LARVAL FISH IN THE VICINITY OF AQUACULTURE INTAKES

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INTRODUCTION

Entrainment and impingement mortality of fishes in water intake facilities has the potential to substantially impact local fish populations (Dempsey 1988; Polgar *et al.* 1988). Investigations on this subject, primarily dealing with cooling water intakes at power plants, have produced disparate results. For instance, Polgar (1988) estimated that more than 50% of the bay anchovies in the Patuxent River near the Chalk Point Steam Electric Station were lost to entrainment while Zeitoun *et al.* (1981) estimated that 90% of native fish larvae at a Great Lakes power plant avoided entrainment. Turnpenny (1988) concluded that the entrainment losses at power stations in Great Britain were "trivial in comparison with commercial landings". Part of the discrepancy in conclusions may come from interpretation of the data. Dempsey (1988) concluded that while numerical losses of ichthyoplankton are high, most would have died anyway and that in terms of "adult equivalents", the losses are not significant. On the other hand, Rago (1984) applies a "Production Forgone" model to ichthyoplankton losses and concludes that ichthyoplankton losses could have a significant ecosystem effect.

Numerous technologies have been proposed or tried to remove impinged organisms from screens or barriers or to prevent impingement in the first place. Fine-mesh traveling screens have been used successfully to retain larvae (Taft *et al.* 1981a) but the larvae are impinged on the screens and washed into fish return systems. Taft *et al.* (1981b) show that impingement mortality rates for larval fish may be near 100%. Weisberg *et al.* (1987) point out that various techniques such as electrified barriers and bubble curtains (Stewart 1981), strobe lights (Patrick *et al.* 1982) and return pump systems (Rogers and Patrick 1985) designed to prevent impingement of juvenile and adult fishes are generally ineffective in reducing impingement of larvae. The general conclusion of most studies aimed at measuring and/or reducing larval mortality in pumped water systems is that reducing entrainment is the key to reducing mortality (Weisberg *et al.* 1987). Although few viable technologies exist for reducing entrainment of fish larvae, wedge-wire screens of 1-2 mm slot sizes have shown some promise (Zeitoun *et al.* 1981; Weisberg *et al.* 1987).

Burst swimming speeds of fish larvae are on the order of 20 body length per second (ie. 10 cm^{-s} for a 5 mm larva) over short distances ($\approx$ 4 body lengths) but sustained swimming speeds are on the order of 1 body length per second or 0.5 cm^{-s} for a 5 mm larva (Webb and Corolla 1981). Thus most larvae $<$ 10 mm would be entrained in a sustained flow of $>$ 15-20 cm^{-s}. Weisberg *et al.* (1987) concluded that wedge-wire screens of 1 mm slot size with an average through-slot velocity of 13 cm^{-s} could successfully reduce entrainment of larvae $>$ 5 mm in length.

Texas Parks and Wildlife Department has recently proposed that all facilities pumping water from Texas estuaries be fitted with 0.5 mm screening to prevent larval fish mortality at these facilities. Data on larval fish distributions in Texas estuaries is quite limited (Holt *et al.* 1990). This report presents the results of a pilot study to examine the impact on larval fishes and shrimps of pumping water into mariculture facilities at three sites on the central and southern Texas Coast. The primary objective of this study was to determine the species composition, density and size structure of ichthyoplankton populations in the vicinity of the intake structures of the three mariculture facilities during their spring and fall pumping seasons. A secondary objective was to determine what organisms were actually being pumped through the system.

MATERIALS AND METHODS

Two of the study sites were located in Matagorda Bay, Calhoun county, and the other was in the lower Laguna Madre in Willacy county (Fig.1). Samples to determine ambient density of larvae near the intakes were taken in surface and bottom collections at three stations at each farm. Water depth at all sites was 1.5-2.0 m. Two sampling trips were made to each farm. Collections were made during late April and May to represent the spring pumping season and again in September to represent the fall pumping season.

Surface and bottom samples were taken in triplicate at each station with 1 m diameter nets of 505 μm mesh pulled by an 8 m shallow-draft skiff. The bottom samples were taken with an epibenthic sled with the net mounted 18 cm off the bottom. Both nets were pulled in an arc to avoid disturbing the vertical structure of the plankton with the prop wash. Net-mounted flowmeters provided sampled water volumes. Samples were preserved in 5 % seawater formalin. Samples were sorted in the laboratory and the larvae were identified to the lowest possible taxa. It was not possible to identify small ($\leq$ 10 mm) anchovies to species so they were lumped as anchovy spp. Anchovies > 10 mm were identified to species and called larval bay or striped anchovy. Anchovies > 15 mm were included in the list but are probably under-represented due to the likelihood of net avoidance by the larger individuals. While white shrimp (*Penaeus setiferus*) postlarvae could be positively identified, we were unable to separate brown (*P. aztecus*) and pink (*P. duorarum*) shrimp and these were lumped as grooved shrimp. Based on the positive identification of a few larger individuals in our collections, we feel that most grooved shrimp were brown shrimp.

Species were picked from the sample, enumerated, and up to 50 individuals of each species were measured to the nearest 0.1 mm. Lengths are notochord length for preflexion larvae and standard length for flexion and post-flexion larvae. No correction was applied to account for shrinkage. All abundances were adjusted for sample volume and are expressed as number per 100 m^3. Surface to bottom temperature, salinity, and turbidity profiles were taken at each site with a Seabird SBE19 CTD.

