TABLE 1.—Number of zooplankton samples for each cruise from which both carbon and nitrogen were measured. The general location of the stations for these samples are given in Wiebe et al. (1975).

Cruise or area	Date	No. of measurements	Diameter of net (mesh size)
Buzzards Bay	Jan.–June 1972	16	70 cm (240 μm)
Slope Water (RV *Gosnold*)	June–Aug. 1972	12	100 cm (333 μm)
Atlantis II 48 (Gulf of Mexico)	Nov. 1968	19	70 cm (240 μm)
Gosnold 166 (New York Bight)	June 1970	33	70 cm (240 μm)
Atlantis II 71 (Sargasso Sea)	Sept. 1972	39	100 cm (333 μm)

$$\text{Nitrogen (mg/m}^3) = -0.0247 + 0.2324 \text{ carbon (mg/m}^3)$$

Essentially the carbon/nitrogen ratio of the bulk zooplankton we collected is a constant (4.30) over a broad range of values and oceanographic habitats. As an atomic ratio, 5.02, this value is lower than that predicted by the Redfield ratio, 6.63 (Redfield et al. 1963), an indication that zooplankton are nitrogen rich relative to their phytoplankton counterparts.

Acknowledgments

We would like to express our appreciation to F. A. Ascioti for his correspondence and attention to detail which enabled us to correct the mistakes in our previous publication. This research was supported by NSF Grant OCE-8709962 and is Contribution No. 6839 from the Woods Hole Oceanographic Institution.

Literature Cited

DAVIS, C. S., AND P. H. WIEBE.
1985. Macrozooplankton biomass in a Warm-Core Gulf Stream Ring: Time series changes in size structure, taxonomic composition and vertical distribution. J. Geophys. Res. 90:8871–8884.

REDFIELD, A. C., B. H. KETCHUM, AND F. A. RICHARDS.
1963. The influence of organisms on the composition of seawater. *In* M. N. Hill (editor), The Sea, Vol. 2, The composition of sea-water, p. 26–77. Intersci. Publ., John Wiley and Sons, N.Y.

RICKER, W. E.
1973. Linear regressions in fishery research. J. Fish. Res. Board Can. 30:409–434.

WIEBE, P. H., S. H. BOYD, AND J. L. COX.
1975. Relationships between zooplankton displacement volume, wet weight, dry weight, and carbon. Fish. Bull., U.S. 73:777–786.

PETER H. WIEBE

Woods Hole Oceanographic Institute
Woods Hole, MA 02543

ELECTROPHORETIC IDENTIFICATION OF EARLY JUVENILE YELLOWFIN TUNA, *THUNNUS ALBACARES*

Early juveniles, 13 mm standard length (SL) or larger, of yellowfin tuna, *Thunnus albacares*, and bigeye tuna, *T. obesus*, cannot be distinguished on the basis of meristic, morphological, or pigmentation characters (Matsumoto et al. 1972). Collette et al. (1984) reported that most species of the genus *Thunnus* can be distinguished at the larval stage by melanophore patterns. Matsumoto et al. (1972) and Nishikawa and Rimmer (1987) suggested that *T. albacares* and *T. obesus* larvae can be separated by the respective absence or presence of postanal ventral melanophores. Confirmation of the identification of *T. albacares* larvae has been obtained through laboratory rearing studies (Harada et al. 1971; Mori et al. 1971). However, the use of postanal ventral pigmentation patterns as reliable characters to distinguish yellowfin and bigeye tuna larvae has been questioned by Richards and Pothoff (1974). Nishikawa and Rimmer (1987) stated that it is virtually impossible to identify to species the early juvenile stages, 15 to 60 mm SL, of *Thunnus* because larval pigmentation patterns become obscured and are no longer diagnostic. Furthermore, Pothoff (1974) was unable to separate *T. albacares* and *T. obesus* as early juveniles, 8 to 100 mm SL, on the basis of osteological characters.

