

NOTES

THE RELATIONSHIP BETWEEN TILEFISH, *LOPHOLATILUS CHAMAELEONTICEPS*, ABUNDANCE AND SEDIMENT COMPOSITION OFF GEORGIA

Elucidation of the relationship between physicochemical factors and fish abundance has long been of interest to fisheries biologists. For example, water temperature frequently exerts a strong influence on the abundance of many pelagic marine fishes (Radoovich 1961; Laurs et al. 1977; Barkley et al. 1978; Moyle and Cech 1982), and this effect has been noted also for freshwater species (Magnuson et al. 1979; Moyle and Cech 1982). For benthic marine fishes, however, substrate composition may be a more important factor affecting fish abundance and distribution. Associations between abundance and substrate composition have been noted for a diverse group of fishes: agonids, bothids, cottids, pleuronectids, scorpaenids, and steichaeids (Day and Pearcy 1968; Powell and Schwartz 1977; Mariave 1977; Barton 1982). Where detectable, however, these associations vary substantially in intensity. This is probably due to the fact that many physicochemical factors are intercorrelated and most fishes probably respond to intercorrelated suites of variables rather than to single factors alone.

In this note we quantify the relationship between catch rate of a demersal species, the tilefish, *Lopholatilus chamaeleonticeps*, and substrate composition. This species is commercially exploited throughout most of its range (Grimes et al. 1980; Low et al. 1983; Turner et al. 1983), although, prior to this study, tilefish resident to the continental slope off Georgia appeared to have been subjected to minimal exploitation (D. Harrington¹). The elucidation of a substrate-abundance relationship for tilefish should aid in the management and harvest of this species.

Methods

A total of 19 bottom longline sets and 19 sediment samples were obtained during daylight hours, between 5 May and 22 November 1982. Fourteen longline sets, each comprising 1.6 km of line, and 12 sediment samples (Table 1) were obtained from the RV *Georgia Bulldog* (University of Georgia Sea Grant Program vessel). Five sets ($\bar{X} \pm 1$ SD length = 0.31

± 0.09 km) and seven sediment samples were collected aboard the RV *Delaware II* (National Marine Fisheries Service vessel). At least one of the authors was present during collections.

Bottom longlining on the *Georgia Bulldog* was conducted using snap-on gangions (~ 0.5 m in length) spaced about 4 m apart, along a 6.3 mm diameter galvanized aircraft cable groundline. Gangions were equipped with 4/0 or 5/0 circle hooks and baited with either fish or squid. A similar system was employed on the *Delaware II* except that a much shorter groundline of 6.3 mm diameter hardlaid nylon was used (Table 1), with hook sizes ranging from 3/0 to 8/0.

Substrate Analysis

Substrate samples were collected with a 25 \times 30 \times 37.5 cm box dredge suspended from a power winch. The dredge was lowered to the bottom and then dragged across the substrate (typically for < 5 min). After retrieval, 1.2-2.0 kg of sediment were removed from the dredge and stored in plastic bags. It is assumed that these samples accurately reflect the composition of surface sediments.

Sediment samples varied in their proximity to longline sets. Fourteen samples were taken at the end of longline sets. Of the remaining five samples, one was taken from the midpoint of a set, three were taken alongside sets within a distance of 0.2 km, and one was taken alongside a set at a distance of 0.6 km. The general area sampled (see Table 1 for Ioran C coordinates) has a relatively homogenous, low-relief bottom topography, and large variations in substrate composition probably do not occur over short distances (V. J. Henry²).

To determine the fraction of each sample composed of sand and silt-clay, a known amount of sediment (i.e., enough to yield a dry weight of between 60 and 100 g) was dried in a forced-air oven at 98°C until a constant weight was reached. The sample was then moistened with water which contained ~ 2 g of Calgon³ as a dispersant, and washed through a sieve which retained particles ≥ 0.0625 mm (4 ϕ) (U.S. standard sieve #230). Sediments retained by the sieve were then oven-dried to a constant weight to

¹D. Harrington, University of Georgia Marine Extension Service, Brunswick, GA 31523, pers. commun. 1983.

²V. J. Henry, Dept. of Geology, Georgia State University, Atlanta, GA 30303, pers. commun. 1983.

³Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 1.—Sediment composition and catch data for longline sets used to establish the relationship between catch rates and sediment composition off Georgia.

