Vertical Distribution of Fish Larvae and Its Relation to Water Column Structure in the Southwestern Gulf of California[1]

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Abstract: The seasonal evolution of vertical distribution of fish larvae and its relationship with seasonal stratification, as measured by a quantitative stability parameter, were analyzed for a region off Bahía de La Paz in the southwestern Gulf of California. Samples were obtained with an opening-closing net (505 μm) in 50-m depth strata from surface to 200-m depth in May, July, and October 2001 and February 2002. Significant differences in total larval abundance and in dominant species (mesopelagic and epipelagic) were found among strata from May to October. More larvae were found in maximum-stability strata (from 16 ± 5 to 48 ± 17 m depth) than below the pycnocline (from 100- to 150-m depth). In February, the 100-m-deep surface mixed layer had a weak pycnocline at its base, and no significant difference was found. Results show that vertical distribution of fish larvae in this area depends mainly on the seasonal evolution of the water column structure, with most fish larvae in the pycnocline, at the most stable stratum of the water column.

Vertical gradients in concentration of fish larvae and zooplankton are usually stronger than horizontal gradients (Ahlstrom 1959, Lasker 1981, Röpke 1993). These vertical gradients may be associated with seasonal changes in the hydrographic structure of the water column, such as temperature and salinity gradients, mixed layer depth, and other changes, as well as biological factors such as behavior and development stage of the species or the vertical distribution of their prey and predators (Lasker 1975, Munk et al. 1989, Moser and Smith 1993).

Studies of vertical distribution of fish larvae in the open sea have shown that the greatest abundance and diversity occur through the pycnocline (layer of sharp change in water density with depth) during periods of strong stratification in the water column or in the surface mixed layer during periods affected by strong winds and tides (e.g., Ahlstrom 1959, Lasker 1975, Loeb and Nichols 1984). However, studies in coastal and reef areas, where the structure of the water column is complex and less constant than in the open sea, have found that vertical distribution of fish larvae depends more on the behavior of each species than on the physics of the water column (Fortier and Harris 1989, Leis 1993).

Even though these studies have generated important information on vertical distribution of fish larvae in specific areas and periods, knowledge on seasonal evolution of vertical distribution of fish larvae in relation to water column structure in tropical regions is still incipient. In particular, although it has been a long time since Sverdrup (1953) linked

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spring phytoplankton bloom to stability through his critical depth hypothesis and Lasker (1975, 1981) postulated that a stable environment promotes aggregation of fish larvae and their prey, thereby enhancing larval survival, studies that relate vertical distribution of fish larvae to stability measurements of the water column are practically nonexistent. Because the hypotheses described in those studies were designed for midlatitude conditions, it is particularly interesting to know whether they apply to vertical distribution of larvae in tropical regions such as the Gulf of California.

The southern Gulf of California is characterized by strong seasonal variation in the structure of the water. In spring and summer the stratification reaches the surface, but in winter the surface mixed layer can reach down to 100-m depth (e.g., Castro et al. 2000, Amador-Buenrostro et al. 2003, Lavín and Marinone 2003, Trasviña-Castro et al. 2003). Bahía de La Paz (Figure 1) is the largest coastal embayment on the southwestern side of the Gulf of California and is connected with the gulf through two entrances. The main entrance (northeast of the bay) is wide (37 km) and deep (250 m), whereas the smaller entrance (south of the bay), is narrow (7 km) and shallow (19 m). In association with the physiography of the main entrance of the bay, a high diversity and abundance of fish species of commercial and ecological importance, both in larval and adult stages, have been recorded (e.g., Balart et al. 1997, González-Armas 2002, Muhlia-Melo et al. 2003, Sánchez-Velasco et al. 2004).

Because of the continuous interaction between the main entrance of the bay and the gulf (Trasviña-Castro et al. 2003, Sánchez-Velasco et al. 2006), it was expected that fish larvae of a large number of species would be distributed vertically as a function of the seasonal changes of the water column structure (e.g., maximum stability, pycnocline and surface mixed layer depth). The aim of this study is to make an initial description of vertical distribution of fish larvae in the southwestern gulf just outside the main entrance to Bahía de La Paz, its seasonal evolution, and its relationships with the vertical structure of the water column. A quantitative measure of stability was used to link the seasonal changes of the vertical distribution of larvae to stratification.