The Lone Star Shrimp Farm pumped their water from Matagorda Bay through a 25 cm diameter pipe. During spring sampling, the water was drawn through a 0.5m high intake standpipe located 250 m offshore. During fall sampling the water was drawn through a slot in the bulkhead along the shoreline. The pumping velocity was about 7 m^{3-m}. The Laguna Madre Shrimp Farm (recently renamed the Harlingen Shrimp Farm) pumped their water from a 3 m deep pond on land which connected to the Laguna Madre through a 200 m long, 50 m wide inlet. The canal had a sill depth of about .75 m at its juncture with the Laguna Madre. Pumping rate of the intake sampled for this study was about 9 m^{3-min} but the facility also used two other pumps which delivered 25 m^{3-min} which we could not sample due to technical difficulties. The Ocean Ventures Shrimp Farm was not operating during the study and consequently there are no pump samples from this facility. Pump samples at both sites were taken by holding the 1 m plankton net over the outflow pipe for a fixed sampling period, usually 5 minutes. Sample volume was determined using the estimated flow rates for each pump supplied by the farm manager.

RESULTS

Samples were not obtained at all three sites at the Lone Star Shrimp Farm in either spring or fall collections due to high winds and thunderstorms during the spring and extremely high concentrations of cabbagehead jellyfish which made net collections nearly impossible in the fall. The result was that only one station was sampled in each season. Only one station was sampled in the fall at the Ocean Ventures Shrimp Farm. Due to unavailability of pump samples at that site we decided to maximize our efforts at sites where both ambient and pump densities could be obtained.

Diversity and density of larval fish in open water samples varied both seasonally and among sites. In spring samples, there were only 9 taxa taken at the Lone Star Shrimp Farm (Table 1) while 22 taxa were taken at Ocean Ventures Shrimp Farm (Table 2) and 29 were taken at the Laguna Madre Shrimp Farm (Table 3). Species composition and density of individuals also differed substantially among sites. The spring collections at both farms in Matagorda Bay were dominated by gobies and anchovies but substantially more individuals of most species were taken at the Ocean Ventures Shrimp Farm site. The Laguna Madre site was dominated almost exclusively by anchovies with gobies well down the list in dominance ranking. Fall collections were more similar among sites in terms of both number of species and density. All sites were dominated by gobies and anchovies except at the Laguna Madre Shrimp Farm where anchovies were relatively low in abundance ranking.

Species of direct economical importance (recreational or commercial species) were found at all sites. White and grooved shrimp postlarvae were usually the most common of these but some sites had relatively high densities of spotted seatrout larvae, especially in the spring Laguna Madre samples. Black drum larvae were also taken at low density at the Ocean Ventures site.

Larval fish and shrimp were clearly taken in through the pumps but in all cases there was a greater diversity of larvae in the water column than in the pump samples (Tables 1-3). The most common species taken in pump samples were shrimp postlarvae. Both white and grooved shrimp were collected and they were often found in higher densities in pump samples than in ambient water column densities. No fish species was consistently taken in the pump samples. Gobies and anchovies were the dominant fish collected in pump samples but other species including, spotted seatrout and silver perch were taken in single samples.

Most organisms taken in the pump samples were < 10mm and generally, mean size of larvae taken in pump samples was smaller than mean size of the same species taken in ambient water column samples. The only larger organisms in the pump samples were a 20.0 mm sheepshead and a 16.0 mm dwarf seahorse

Details of the surface, bottom, and pump densities of some of the common or "important" species taken in pump samples are given in Figures 2-6. White shrimp (Fig. 2) were taken in every pump sample and always at higher than ambient densities. Grooved shrimp were taken in three of the four pump samples and, like white shrimp, at higher than ambient densities (Fig. 3). In water column samples, white shrimp were always found at equal or higher densities in surface tows than in bottom tows while bottom catches usually slightly exceeded surface catches for grooved shrimp. Spotted seatrout catches were substantially higher in bottom than surface tows in all but the spring Ocean Ventures site (Fig. 4). Spotted seatrout were taken in pump samples only at the Lone Star Shrimp Farm site but at higher than ambient densities. Spotted seatrout in the pump samples were also larger, averaging 8.3 mm (n=11) in pump samples and only 3.9 mm (n=23) in water column samples. Gobies were taken in spring pump samples at both the Lone Star Shrimp Farm and the Laguna Madre Shrimp Farm (Fig. 5) but at very low densities relative to ambient densities in the water column. Despite high ambient densities in the fall, there were no gobies taken in pump samples at either farm. Anchovies were taken in pump samples only at the Lone Star Shrimp Farm. Despite the high ambient densities of several size classes of anchovies, only the smallest individuals (anchovy spp.) were taken in pump samples and at extremely low densities relative to ambient water column densities (Fig. 6). In a few cases there were species taken in pump samples which were not collected in the ambient water column samples near the intake during that season (Table 1 and 3). Sheepshead and an unidentified carangid were taken only in pump samples.

DISCUSSION

The results of this pilot study offer some indications of the effect on ichthyoplankton of pumping water at mariculture facilities. It must be remembered that this small study could not provide a thorough examination of the ichthyoplankton potentially vulnerable to entrainment at all mariculture sites in all seasons. More importantly, the data on larvae pulled through pumps is based on relatively small samples sizes and are from experimental methods which need further refinement. In particular, the sample volumes of the pump samples are only general approximations and the data on larvae taken in through the pumps is more qualitative than quantitative.

It is clear from the net tows taken in the vicinity of intake structures of existing mariculture facilities that there are large numbers of ichthyoplankton which are potentially vulnerable to entrainment in water pumping systems. Data from this study show however, that most fish species found in ambient water column samples were not taken in any pump samples or were taken in low densities in relation to water column densities. It appears that avoidance response of most fish larvae found in the vicinity of the two mariculture farms covered in this study is effective in preventing entrainment through the pumps. The only fish species taken at equivalent or higher than ambient density was spotted seatrout and this occurred only at the Lone Star Shrimp Farm. The physical layout of the intake structures is substantially different between the farms and the potential effect of this will be discussed below.