Date	Loran C coordinates	Minimum and maximum depths (m) of longline sets	Groundline length (km)	Number of hooks	Soak time (h)	Tilefish per 100 hook-h ⁻¹	Percent sand (≥4φ)	Percent silt-clay (<4φ)
5-5-82	45086.1 60777.3	187-190	1.61	242	3.3	2.11	'58	42
5-29-82	45092.9 60743.2	193-194	1.61	390	4.3	1.72	53	47
5-29-82	45093.8 60729.9	² 196	1.61	348	5.3	3.29	'49	51
5-30-82	45088.0 60869.4	140-143	1.61	284	3.5	0	85	15
5-30-82	45080.8 60864.2	164	1.61	330	4.2	0	69	31
5-30-82	45076.8 60854.7	182-185	1.61	247	4.0	0.41	64	36
5-30-82	45073.0 60847.0	203	1.61	254	3.6	0	64	36
5-30-82	45069.6 60841.0	219	1.61	298	2.9	0.57	79	21
6-29-82 ³	44736.5 61531.7	No data	0.18	50	2.5	0	88	12
7-1-82 ³	45039.6 60974.6	199	0.35	100	2.0	0	69	31
7-2-82 ³	45065.4 60868.6	No data	0.35	100	1.0	0	80	20
7-12-82 ³	26979.6 39551.5 (9960-chain)	216-223	0.35	103	1.0	0	98	2
7-24-82	45109.8 60548.5	186-187	1.61	258	3.2	3.56	'40	60
7-25-82	45101.0 60549.0	217-219	1.61	241	4.0	3.80	48	52
8-13-82	45076.0 60842.6	195-201	1.61	266	3.0	0.50	74	26
8-14-82	45085.6 60735.0	230	1.61	352	3.7	2.98	57	43
8-17-82	45093.8 60555.9	255-258	1.61	245	3.9	1.67	55	45
11-22-82	45097.8 60720.5	186	1.61	311	3.5	3.95	'48	52
11-22-82	45095.8 60716.0	189-191	1.61	250	2.9	5.34	52	48

¹Substrate samples were taken during a different cruise, however, samples were always taken within 65 d of each other.

²A single depth measurement means that only one reading was taken during the longline set. This depth is an approximation of longline depth.

³Samples taken from the *Delaware II*.

determine the percentage of sand and larger particles in the sample. The silt-clay fraction was obtained by subtraction. Replicate subsamples were taken from six collections to establish the technique's precision. The mean difference in percent silt-clay fraction among the six replicates was 2.5% ($s = 1.4\%$). A *t*-test for paired samples indicated that significant differences did not exist among replicate determinations for a given sample ($t = 0.30$, $df = 5$, $P > 0.7$).

Statistical Analysis

To determine the relationship between tilefish

catch rate and sediment composition, we used the silt-clay fraction of each substrate sample as an independent variable (*X*) and catch rate (i.e., tilefish caught/100 hook-h per soak time) as the dependent variable (*Y*). Exponential and polynomial regression models were fit to the data using the SAS statistical programs (SAS Institute Inc. 1982). The best polynomial model was compared with the nonlinear exponential model using R^2 as the criterion for model performance. Similar patterns of variation were observed in plots of residuals from all models, hence R^2 values are a reasonable criterion for model selection.

Results

The size structure of tilefish caught off Georgia was typical of unexploited to lightly exploited tilefish stocks (Grimes et al. 1980; Turner et al. 1983). This size structure remained relatively constant for ~ 10 mo, after which a slight decrease in catch rates and a possible truncation of size structure were observed (authors' unpubl. data). These results confirm verbal reports that little exploitation has occurred off Georgia (Harrington footnote 1). Hence, the data used in this analysis were probably not influenced by prior exploitation.

A total of 323 tilefish were taken on 19 longline sets (Table 1). Catch rates ranged from 0 to 5.34 tilefish/100 hook-h. Parameter estimates for linear and quadratic terms of the polynomial regressions were significantly different from zero (Table 2). Inclusion of a cubic term, however, did not significantly improve ($F = 0.75, P > 0.40$) the fit which was obtained using a second-degree polynomial. The second-degree polynomial yielded a higher R^2 value than the nonlinear exponential model (Table 2) and hence was deemed to be the model of best fit. The y -intercept of this model also was not significantly different than zero (Table 2, Fig. 1) which contributes to its biological realism. Using this equation, 74% of the variation in catch rate could be accounted for by substrate composition alone.