Electrophoresis of water soluble proteins has been used to distinguish morphologically similar larval and early juvenile marine fishes (Morgan 1975; Smith and Crossland 1977; Sidell et al. 1978; Smith and Benson 1980). Sharp and Pirages (1978) presented starch gel electrophoretic patterns for several loci of adults of many scombrid species, including most members of the genus *Thunnus*. Although electrophoretically very similar, adults of yellowfin and bigeye tuna can be unambiguously distinguished by the electrophoretic pattern of the muscle isozyme of glycerol-3-phosphate dehydrog-

enase (alpha glycerol phosphate). This locus has been used to identify adults of the genus *Thunnus* in the absence of complete morphological data (Dotson and Graves 1984). This paper describes an application of the above techniques, modified for work with small tissue samples, to the identification of an opportunistic collection of early juvenile tuna, in excellent morphological condition, which were frozen shortly after capture. The early juveniles in this collection encompassed the pigmentation patterns reported for both *T. albacares* and *T. obesus*.

Specimens were collected aboard the MV *Royal Polaris*, a San Diego-based sportfishing boat, about 1 km off Clipperton Island in the eastern Pacific (lat. 10°23'N, long. 109°15'W), 8 May 1986, from hours of 2100 to 2400. The early juveniles were caught underneath floodlights at a depth of about 1 m with a fine (1 mm) mesh, long-handled dip net. They were not present at the surface. After each pass, the dip net contents were sorted for scombrid larvae. Approximately 100 specimens were collected, most of which were quickly frozen in seawater.

Adult specimens of *T. albacares* and *T. obesus* were collected by hook and line off the Pacific coast of southern and northern Baja California, Mexico, respectively. White muscle tissue samples were removed from freshly caught specimens and quickly frozen.

The early juveniles collected off Clipperton Island were thawed in the laboratory and examined under a dissecting microscope. Those juveniles positively identified to the morphologically indistinguishable *T. albacares/T. obesus* complex were measured for total length (TL) to the nearest millimeter and examined for postanal ventral pigmentation pattern. Heads were removed and placed in 95% ethanol for otolith studies. The remaining trunk and tail musculature was placed in a small (1.0 mL) microfuge tube, and 60 μL of cold grinding buffer (0.1 M Tris, pH 7.5) was quickly added. Tissues were homogenized with a cold ground-glass rod contoured to fit snugly within the microfuge tube. Approximately 10 seconds of rod rotation were required to completely disrupt the tissues. The homogenate was centrifuged for 2 minutes in a microfuge and stored on ice until electrophoresis.

Two grams of adult tissue were disrupted for approximately 20 seconds in 4 volumes of cold grinding buffer in a motor-driven, ground-glass tissue homogenizer. The homogenate was centrifuged at 5,000 *g*, 4°C, for 10 minutes. The supernatant was removed, diluted 10:1 with cold grinding buffer, and stored on ice until electrophoresis.

Horizontal starch gel electrophoresis was performed on 12% (W/V) gels run in the Tris/Citrate II system of Selander et al. (1971). Gels were run at 45 to 50 mA for 3.5 hours. Glycerol-3-phosphate dehydrogenase was stained using the protocol of Shaw and Prasad (1970). Three sets of standards composed of the supernatants of muscle tissue homogenates of adult yellowfin and bigeye tuna were placed in each gel to score the early juveniles.

A total of 77 early juveniles, ranging in length from 10 to 21 mm TL, were processed. Glycerol-3-phosphate dehydrogenase activity was scored for 68 individuals. All early juveniles displayed a muscle-type glycerol-3-phosphate dehydrogenase band of low anodal mobility, identical to that of the yellowfin tuna adults (Fig. 1). No individuals with the faster migrating *T. obesus* glycerol-3-phosphate dehydrogenase band were detected.