MATERIALS AND METHODS

Physical and zooplankton data were obtained at nine stations on board the R/V *Francisco de Ulloa* (CICESE) during four oceanographic cruises, 19 to 23 May, 21 to 25 July, and 26 to 30 October 2001 and 11 to 15 February 2002, in the vicinity of the main entrance to Bahía de la Paz (Figure 1).

Vertical profiles of temperature and conductivity were obtained at each station with a conductivity, temperature, depth profiler (model 911 plus, Sea-Bird Electronics, Bellevue, Washington). The data were processed with the manufacturer's software to obtain temperature and salinity profiles interpolated to 1-m intervals. A Hanning filter was applied five times to the potential temperature (T) and salinity (S) profiles before calculating the potential density anomaly, $\gamma(z) = \rho(z) - 1{,}000$, where ρ is density and z is depth, which was then used to calculate the stability parameter, $E(z) = -\rho^{-1}\, d\rho/dz$; the latter is a local measure of stratification, being maximum where the pycnocline is the strongest.

The depth of the surface mixed layer (H_{mix}), the range of the pycnocline, and the depth of maximum stability (Z_{Emax}) were estimated by examination, for each station, of the profiles $T(z)$, $S(z)$, $\gamma(z)$, and, especially, $E(z)$. Mean profiles of those variables were also obtained for each cruise.

The zooplankton samples were collected during both daylight and darkness with an opening-closing conical zooplankton net with 50-cm mouth diameter, 250-cm mesh length, and 505-μm mesh size, at four depth strata: 0–50 m, 50–100 m, 100–150 m, and 150–200 m. The depth of each stratum was calculated by the cosine of the wire angle method following the standard specifications of Smith and Richardson (1979). The mean bottom depth was 250 m. The deepest interval was not sampled in February 2002 due to technical problems (the cable had to be cut during