Discussion

Tilefish abundance, as estimated by catch rates off Georgia's continental slope, was strongly correlated with the silt-clay fraction of the substrate. This relationship was nonlinear, and based on R^2 values, a second-degree polynomial regression provided the best fit to the data. Off the northeastern United States, tilefish also were most abundant on fine-grain sediments (Able et al. 1982), although they were also found in horizontal burrows in the sides of submarine canyons (Warne et al. 1977), and in boulder fields (Valentine et al. 1980). Because tilefish construct vertical burrows in the substrate (Able et al. 1982), they require sediments which possess sufficient stability to prevent the collapse of their burrows. It would appear that bottom areas off Georgia which contain a sand fraction > 60% do not support substantial tilefish densities (Table 1, Fig. 1). It is likely that such substrates are not stable enough to allow tilefish to construct burrows. Thus, the observed correlation between catch rate and substrate composition has a biologically realistic explanation: substrates with high silt-clay fractions are conducive

TABLE 2.—Comparison of regression models. Either F -tests (b_1), t -tests (b_0), or asymptotic confidence intervals (exponential model) were used to test the significance of parameters.

Model	b_1	b_0	R^2
$y = 0.087X - 1.496$	**	*	0.64
$y = 0.155(e^{0.058X})$	*	ns	0.68
$y = 0.002X^2 - 0.050X + 0.122$	***	ns	0.74

ns = nonsignificant

* = $P < 0.05$

** = $P < 0.001$

*** = $P < 0.0001$

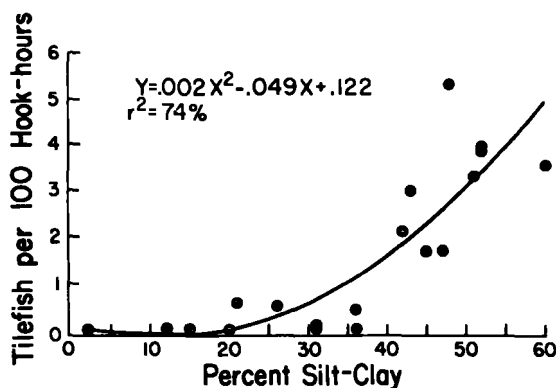


FIGURE 1.—Relationship between the silt-clay fraction of the sediments and tilefish catch rates off Georgia, U.S.A.

to the construction and maintenance of tilefish burrows, while substrates with high sand fractions are not. A similar explanation, based on submarine observations, has been proposed by Able et al. (1982) to explain tilefish distributions off the northeastern United States. Although we have not observed tilefish burrows off Georgia, they have been identified in soft bottom areas off South Carolina (R. Jones⁴).

While the relationship between catch rates and sediment composition is quite strong, several potential sources of error exist in our data. First, catch rate data were collected from two different vessels using different gear. Pooling data from the different vessels, however, would tend to obscure the relationship between catch rates and sediment composition. Hence, if differences in sampling methods did have an effect on our data, it would make the estimates of the catch rate-sediment relationship conservative.

Second, only one substrate sample was collected with each longline set. While quantification of

⁴R. Jones, Harbor Branch Foundation, Fort Pierce, FL 33450, pers. commun. 1983.

geographical variation in substrate composition was beyond the scope of this project, low relief areas off Georgia generally do not display large variations in substrate composition (Henry footnote 2). Evidence to substantiate this point is presented in Table 1, as substrate samples from areas with similar loran coordinates typically possessed similar substrate compositions.

Third, while a seasonal component to catch rate has been observed off New Jersey (Grimes et al. 1980), our data for this analysis do not strongly display this trend (Table 1).

In addition, because the area fished did not display evidence of significant prior exploitation, our results were not affected by the potentially confounding influence of commercial fishing.

In conclusion, approximately three-quarters of the variation in tilefish catch rate off Georgia could be attributed to variation in a single physicochemical factor: the silt-clay fraction of the substrate. At present, however, the generality of this relationship is unknown with respect to other geographical areas or locations with different exploitation histories. In addition, temperature also has been shown to affect the distribution of tilefish off the northeastern United States (Grimes et al. 1980). It is likely that within areas possessing suitable thermal regimes, substrate composition is a major factor affecting tilefish abundance. While a variety of associations between fish abundance and physicochemical factors have previously been identified (Moyle and Cech 1982), to our knowledge, none approach the intensity of the relationship described herein. We believe that identification of this relationship will aid fisheries biologists in the identification and demographic quantification of tilefish stocks as well as the location of new fishing grounds.

