NOTES

REARING CONTAINER SIZE AFFECTS MORPHOLOGY AND NUTRITIONAL CONDITION OF LARVAL JACK MACKEREL, *TRACHURUS SYMMETRICUS*

Container size may be a critical variable in the rearing of marine fish larvae. Northern anchovy, *Engraulis mordax*, grew faster in 500 l than in 10 l containers (Theilacker and McMaster 1971), and Blaxter (1976) suggested that growth of laboratory-reared fish may depend on space available in tanks as well as food supply and fish density. On intuitive grounds, large containers are preferable for rearing studies but small containers are often used because fewer food organisms are required, treatments can be replicated easily, and daily mortality can be easily monitored. Thus, information is needed on the extent container size affects results of laboratory studies on marine larvae. In this paper, I compare the growth, morphology and nutritional condition of jack mackerel, *Trachurus symmetricus*, larvae reared in 10 l and 100 l containers.

Methods

I collected jack mackerel eggs by towing a 1 m (0.505 mm mesh) plankton net just below the sea surface 61 km off southern California in May 1976. Sea surface temperature was 15.3° C. I sorted and staged normally developing eggs from the plankton and stocked eggs of the same stage at 5/l into 10 l and 100 l black circular rearing containers containing 5 μm filtered seawater at 15.0° C and a light cycle of 12 h light and 12 h dark. I used two treatments for each container size, one fed and the other unfed. Data from the 100 l treatments were reported earlier (Theilacker 1978). Larval diet consisted of a naked dinoflagellate, *Gymnodinium splendens* (50/ml), a rotifer, *Brachionus plicatilis* (30-40/ml), and a copepod, *Tisbe* sp. (1-2/ml). This feeding method has been described previously (Lasker et al. 1970; Theilacker and McMaster 1971; Hunter 1976).

Larvae began to eat 5 d after hatching. I sampled 5-30 larvae daily from fed and starved treatments beginning on day 6 and preserved the larvae in Bouin's solution. Four to five weeks after preservation, I measured standard length (SL, tip of upper jaw to perpendicular at end of notochord), head length (HL, tip of upper jaw to cleithrum), eye diameter (ED), body depth at the pectoral fin (BD-1), and body depth at the anus (BD-2). Shrinkage of jack mackerel body parts in Bouin's solution was as follows: SL, 8%; HL, 18%; ED, 10%; BD-1 and BD-2, 25% (Theilacker 1980). (Data in Table 1 are preserved measurements.) After measurement, I used standard techniques (Theilacker 1978) to prepare larvae for histological examination.

I examined the tissue microstructure of all larvae in fed and starved treatments to determine whether larvae were eating or starving. The onset of starvation in jack mackerel larvae is characterized by a change in the acinar arrangement of pancreatic cells and a sloughing of mucosal cells from the midgut into the lumen (Theilacker 1978). I graded these characteristics of the pancreas and gut and classified individual larval nutritional condition as "healthy," "intermediate," or "starved" (Theilacker 1978). Because histological assessments of larval condition are based on tissue microstructure, these assessments are independent of larval size.

Results

Diameter of jack mackerel eggs collected for this study averaged 1.0 mm. Larvae hatched at 2.45 mm SL (preserved) on day 0 and began to eat at 3.35 mm SL at age 5 d when most yolk was absorbed.

Fed larvae were larger in 100 l than in 10 l containers on each day after the onset of feeding (day 5), but statistically significant differences in size among larvae in the large and small containers did not occur until the larvae had fed for 4 d, age 9 d (P = 0.002; Hotelling T^2 multivariate analysis; Table 1).

Among groups receiving no food, larvae in 10 l containers were larger than those starved in 100 l containers at age 8 d, third day of starvation (P = <0.001; Hotelling T^2 multivariate analysis; Table 1.) Also, starved larvae in small containers survived 2 d longer than those in large containers, 10 d versus 8 d.

Nutritional condition of fed larvae reared in 10 l and 100 l containers was similar for 5 feeding days,

TABLE 1.—Daily mean body measurements of fed and starved jack mackerel larvae maintained in 10 l and 100 l containers.

Body parts[1]	Day 6				Day 7				Day 8				Day 9				Day 10				Day 11	
	10		100		10		100		10		100		10		100		10		100		10	
	mm	SD	mm	SD	mm	SD	mm	SD	mm	SD	mm	SD	mm	SD	mm	SD	mm	SD	mm	SD	mm	SD
FED																						
Standard length	3.30	0.16	3.35	0.11	3.43	0.05	3.48	0.13	3.38	0.19	3.56	0.13	3.37	0.13	3.83	0.24	3.35	0.21	3.72	0.20	3.35	0.15
Head length	.67	.03	.70	.03	.73	.02	.74	.04	.73	.05	.77	.03	.71	.03	.85	.06	.75	.07	.85	.07	.76	.06
Eye diameter	.23	.02	.25	.02	.26	.01	.26	.01	.26	.02	.29	.02	.25	.02	.32	.02	.27	.02	.31	.03	.25	.01
Body depth-1	.40	.02	.43	.11	.48	.03	.48	.03	.48	.04	.52	.04	.48	.04	.59	.04	.46	.06	.58	.06	.47	.03
Body depth-2	.18	.01	.20	.05	.19	.01	.20	.02	.19	.02	.22	.02	.19	.02	.25	.01	.20	.02	.23	.02	.18	.01
n	4		15		5		15		5		15		5		10		17		15		7	
^2P	0.463				0.523				0.109				0.002				0.001					
STARVED																						
Standard length			3.31	0.11	3.27	0.15	3.35	0.13	3.29	0.12	3.04	0.17	2.99	0.33			3.07	0.21				
Head length			.66	.04	.68	.03	.69	.02	.71	.03	.64	.04	.65	.04			.66	.05				
Eye diameter			.24	.02	.24	.02	.25	.01	.24	.02	.23	.01	.24	.01			.25	.02				
Body depth-1			.41	.03	.40	.03	.42	.02	.38	.02	.42	.03	.36	.02			.35	.02				
Body depth-2			.18	.02	.18	.01	.18	.01	.17	.01	.17	.01	.17	.01			.17	.01				
n			14		28		15		15		19		16				26					
^2P					0.351				<0.001													