The lack of bigeye tuna juveniles in this study could be the result of two possibilities: either the early juveniles were all yellowfin tuna or both yellowfin and bigeye tuna early juveniles share a muscle-type glycerol-3-phosphate dehydrogenase isozyme of similar electrophoretic mobility. However, differential ontogenetic expression of electrophoretically distinct isozymes has not been reported for fishes in studies that have used adult allozymes to identify larvae or early juveniles (Morgan 1975; Smith and Crossland 1977; Sidell et al. 1978; Smith and Benson 1980) or in investigations of ontogenetic expression of electrophoretic loci (Shaklee et al. 1974; Siebenaller 1984). Thus, the electrophoretic similarity of the glyceraldehyde-3-phosphate alleles of the early juveniles investigated in this study most likely indicates that they were all yellowfin tuna.

On the same trip during which the early juveniles were collected at Clipperton Island, about 300 adult yellowfin tuna were caught on hook and line but no bigeye tuna were taken. Histological examination of ovarian tissue from several of the adult yellowfin tuna revealed postovulatory follicles, indicating that spawning was taking place (Anonymous 1987). On the basis of this information, it is not unexpected that all the early juveniles identified electrophoretically in this study proved to be *T. albacares*.

A wide range of postanal ventral pigmentation patterns (red and black) was displayed by the early juveniles. Since these specimens were collected at night, the pigment cells, when present, were distinct and brightly colored as reported by Matsumoto et al. (1972). While some individuals had no melanophores in this region, others had from one to eight.