Penaeid shrimp were particularly vulnerable to entrainment. Power plant entrainment studies typically emphasize fish (Weisberg *et al.* 1987; Dempsey 1988;

Turnpenny 1988) and entrainment and impingement of invertebrates has received less attention. Both white shrimp and grooved shrimp postlarvae were consistently taken in pump samples at higher than ambient densities in this study. While most investigators report lower entrainment densities than ambient densities, Zeitoun *et al.* (1981) found minnows entrained at higher than ambient densities in June and July but not in August in a Great Lakes power station intake. They offered no explanation for entrainment at higher than ambient densities but suggested that by August, the minnows had grown sufficiently large to avoid the intake. It is not clear why shrimp were entrained through the pumps at higher than ambient densities in this study. It could be due to an inferior ability of shrimp postlarvae to detect or avoid the pumps relative to fish or to some behavioral trait which actually attracts them to the pumps. We have no direct evidence to support either of these or any other hypothesis but the data are clear that high rates of entrainment do, in fact, occur.

The different physical structure of the two intake systems may have some effect on larval entrainment. The Lone Star Shrimp Farm intake was out in open water in the spring sampling period and along a bulkheaded shoreline in the fall, while the Laguna Madre Shrimp Farm intake was in an inland pond at the end of a 200 m long inlet. While we were able to sample immediately adjacent to the intake of the Lone Star Shrimp Farm, the shallow waters of the Laguna Madre prevented us from getting closer than 100-200 m from the shoreline and the intake water for the Laguna Madre Shrimp Farm was drawn from water immediately along the shore. Thus, the data from the Laguna Madre Shrimp Farm represent ambient densities of larvae only in the general vicinity of the intake.

While shrimp larvae were entrained in high numbers in both systems, fish larvae appeared more vulnerable to the open water pumping system of the Lone Star Shrimp Farm. Pelagic larvae such as anchovies, gobies, and sciaenids were common at both sites but they were taken in pump samples primarily at the Lone Star Shrimp Farm. Anchovies, gobies, sciaenids, and a carangid were taken in pump samples at the Lone Star Shrimp Farm while only gobies and a rather large (20 mm) sheepshead were the only pelagic larvae taken at the Laguna Madre Shrimp Farm (the other fish taken there was a demersal species, dwarf seahorse). We were not able to directly sample the intake canal but these data suggest that most pelagic fish larvae were not drawn into or attracted to the canal but shrimp postlarvae were clearly there.

This limited study suggest that both shrimp and fish larvae are potentially vulnerable to entrainment in pump systems of mariculture operations. There is a suggestion that the physical layout of the intake system may influence the kinds and numbers of larvae entrained. The "intake canal" system used at the Laguna Madre Shrimp Farm appears to entrain fewer fish larvae than the "open-water standpipe" system used at the Lone Star Shrimp Farm

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Table 1. Ambient mean density (No. larvae per 100 m3) and mean length (mm) of each taxa taken in net tows at open water sitesadjacent to each farm. Mean density and mean length of larvae collected in pump samples in each season at the Lone Star Shrimp Farm.

		Nets		Pump	
Trip	Species	Density	Length	Density	Length
Spring	Goby sp.	284.5	7.0	30.1	6.3
	Larval anchovy spp.	206.3	6.5	1.5	5.0
	Larval bay anchovy	25.3	12.7		
	Larval striped anchovy	4.9	11.4		
	Bay anchovy	4.9		0.7	
	Grooved Shrimp	0.9	9.4		
	Skillet fish	0.9	7.2		
	Hogchoker	0.9	3.2		
	Least puffer	0.4	7.4		
	White shrimp			2.2	5.8
	Naked goby			15.4	6.7
	Jack sp2.			0.7	
	No. of Individuals	529.0		50.7	
	No. of species	9		6	
Fall	Goby sp.	148.5	2.8		
	Larval anchovy spp.	80.9	5.8	1.1	5.8
	Larval bay anchovy	3.8	12.8		
	Bay anchovy	3.6			
	Spotted seatrout	2.5	3.9	11.6	8.3
	Larval striped anchovy	0.4	11.8		
	White shrimp	0.4	10.4	43.4	9.9
	Seriola sp.	0.1	17.5		
	Dwarf seahorse	0.1	16.7		
	Pipefish sp.	0.1	11.0		
	Hogchoker	0.1			
	Grooved Shrimp			6.4	13.0
	Silver perch			1.1	6.1
	No. of Individuals	240.5		63.5	
	No. of species	11		5	

Table 2. Ambient mean density (No. larvae per 100 m3) and mean length of each taxa taken in net tows at open water sitesadjacent to each farm. Mean density and mean length of larvae collected in pump samples in each season at the Ocean Ventures Shrimp Farm. (There were no pump samples)

		Nets	
Trip	Species	Density	Length
Spring	Goby sp.	1204.5	4.9
	Larval anchovy spp.	650.7	6.0
	Larval bay anchovy	429.9	12.5
	Bay anchovy	168.6	
	Larval striped anchovy	18.8	11.4
	Clupied sp.	17.7	18.9
	Silver perch	14.6	8.6
	Blenny sp.	9.3	4.8
	Grooved Shrimp	9.2	11.93
	Skilletfish	8.8	4.9
	Striped anchovy	4.8	
	Least puffer	1.4	13.4
	Silverside sp.	0.7	7.0
	White shrimp	0.6	9.8
	Sand seatrout	0.5	22.3
	Pipefish sp.	0.4	12.3
	Black drum	0.3	3.0
	Spotted seatrout	0.3	2.6
	Sea bass sp.	0.1	18.1
	Pinfish	0.1	10.8
	Lined Sole	0.1	1.9
	Lizardfish sp.	0.1	32.0
	No. of Individuals	2541.3	
	No. of species	22	

Table 2. (cont.)