ACKNOWLEDGMENTS

We appreciate the assistance of the captains and crews of both the *Georgia Bulldog* and the *Delaware II*, without whom this work would not have been possible. The following individuals either reviewed the manuscript or aided in other aspects of the study: K. Able, C. Barans, P. Bartlett, E. Chin, D. Beaumariage, D. Daniels, D. Erickson, M. Freeman, S. Floyd, C. Grimes, E. Guthertz, D. Harrington, V. Henry, J. Hill, B. Low, L. Parker, L. Pittman, M. Rawson, D. Stouder, G. Ulrich, and C. Wenner. Facilities and logistic support for this study were graciously provided by the University of Georgia Marine Extension Service at Brunswick. We also wish to acknowledge the continued support of our

research by the Georgia Sea Grant College Program under contract #NA80AA-D-00091. The manuscript was ably typed by Bonnie Fancher.

LITERATURE CITED

- ABLE, K. W., C. B. GRIMES, R. A. COOPER, AND J. R. UZMANN.
1982. Burrow construction and behavior of tilefish, *Lopholatilus chamaeleonticeps*, in Hudson Submarine Canyon. Environ. Biol. Fishes 7:199-205.
- BARKLEY, R. A., W. H. NEILL, AND R. M. GOODING.
1978. Skipjack tuna, *Katsuwonus pelamis*, habitat based on temperature and oxygen requirements. Fish. Bull., U.S. 76: 653-662.
- BARTON, M.
1982. Comparative distribution and habitat preferences of two species of stichaeoid fishes in Yaquina Bay, Oregon. J. Exp. Mar. Biol. Ecol. 59:77-87.
- DAY, D. S., AND W. G. PEARCY.
1968. Species associations of benthic fishes on the continental shelf and slope off Oregon. J. Fish. Res. Board Can. 25: 2665-2675.
- GRIMES, C. B., K. W. ABLE, AND S. C. TURNER.
1980. A preliminary analysis of the tilefish, *Lopholatilus chamaeleonticeps*, fishery in the Mid-Atlantic Bight. Mar. Fish. Rev. 42(11):13-18.
- LAURS, R. M., H. S. H. YUEN, AND J. H. JOHNSON.
1977. Small-scale movements of albacore, *Thunnus alalunga*, in relation to ocean features as indicated by ultrasonic tracking and oceanographic sampling. Fish. Bull., U.S. 75:347-355.
- LOW, R. A., JR., G. F. ULRICH, AND F. BLUM.
1983. Tilefish off South Carolina and Georgia. Mar. Fish. Rev. 45(4-6):16-26.
- MAGNUSON, J. J., L. B. CROWDER, AND P. A. MEDVICK.
1979. Temperature as an ecological resource. Am. Zool. 19: 331-343.
- MARLIAVE, J. B.
1977. Substratum preferences of settling larvae of marine fishes reared in the laboratory. J. Exp. Mar. Biol. Ecol. 27: 47-60.
- MOYLE, P. B., AND J. J. CECHE, JR.
1982. Fishes: an introduction to ichthyology. Prentice Hall, Englewood Cliffs, NJ, 593 p.
- POWELL, A. B., AND F. J. SCHWARTZ.
1977. Distribution of paralichthid flounders (Bothidae: *Paralichthys*) in North Carolina estuaries. Chesapeake Sci. 18: 334-339.
- RADOVICH, J.
1961. Relationships of some marine organisms of the northeast Pacific to water temperatures. Particularly during 1957 through 1959. Calif. Dep. Fish Game, Fish. Bull. 112. 62 p.
- SAS INSTITUTE INC.
1982. SAS user's guide, stat. SAS Institute Inc., Cary, NC.
- TURNER, S. C., C. B. GRIMES, AND K. W. ABLE.
1983. Growth, mortality, and age/size structure of the fisheries for tilefish, *Lopholatilus chamaeleonticeps*, in the Middle-Atlantic-Southern New England region. Fish. Bull., U.S. 81:751-763.
- VALENTINE, P. C., J. R. UZMANN, AND R. A. COOPER.
1980. Geology and biology of Oceanographer Submarine Canyon. Mar. Geol. 38:283-312.
- WARME, J. E., R. A. SLATER, AND R. A. COOPER.
1977. Bioerosion in submarine canyons. In D. J. Stanley and

GARY D. GROSSMAN
MICHAEL J. HARRIS
JOSEPH E. HIGHTOWER

School of Forest Resources
University of Georgia
Athens, GA 30602

THE DEVELOPMENT AND OCCURRENCE OF LARVAE OF THE LONGFIN IRISH LORD, *HEMILEPIDOTUS ZAPUS* (COTTIDAE).