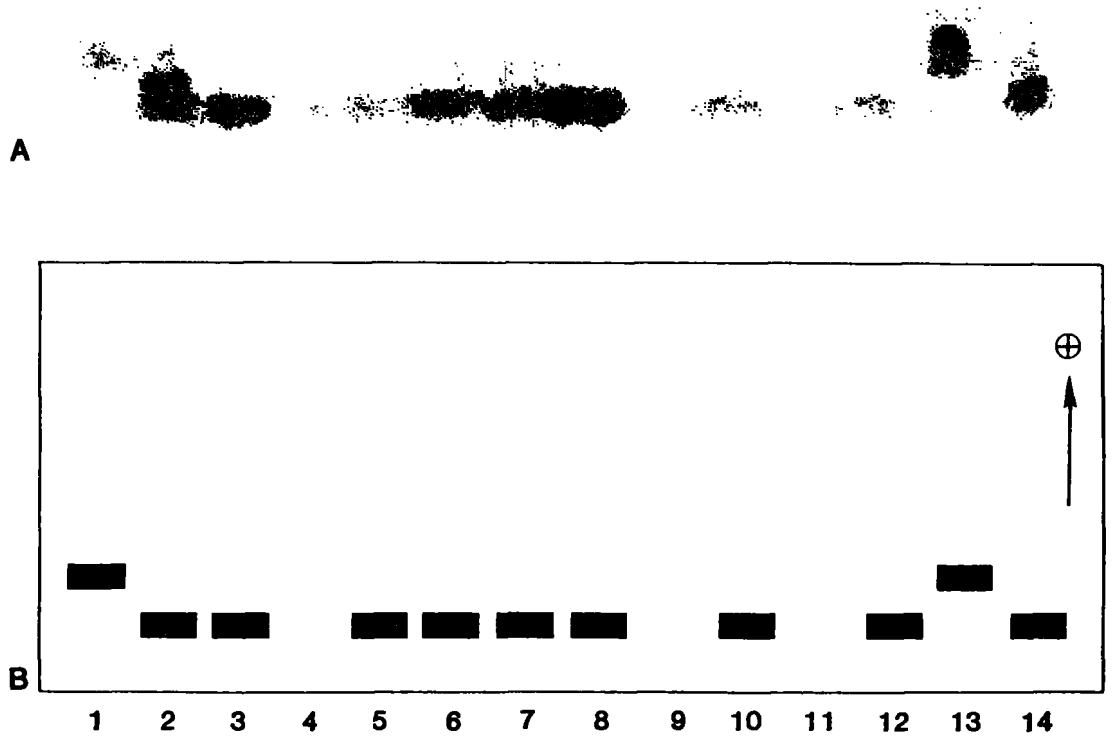

FIGURE 1.—Photograph (A) and line drawing (B) of a gel demonstrating electrophoretic mobilities of muscle-type glycerol-3-phosphate dehydrogenase alleles of yellowfin and bigeye tuna. Bigeye tuna display an allele with a greater anodal mobility. The gel includes adult bigeye (lanes 1 and 13) and yellowfin (lanes 2 and 14) tuna standards and 7 early juveniles, all identified as yellowfin tuna. Note that three individuals (lanes 4, 9, and 11) did not have sufficient activity to stain.

According to Matsumoto et al. (1972) and Nishikawa and Rimmer (1987), yellowfin larvae less than about 12 mm SL have no black pigment spots in the ventral tail region. However, Mori et al. (1971) reported and illustrated that there is black pigmentation on the ventral edges of the tail in laboratory-reared yellowfin larvae at 7.8 mm TL. Twenty-one individuals in the 10 to 12 mm TL size range were electrophoretically typed as yellowfin tuna in this study. Six of these early juveniles had black postanal ventral pigmentation (characteristic of bigeye tuna), while 15 had no black postanal ventral pigmentation (characteristic of yellowfin tuna).

Variability in larval and early juvenile pigmentation within species, including large changes in pigmentation over small size ranges, is found within many marine fishes (Powles and Markle 1984). Richards and Pothoff (1974) have suggested that the variability of postanal ventral pigmentation is not consistent with specific differentiation within the *T. albacares*/*T. obesus* complex. This study supports their claim.

Early life history studies are necessary for an understanding of recruitment within each species of tuna. Due to the morphological similarity of yellowfin and bigeye tuna larvae and early juveniles, specific separation has not been possible. This study provides a simple method for identifying yellowfin and bigeye tuna larvae and early juveniles. With this technique and additional material, it may be possible to find a morphological character that will allow rapid identification of these two species.

Acknowledgments

We would like to thank the owner, Frank LoPreste, and skipper, Steve Loomis, as well as the crew of the MV *Royal Polaris* for providing the opportunity to collect specimens. William H. Bayliff and Witold L. Klawe reviewed the manuscript.

Literature Cited

ANONYMOUS.
1987. Annual report of the Inter-American Tropical Tuna Commission 1986. Inter-Am. Trop. Tuna Comm., 264 p.

COLLETTE, B. B., T. POTTHOFF, W. J. RICHARDS, S. UEYANAGI, J. L. RUSSO, AND Y. NISHIKAWA.
1984. Scombroidei: development and relationships. *In* H. G. Moser et al. (editors), Ontogeny and systematics of fishes, p. 591–620. Am. Soc. Ichthyol. Herpetol., Spec. Publ. No. 1.

DOTSON, R. C., AND J. E. GRAVES.
1984. Biochemical identification of a bluefin tuna establishes a new California size record. Calif. Fish Game 70:58–64.

HARADA, T., K. MIZUNO, O. MURIATA, S. MIYASHITA, AND H. HURUTANI.
1971. On the artificial fertilization and rearing of larvae in yellowfin tuna. Mem. Fac. Agric. Kinki Univ. 4:145–151.

MATSUMOTO, W. M., E. H. AHLSTROM, S. JONES, W. L. KLAWE, W. J. RICHARDS, AND S. UEYANAGI.
1972. On the clarification of larval tuna identification particularly in the genus *Thunnus*. Fish. Bull., U.S. 70:1–12.

MORGAN, R. P.
1975. Distinguishing larval white perch and striped bass by electrophoresis. Chesapeake Sci. 16:68–70.

MORI, K. S., S. UEYANAGI, AND Y. NISHIKAWA.
1971. The development of artifically fertilized and reared larvae of the yellowfin tuna, *Thunnus albacares*. Bull. Far Seas Fish. Res. Lab. (Shimizu) 5:219–232.