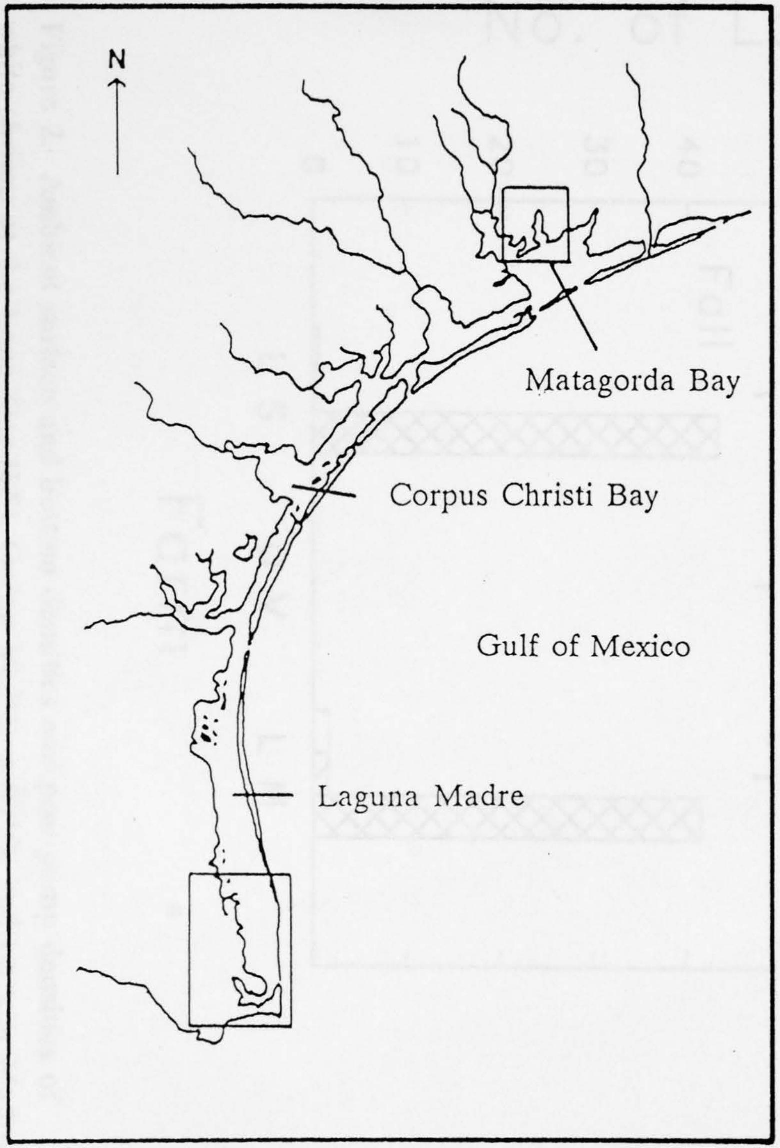
Trip	Species	Nets Density	Nets Length
Fall	White shrimp	73.5	
	Skilletfish	0.2	4.2
	Silverside sp.	0.2	3.1
	Naked goby	123.6	4.4
	Larval bay anchovy	42.8	12.7
	Larval anchovy spp.	2.8	8.3
	Grooved Shrimp	0.2	8.96
	Green Goby	27.2	6.0
	Goby sp.	4.8	3.5
	Feather blenny	1.8	2.9
	No. of Individuals	276.9	
	No. of species	10	

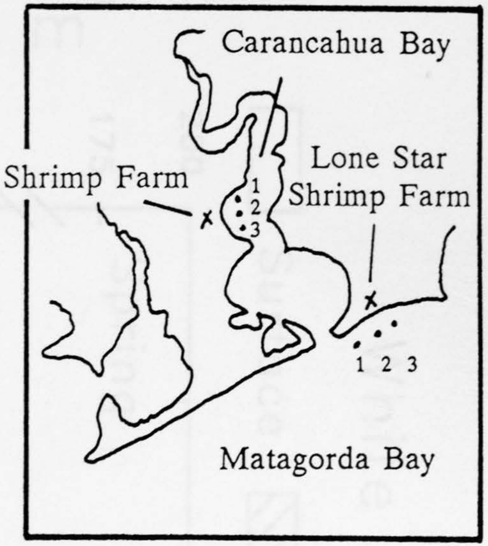
Table 3. Ambient mean density (No. larvae per 100 m3) and mean length of each taxa taken in net tows at open water sitesadjacent to each farm. Mean density and mean length of larvae collected in pump samples in each season at the Laguna Madre Shrimp Farm.

		Nets		Pump	
Trip	Species	Density	Length	Density	Length
Spring	Larval anchovy spp.	372.1	5.8		
	Larval striped anchovy	272.1	13.0		
	Larval bay anchovy	200.7	12.4		
	Striped anchovy	132.9			
	Bay anchovy	55.2			
	Clupied sp.	30.7	7.5		
	Spotted seatrout	21.9	2.0		
	White shrimp	19.5	7.6	197.8	6.9
	Goby sp.	11.7	3.7	2.4	11.9
	Grooved Shrimp	6.0	8.6	58.7	9.6
	Naked goby	3.8	3.2		
	Striped Burrfish	3.1	2.2		
	Pipefish sp.	1.0	14.7		
	Lined Sole	0.8	2.2		
	Silver perch	0.8	2.8		
	Least puffer	0.8	2.1		
	Gulf pipefish	0.4	11.8		
	Skilletfish	0.3	2.3		
	Menticirrhus sp.	0.2	2.4		
	Green Goby	0.2	5.0		
	Sand seatrout	0.2	4.5		
	Blenny sp.	0.2	3.1		
	Hogchoker	0.2	1.6		
	Jack sp2.	0.2	1.8		
	Dwarf seahorse	0.1	4.2	1.6	16.0
	Feather blenny	0.1	2.9		
	Pinfish	0.1	27.0		
	Pigfish	0.1	11.8		
	Silverside sp.	0.1	7.1		
	Sheepshead			0.8	20.0
	No. of Individuals	1135.3		261.4	
	No. of species	29		5	

Table 3. (cont.)

