larval ecology of marine bottom invertebrates. *Biological Review*, 25: 1-25.
- White, M. G. 1991. Age determination of antarctic fish. In G. di Prisco, B. Maresca, and B. Tota (Eds.), *Biology of Antarctic Fish*, Berlin: Springer-Verlag, 87-100.

Responses of antarctic fishes to tactile stimuli

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Antarctic fishes, particularly the southernmost populations, must feed during long periods of darkness. They have no particular visual adaptations for feeding in low light (Eastman 1988; Pankhurst and Montgomery 1989), so they must rely on either mechanical or chemical cues to locate prey. A variety of notothenioids respond well to hydromechanical stimuli through lateral line (Janssen et al. 1990), and a plunderfish (Artedidraconidae) uses its mandibular barbel as a lure (similar to anglerfish), biting when the barbel is pinched (Janssen et al. forthcoming). Observations presented below indicate that tactile stimuli, integrated with lateral line responses, are important to those fishes whose diet is primarily polychaetes.

In laboratory aquaria blinded *Trematomus bernacchii* fed on errant polychaetes, benthic amphipods (*Orchomene* sp.), and *Euphausia crystallorophias* showed a stereotypical response to

Habitat, diet, and presence or absence of response to tactile stimuli in McMurdo notothenioids

Species	Habitat	Diet	Fin tact. response	Conjectural bites
<i>T. bernacchii</i>	benthic	polychaeta	yes	yes
<i>T. centronotus</i>	benthic	polychaeta	yes	no
<i>T. hansonii</i>	benthic	polychaeta	yes	yes
<i>T. loennbergi</i>	benthopelagic	polychaeta	yes	yes
<i>P. borchgrevinki</i>	cryopelagic	zooplankton	no	no
<i>T. nicolai</i>	anchor ice	zooplankton, fish	no	no
<i>G. acuticeps</i>	anchor ice	fish	yes	no

Note: Diet for each fish is the one or two most important items as reported by Eastman.

prey touching pelvic and anal fins. The fish repositioned its head to about above the position where the prey collided with the fin (the fin was moved aside as the body turned). It then bit at the hydromechanical stimuli from the prey.

To experiment with the response of the fishes listed in the table, a "worm-shaped" piece of squid mantle or silicone rubber attached to a thread was dragged along the bottom, so it delicately contacted one of the pelvic fins. Alternatively, a piece of squid or silicone rubber was attached to a thin wire and delicately touched the anal fin. There were ten trials for each fish.

The four polychaete eaters, *T.bernacchii* (n=12 individuals), *T.centronotus* (n=8), *T.hansoni* (n=2), and *T.loennbergi* (n=5), in all trials responded to pelvic fin and anal fin stimulation by the "worm" by repositioning their heads near the spot where the fin had been touched (table). Subsequent movement of the worm (now near the fish's jaw, but not touching it) elicited a biting response to the hydromechanical stimulus. *Gymnodraco* (n=4) responded to pelvic fin and anal fin stimulation by turning toward the stimulus slowly in several stops and by shaking its head at several, but not all of the stops. The function of the head shake is not clear, but it may be a tactile search or attempt to startle prey. Neither of the zooplankton eaters, *P. borchgrevinki* (n=5) and *T. nicolai* (n=5), oriented to fin stimulation and instead tended to flick their pelvic fins, as if irritated.

If pelvic fins of blinded *T.bernacchii* were touched and the worm quickly withdrawn, the fish repositioned, waited a few seconds, then engaged in a series of one or more "conjectural bites," even though there was no worm present. (A "conjectural bite" is an apparently untargeted bite at the bottom.) Polychaetes are cryptic because they are frequently mostly or completely buried. Thus, a conjectural bite may be a means of capturing hidden prey by "guessing" its location.