NISHIKAWA, Y., AND D. W. RIMMER.
1987. Identification of larval tunas, billfishes and other scombroid fishes (suborder Scombroidei): an illustrated guide. Aust. CSIRO Mar. Lab. Rep. 186:1–20.

POTTHOFF, T.
1974. Osteological development and variation in young tunas, genus *Thunnus* (Pisces, Scombridae), from the Atlantic Ocean. Fish. Bull., U.S. 72:563–588.

POWLES, H., AND D. E. MARKLE.
1984. Identification of larvae. *In* H. G. Moser et al. (editors), Ontogeny and systematics of fishes, p. 31–33. Am. Soc. Ichthyol. Herpetol., Spec. Publ. No. 1.

RICHARDS, W. J., AND T. POTTHOFF.
1974. Analysis of the taxonomic characters of young scombrid fishes, genus *Thunnus*. *In* J. H. S. Blaxter (editor), The early life history of fish, p. 623–648. Springer-Verlag, Berlin.

SELANDER, R. K., M. H. SMITH, S. Y. YANG, W. E. JOHNSON, AND J. B. GENTRY.
1971. Biochemical polymorphism and systematics in the genus *Peromyscus*. I. Variation in the old-field mouse (*Peromyscus polionotus*). Univ. Texas Publ. 7103:49–90.

SHAKLEE, J. B., M. J. CHAMPION, AND G. S. WHITT.
1974. Developmental genetics of teleosts: biochemical analysis of lake chubsucker ontogeny. Dev. Biol. 38:356–382.

SHARP, G. D., AND S. W. PIRAGES.
1978. The distribution of red and white swimming muscles, their biochemistry, and the biochemical phylogeny of selected scombrid fishes. *In* G. D. Sharp and A. E. Dizon (editors), The physiological ecology of tunas, p. 41–78. Academic Press, N.Y.

SHAW, C. R., AND R. PRASAD.
1970. Starch gel electrophoresis of enzymes—a compilation of recipes. Biochem. Genet. 4:297–320.

SIDELL, B. D., R. G. OTTO, AND D. A. POWERS.
1978. A biochemical method for distinction of striped bass and white perch larvae. Copeia 1978:340–343.

SIEBENALLER, J. F.
1984. Analysis of the biochemical consequences on ontogenetic vertical migration in a deep-living teleost fish. Physiol. Zool. 57:598–608.

SMITH, P. J., AND P. G. BENSON.
1980. Electrophoretic identification of larval and 0-group flounders (*Rhombosolea* spp.) from Wellington Harbour, N.Z. J. Mar. Freshwater Res. 14:401–404.

SMITH, P. J., AND J. CROSSLAND.
1977. Identification of larvae of snapper, *Chrysophrys auratus* Forster, by electrophoretic separation of tissue enzymes. N.Z. J. Mar. Freshwater Res. 11:795–798.

JOHN E. GRAVES
MARIE A. SIMOVICH

Department of Biology,
University of San Diego
Alcala Park,
San Diego, CA 92110

KURT M. SCHAEFER

Inter-American Tropical Tuna Commission
c/o Scripps Institution of Oceanography
La Jolla, CA 92093

A COMPARISON OF DEMERSAL ZOOPLANKTON COLLECTED AT ALLIGATOR REEF, FLORIDA, USING EMERGENCE AND REENTRY TRAPS

Demersal zooplankton have been shown to be important components of a number of marine communities, including coral reefs (Porter and Porter 1977; Alldredge and King 1977), kelp beds (Hammer 1981), and other habitats (Thomas and Jelley 1972). They probably play an important role in the flux of particulate material through benthic communities (Porter and Porter 1977). Demersal zooplankton can also be important prey for fish and other consumers (Alldredge and King 1977, 1980).

Demersal zooplankton are usually sampled by techniques that take advantage of their migration into or out of the plankton. Studies by Alldredge and King (1980, 1985) and Youngbluth (1982) suggest