Trip	Species	Nets Density	Nets Length	Pump Density	Pump Length
Fall	Goby sp.	100.7	3.5		
	Grooved Shrimp	1.1	8.98	1.41	7.84
	White shrimp	0.9	6.2	6.43	6.13
	Pipefish sp.	0.6	10.9		
	Spotted seatrout	0.6	3.4		
	Larval anchovy spp.	0.3	5.1		
	Naked goby	0.3	3.4		
	Gulf pipefish	0.2	7.6		
	Leatherjacket	0.2	4.4		
	Feather blenny	0.2	4.2		
	Larval striped anchovy	0.1	11.0		
	Blenny sp.	0.1	6.2		
	Sand seatrout	0.1	5.4		
	No. of Individuals	105.2		7.8	
	No. of species	13		2	





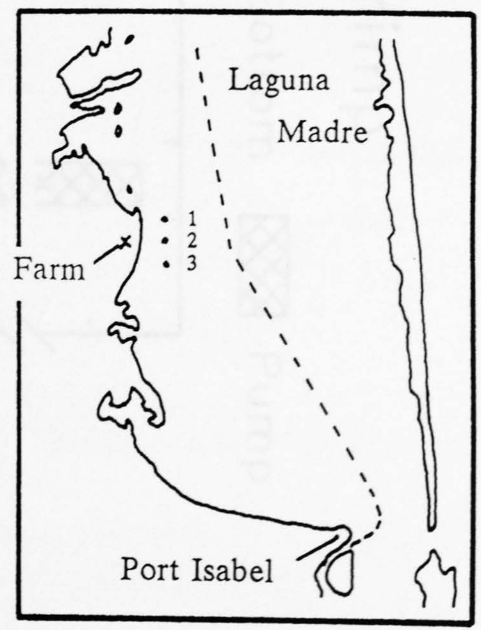


Figure 1. Location of shrimp farms and open water ichthyoplankton sample sites.

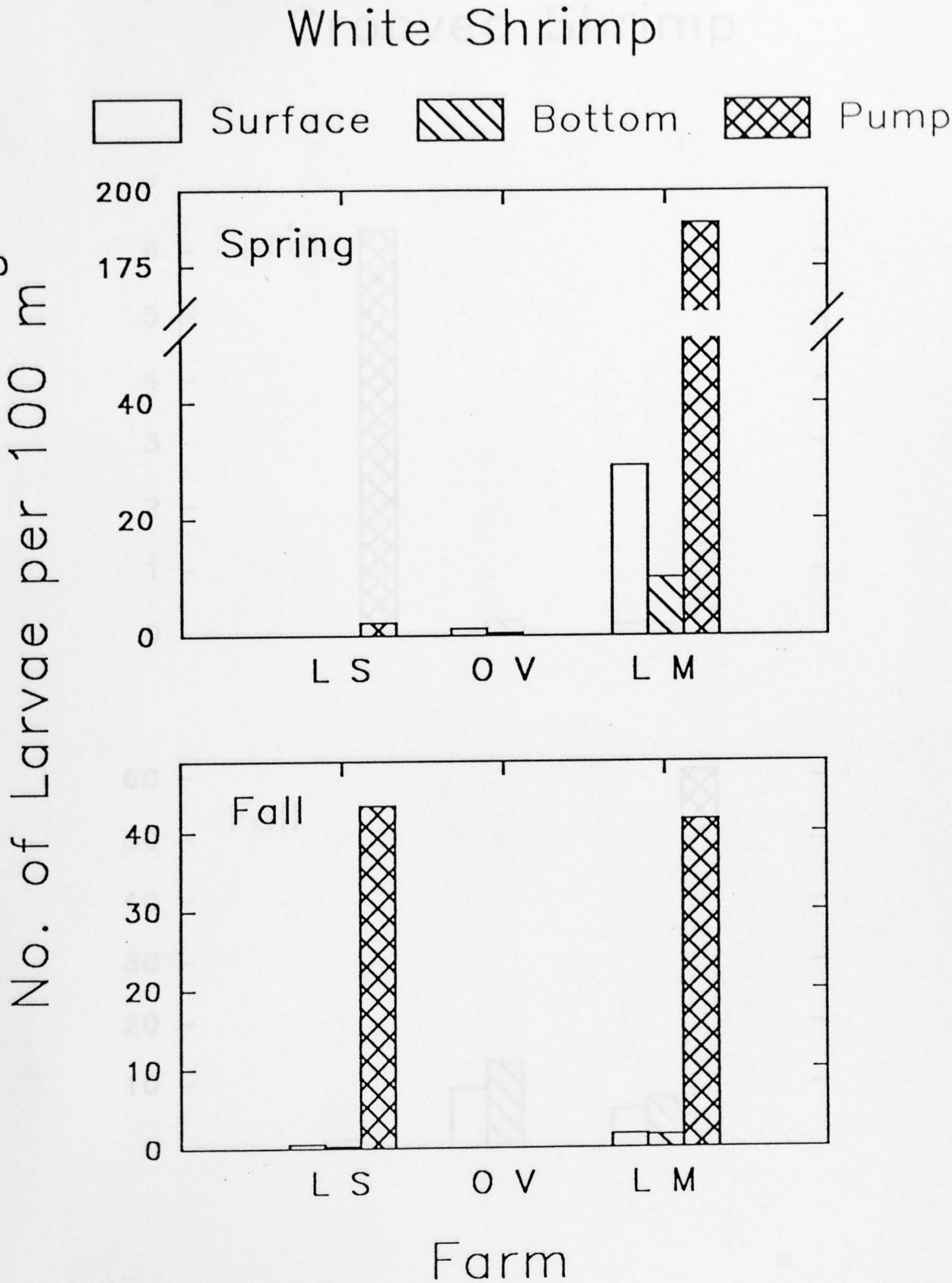


Figure 2. Ambient surface and bottom densities and post-pump densities of white shrimp at the Lone Star (LS), Ocean Ventures (OV), and Laguna Madre (LM) Shrimp Farms during spring and fall sampling periods.