The subfamily Hemilepidotinae, endemic to the North Pacific Ocean, is one of the more generalized subfamilies within the Cottidae (Peden 1978). According to Peden (1978), the subfamily is composed of three subgenera: 1) *Calycilepidotus* which includes *Hemilepidotus spinosus*; 2) *Hemilepidotus* which includes *H. hemilepidotus*, *H. jordani*, *H. zapus*, and *H. gilberti*; and 3) *Melletes* which includes *H. papilio*. The early life histories of most species are inadequately known and separation of larvae in mixed samples is difficult. Gorbunova (1964) described a number of larval series which she labeled *H. hemilepidotus*, *H. gilberti*, *H. gilberti zapus*, *H. jordani*, and *H. papilio*,¹ but these descriptions are incomplete as well as incorrect for several species (Peden 1978; Richardson and Washington 1980). Hattori (1964) described a series of *H. gilberti* larvae (7.1-32.5 mm), and Peden (1978) illustrated postlarvae (> 18 mm) of *H. hemilepidotus*, *H. spinosus*, *H. zapus*, and *H. jordani*. Richardson and Washington (1980) described larvae of *H. hemilepidotus* and *H. spinosus*. We here provide the first complete description of *H. zapus* larvae, and include comments on larval occurrence in the eastern Bering Sea. This work supplements and clarifies the work of previous researchers by providing diagnostic characters useful in distinguishing the species.

MATERIALS AND METHODS

Specimens of *H. zapus* used in this study were collected during ichthyoplankton surveys conducted in the Bering Sea by the Northwest and Alaska Fisheries Center between 1977 and 1980. Morphological

measurements were made on 57 unstained larvae (6.7-22.0 mm SL) following Matarese et al. (1981), except depth at caudal peduncle which was measured at the point of least depth. Measurements were grouped by 1 mm SL intervals, and the means of the measurements within each interval were plotted as percentage of the mean of standard lengths or head lengths within the interval (Kendall and Vinter 1984). A computer-generated best nonparametric curve, based on all data points, was drawn to illustrate relative growth trends. Counts of meristic structures were made on 13 specimens differentially stained according to Dingerkus and Uhler (1977) following procedures outlined in Matarese et al. (1981). Terminology of head spination generally follows Richardson and Laroche (1979) and Richardson and Washington (1980). Illustrations were made by the junior author with a camera lucida, and all specimens were preserved in either 3% Formalin² buffered with sodium borate or 100% glycerin.

Identification of *Hemilepidotus zapus*

We have routinely collected three types of Hemilepidotinae larvae during ichthyoplankton surveys in the eastern Bering Sea (1977-80). According to Peden (1978), four species of adults occur in this area: *Hemilepidotus hemilepidotus*, *H. jordani*, *H. zapus*, and *H. papilio*. Although preflexion larvae of *H. hemilepidotus* and *H. jordani* cannot presently be separated, we can separate the two species at notochord flexion according to differences in external pigment along the posterior body. *Hemilepidotus hemilepidotus* larvae develop pigment above the notochord along the posterior body earlier and in greater density than larvae of *H. jordani* (Fig. 1A, B). Initially, the third series of larvae (< 17.0 mm SL) was misidentified as *H. papilio* (see Waldron and Vinter³) based on the presence of urostyle pigment (Gorbunova 1964). With the acquisition of larger specimens, > 17.0 mm SL, the complete series was later identified as *H. zapus* based on a set of characters taken in part from Peden (1978) (Table 1). Gorbunova's (1964) specimen attributed to *H. zapus* lacks pigment on the urostyle; of her two illustrations of *H. papilio* (footnote 1) only the 10.7 mm SL

²References to trade names do not imply endorsement by the National Marine Fisheries Service, NOAA.

³Waldron, K. D., and B. M. Vinter. 1978. Ichthyoplankton of the eastern Bering Sea. Unpubl. manuscr., 77 p. Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard E., Seattle, WA 98112.

¹*Hemilepidotus papilio* (= *Melletes papilio* from Gorbunova (1964)).