[1] Preserved measurements.
[2] Probabilities for equal body measurements between container sizes (multivariate analysis; Hotelling T^2).

TABLE 2.—Daily histological condition of fed and starved jack mackerel larvae maintained in 10 l and 100 l containers.

Histological grade[1]	FED											STARVED						
	Day 6		Day 7		Day 8		Day 9		Day 10		Day 11	Day 6	Day 7		Day 8		Day 9	Day 10
	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	10
Starved (1.00-1.66)	0	1	0	0	1	1	1	1	8	1	3	7	20	6	12	15	8	22
Intermediate (1.67-2.33)	3	1	0	2	0	3	0	0	4	2	0	3	3	6	0	1	1	2
Healthy (2.34-3.00)	1	12	5	13	3	11	4	9	4	12	3	3	1	2	0	2	0	0
Average grade	2.25	2.77	2.90	2.80	2.50	2.62	2.60	2.80	1.80	2.65	2.08	1.88	1.32	1.71	1.00	1.25	1.11	1.08
^2n	4	14	5	15	4	15	5	10	16	15	6	13	24	14	12	18	9	24
^3P	>0.10		>0.10		>0.10		>0.10		>0.05			>0.10			>0.10			

[1] Theilacker (1978).
[2] Total number of larvae within each treatment does not agree with Table 1, as several larvae were lost during the microtechnique procedure.
[3] Probabilities for equal histological grades between container sizes (two-sample nonparametric Kolmogorov-Smirnov Test).

until age 10 d when it was significantly better in the large containers ($P = <0.05$; Kolmogorov-Smirnov Test; Table 2); fewer larvae were classed as "starved" in the larger containers. For larvae given no food, no difference existed in condition of larvae between large and small containers.

Fed larvae died at ages 12-13 d in the small containers. On day 13 there was also a major mortality in the large containers, but a few larvae survived through the juvenile stage, and one fish lived for 49 d, 31 mm SL. I did not sample these survivors unless they appeared to be dying. For jack mackerel there is no well-defined metamorphosis; the juvenile stage begins at the completion of fin formation, 12-16 mm (Ahlstrom and Ball 1954). In the large container, fin formation was complete at 14 mm, 39 d of age ($n = 1$); size at age for this laboratory-reared fish was similar to field-collected fish (age of wild fish is being determined by reading daily growth increments in otoliths (Methot[1])).

Conclusions

Relating experimental results from laboratory to field conditions must be done with caution. Blaxter (1975) compared morphology, chemistry,

[1] R. Methot, Southwest Fisheries Center La Jolla Laboratory, National Marine Fisheries Service, NOAA, P.O. Box 271, La Jolla, CA 92038, pers. commun. January 1980.

and physiology between reared and wild larvae and concluded that results on growth, nutrition, and mortality of laboratory-reared larvae should not be related to the field. My study shows that jack mackerel larvae reared with food in 10 l containers were smaller and in poorer nutritional condition than larvae reared in 100 l containers. These container-effects occurred at an early age, i.e., morphological differences were evident 9 d after hatching and histological differences 10 d after hatching. Larvae may grow faster and show fewer signs of starvation in large containers because: 1) there is a lower probability of damage from contact with the walls; and/or 2) the same prey density in a larger container may permit the formation of larger food patches and thereby elevate the actual density of food encountered by the larvae; and/or 3) water chemistry in larger containers may be more favorable.

In contrast to results of the feeding experiments, larvae starved in 10 l containers survived 2 d longer and were larger at age 8 d than those in 100 l containers. This indicates that activity may be affected by container size. Larvae in small containers may be less active, consume energy reserves less rapidly, and therefore live longer without food.

The effect of container size on growth, nutritive condition, and possibly activity in jack mackerel larvae, emphasizes the caution that must be exercised when relating results from laboratory to field conditions. The large container may have had no effect on growth and development of jack mackerel, but survival was poor. Further studies are needed to determine the minimum container size required to simulate natural conditions in the laboratory. Because spatial requirements of larval fish depend on locomotory patterns as well as on genetic adaptations to life near solid surfaces (Kinne 1977), optimum container size will probably vary with fish species. In larval fish experiments, container size is a variable that must be considered with temperature, light, food type and availability, and stocking density.

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