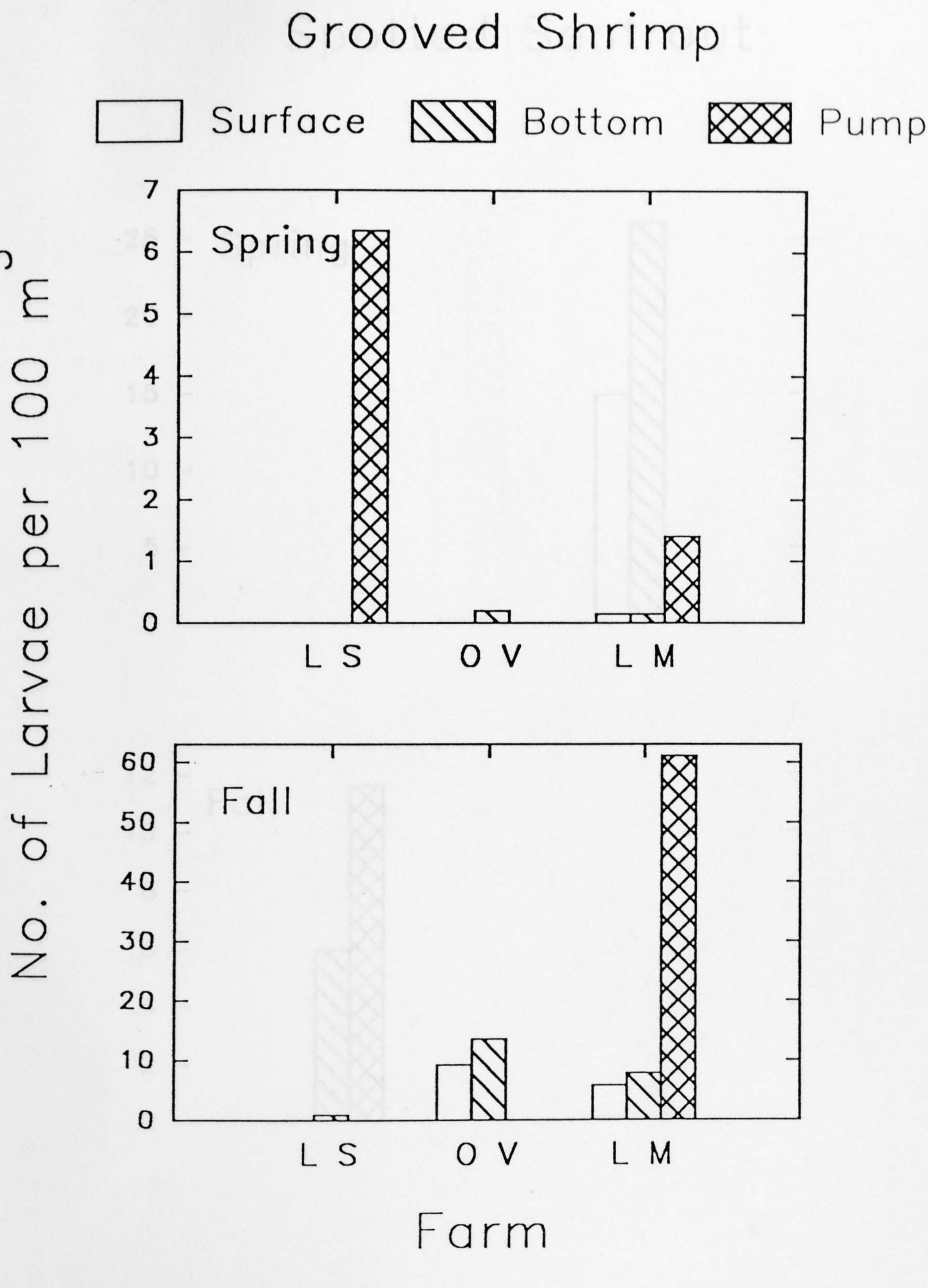


Figure 3. Ambient surface and bottom densities and post-pump densities of grooved shrimp at the Lone Star (LS), Ocean Ventures (OV), and Laguna Madre (LM) Shrimp Farms during spring and fall sampling periods.