To determine if *Pagothenia borchgrevinki* and the species of *Trematomus* exhibited conjectural bites with the eyes intact, ten specimens each of *T.bernacchii*, *T.hansoni*, *T.loennbergi*, *T.nicolai*, *T.centronotus* and *P.borchgrevinki* were given a one trial touch with squid or silicone rubber (on wire) to the pelvic fin and observed for conjectural bites. All individuals of the polychaete eaters engaged in conjectural bites, with the exception of the *T.centronotus*. No individual of the nonpolychaete eaters exhib-

ited conjectural bites. All individuals tested subsequently ate pieces of squid presented to the snout.

These observations indicate that methods used by antarctic fishes to locate prey during the antarctic night are apparently diverse and contingent on the diet of the particular species. The eyes of the polychaete eaters are not well positioned for observing polychaetes, and it is likely that, even in lighted conditions, most polychaetes are detected by a combination of tactile, hydromechanical, and, probably, chemical cues. A better understanding of the adaptiveness of the diverse behaviors will require a better understanding of habitats, winter diets, and predatory behavior.

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References

- Eastman, J. T. 1985. *Pleuragramma antarcticum* (Pisces, Nototheniidae) as food for other fishes in McMurdo Sound, Antarctica. *Polar Biology*, 4:155-60.
- Eastman J. T. 1988. Ocular morphology in antarctic nototheniidae fishes. *Journal of Morphology*, 196: 283-306.
- Janssen, J., S. Coombs, J. C. Montgomery, and V. Sideleva. 1990. Comparisons in the use of the lateral line for detecting prey in notothenioids and sculpins. *Antarctic Journal of the U.S.*, 15(5):214-15.
- Janssen, J., M. Slattery, and W. Jones. 1993. Feeding responses to mechanical stimulation of the barbel in *Histiadraco velifer* (Arteidraconidae). *Copeia*, forthcoming.
- Pankhurst, N. W. and J. C. Montgomery. 1989. Visual function in four antarctic nototheniid fishes. *Journal of Experimental Biology*, 142:311-24.

Polyunsaturated fatty acids are metabolized by both mitochondrial and peroxisomal pathways of antarctic fishes

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The adaptive significance of large fat stores to warm-bodied polar animals (e.g., seals, whales, and seabirds) is relatively easy to understand. Fatty compounds provide very significant energy stores for metabolism and also insulate the organism from excessive heat loss to the cold environment. Antarctic fishes are also characterized by extensive body content of lipid despite being

isothermal with the water in which they live and having much lower metabolic rates than warm-bodied organisms. For example, fatty compounds account for 37 percent of dry weight of skeletal muscle tissue from *Pagothenia borchgrevinki* and *Dissostichus mawsoni* from McMurdo Sound (Lin et al. 1974).

Convincing evidence has accumulated to support the idea that the high fat content of these pelagic species which lack swimbladders confers buoyancy (Eastman and DeVries 1981), but even demersal antarctic species display high lipid content (e.g., *Gobionotothen gibberifrons*; Lund and Sidell 1992). These extensive fat stores are composed predominantly of triacylglycerols (Clarke et al. 1984), but are exceptionally rich in long-chain polyunsaturated fatty acids (PUFA), which are poor substrates for energy metabolism in other animals. In recent years, our laboratory group has been examining the extent to which antarctic fishes rely upon fatty compounds to support their energy metabolism and the possible implications of very high lipid content of their tissues upon other physiological processes, notably the transcellular movement of oxygen to support respiration of the tissues.

Two subcellular organelles, mitochondria and peroxisomes, contain pathways capable of catabolic β -oxidation of fatty acids (Lazarow and deDuve 1976). Peroxisomes are thought to oxidize fatty acids that are poor substrates for mitochondrial β -oxidation, such as some PUFAs (reviewed by Osmundsen et al. 1987). Our laboratory has shown previously that antarctic fishes have high capacities for the oxidation of fatty fuels (Crockett and Sidell 1990) and that a significant fraction of the total neutral lipid stores are represented by PUFA, particularly eicosapentaenoic