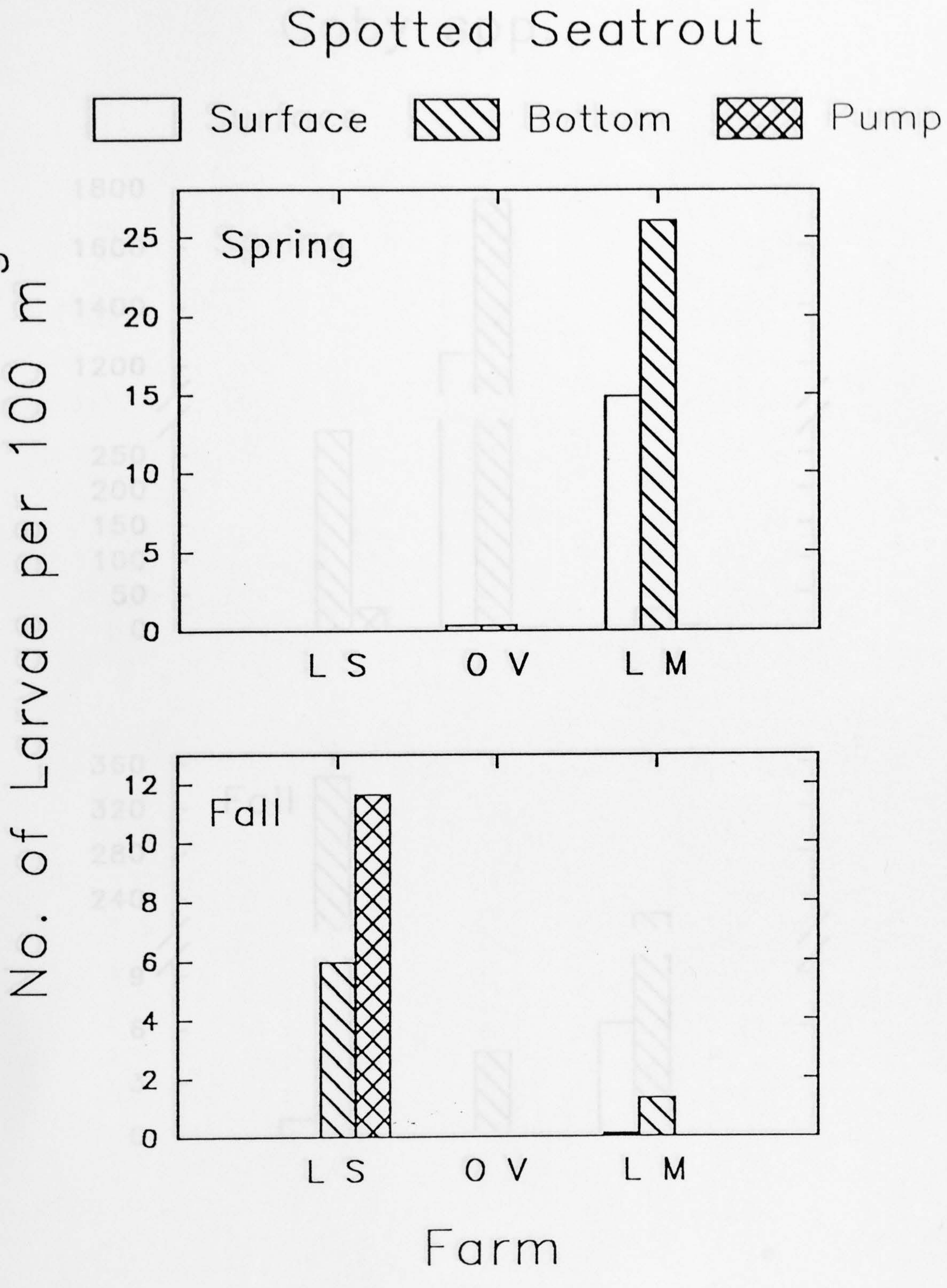


Figure 4. Ambient surface and bottom densities and post-pump densities of spotted seatrout at the Lone Star (LS), Ocean Ventures (OV), and Laguna Madre (LM) Shrimp Farms during spring and fall sampling periods.

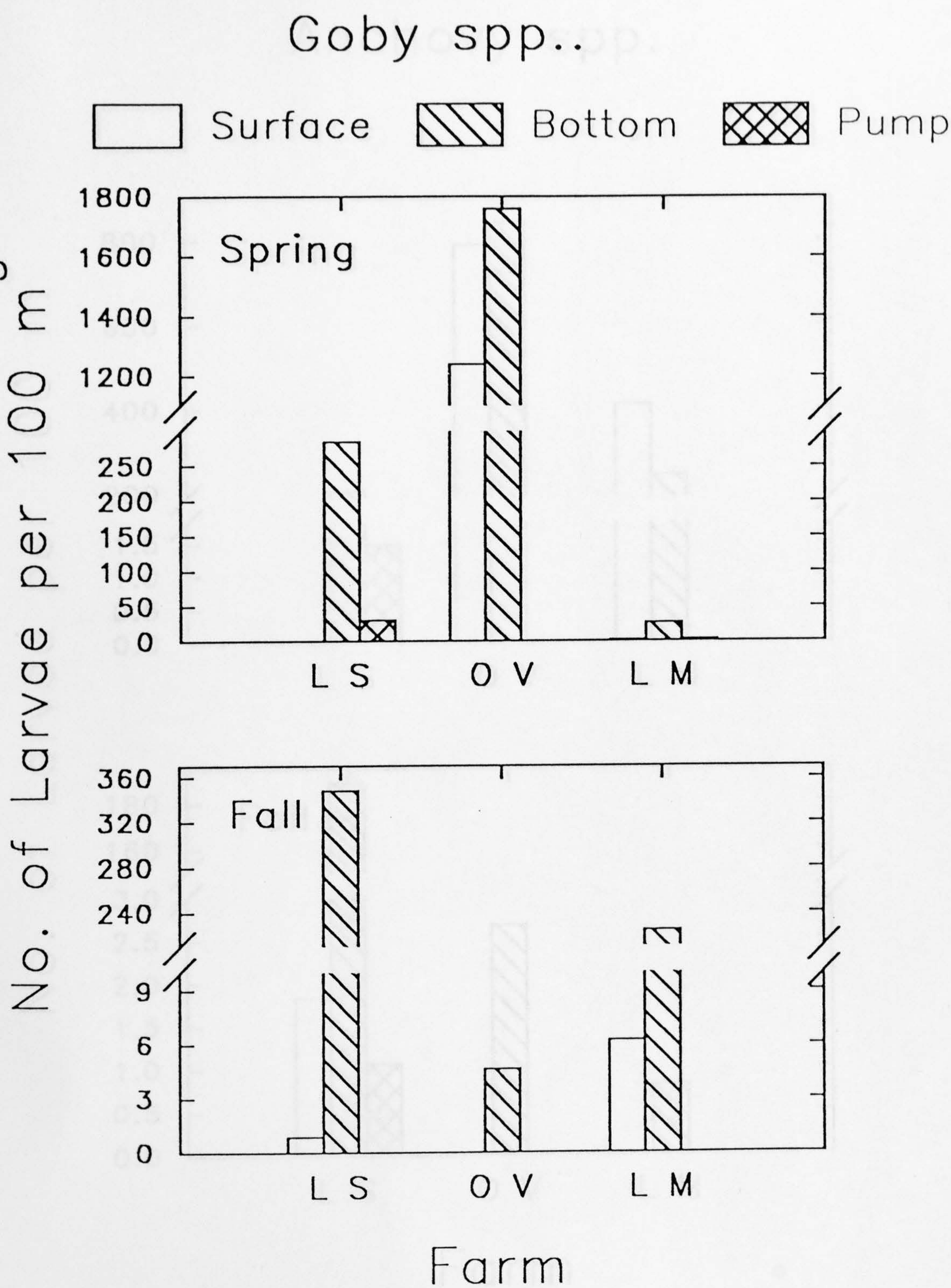


Figure 5. Ambient surface and bottom densities and post-pump densities of Goby spp. at the Lone Star (LS), Ocean Ventures (OV), and Laguna Madre (LM) Shrimp Farms during spring and fall sampling periods.

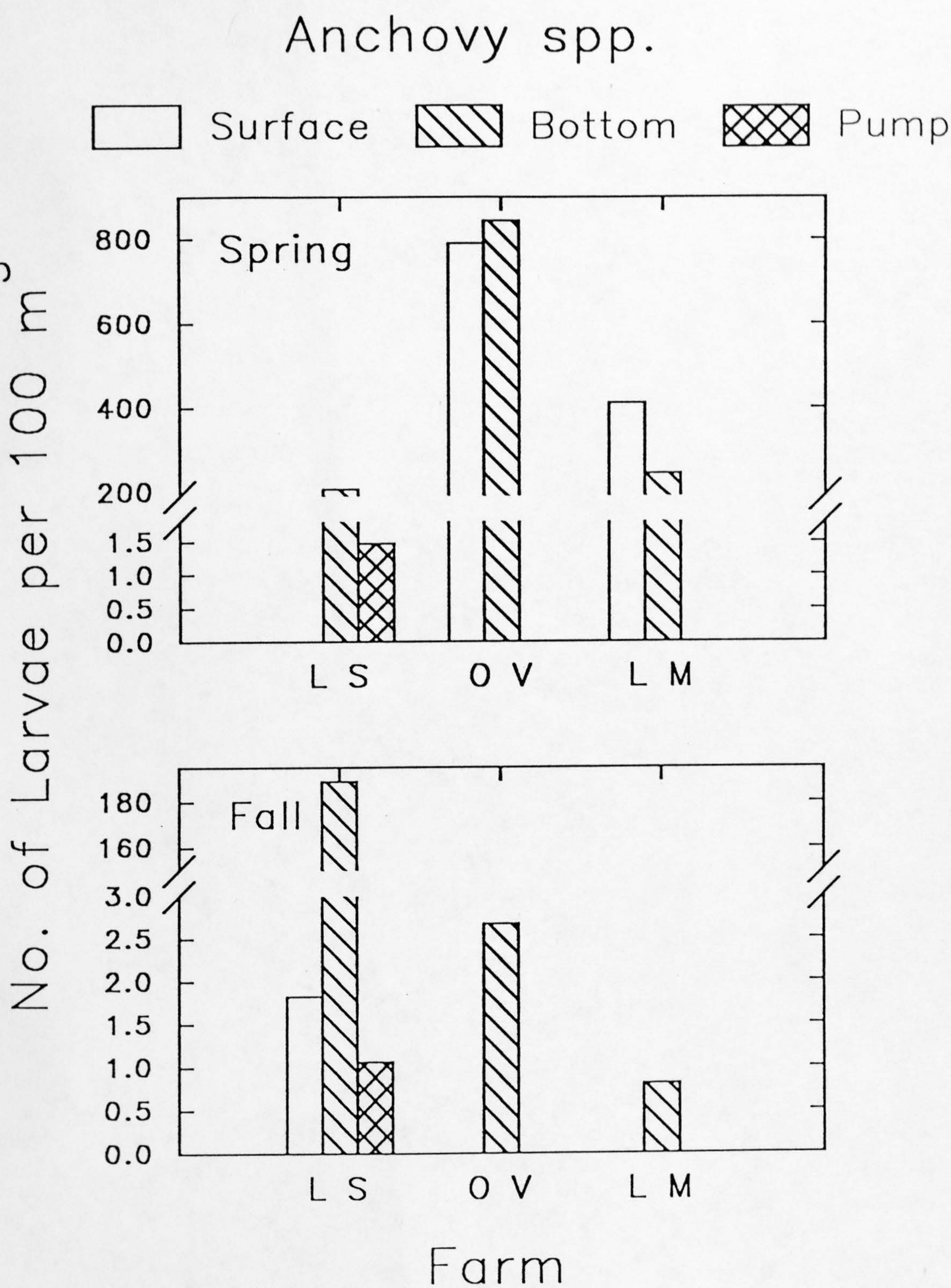


Figure 6. Ambient surface and bottom densities and post-pump densities of Anchovy. spp. at the Lone Star (LS), Ocean Ventures (OV), and Laguna Madre (LM) Shrimp Farms during spring and fall sampling periods.