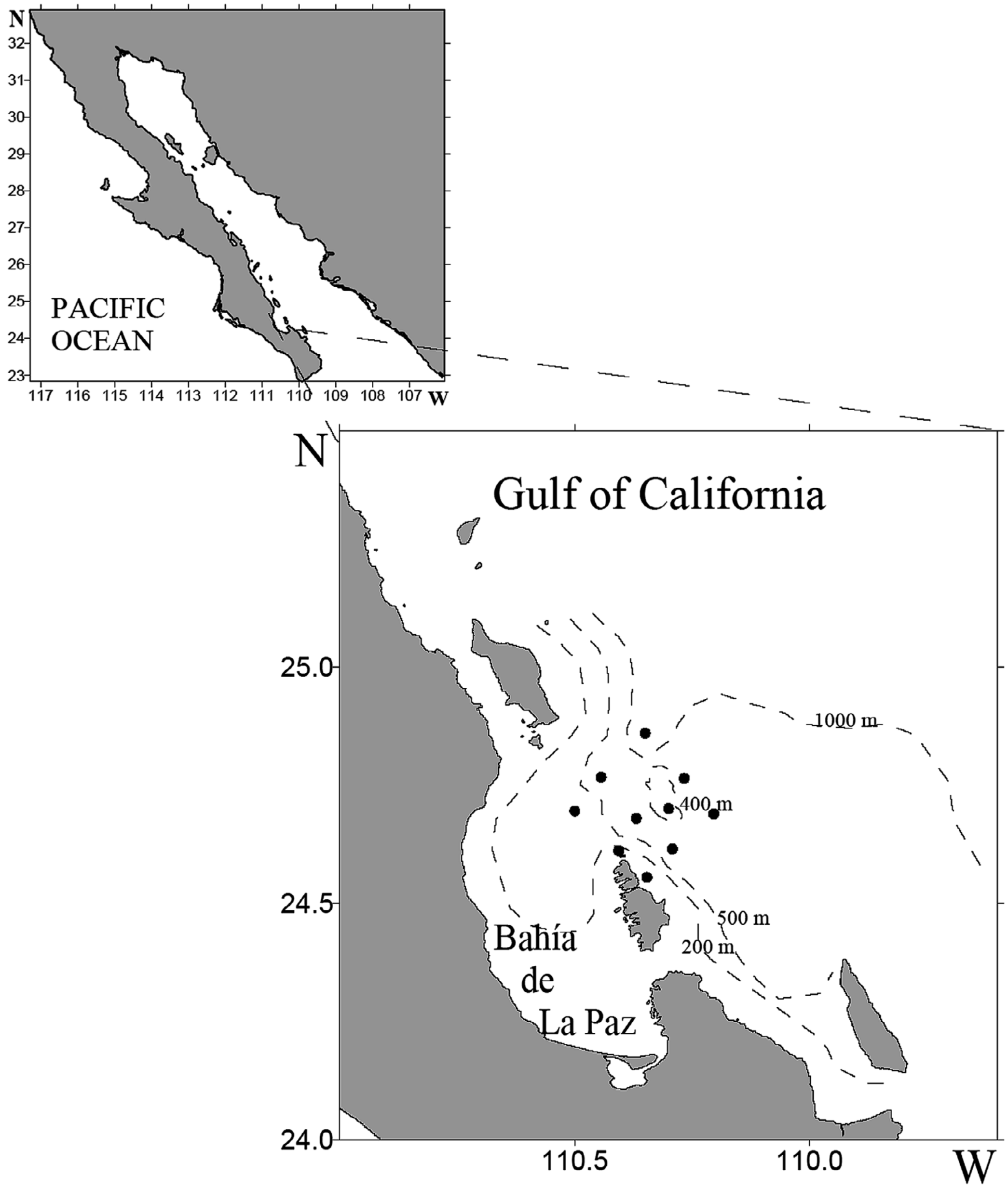

FIGURE 1. Location of the study area and sampling stations.

the cruise). The filtered water volume was calculated using calibrated flowmeters placed in the mouth of the nets. Each sample was fixed with 5% formalin buffered with sodium borate. Larvae were removed from the samples and identified according to the descriptions of Moser (1996). Larval abundance was standardized to number of larvae per 10 m^2.

Because of the great variance characteristic of the zooplankton organisms, which are dis-

TABLE 1

Total Larval Abundance between Light and Darkness Hours off Bahía de La Paz (Gulf of California) (Nonparametric Mann-Whitney Test [Mann and Whitney 1947])

Cruise	Water Column Level (m) 0–50	50–100	100–150	150–200	All Levels
May 2001	5 (1/14)	2 (1/14)	5 (1/14)	2 (1/14)	2 (1/14)
July 2001	0 (0/12)	0* (2/16)	2 (2/16)	3 (0/12)	3 (2/16)
October 2001	1 (0/12)	3 (2/16)	5 (2/16)	4 (0/12)	3 (2/16)
February 2002	13 (1/15)	6 (2/18)	13 (2/18)		7 (2/18)

Note: Numbers within parentheses represent critical values (minimum/maximum). Asterisk indicates value outside the critical range that was significantly different ($P \leq .05$).

tributed in patches in the sea (Margalef 1968), the nonparametric Mann-Whitney test (Sokal and Rohlf 1979) was used to assess the statistical significance of differences of the total larval abundance between day and night hours and among the different depth strata in each sampled period. There was no significant difference in total larval abundance between day and night hours in all cases ($P > .05$), except in one stratum in July (Table 1).

Similarities among the different depth strata were based on taxa with a frequency of occurrence ≥5% in each period. To reduce the weight of the most abundant species, the standardized data were fourth-root transformed. Groups of strata were defined using the Bray-Curtis dissimilarity index, a technique that is not affected by multiple absences and gives more weight to abundant species than to rare ones (Bray and Curtis 1957, Field et al. 1982). Dendrograms were made by the flexible agglomerative clustering method (Sokal and Sneath 1963).

RESULTS

The T-S diagram and the average profiles $T(z)$, $S(z)$, $\gamma(z)$ (Figure 2) show the usual seasonal pattern of the Gulf of California hydrography (Castro et al. 2000, Lavín and Marinone 2003). The 0- to 150-m layer was occupied most of the year by Gulf of California Water (GCW $S > 35$ ups, $T > 12°C$), except in October when Tropical Surface Water (TSW $S < 35$ ups, $T > 18°C$) completely displaced the GCW in the 0- to 60-m layer. Subtropical Subsurface Water (StSsW) was present from 150 to 500 m, and Pacific Intermediate Water (PIW) in the remainder of the sampled water column. The seasonal evolution of stratification in the top 200 m of the water column, described here, is based on the mean stability profiles $E(z)$ (Figure 3).

In May, some stratification was present from the surface to 100 m; the high values of the stability parameter $E(z)$ in the upper 50 m ($Z_{Emax} = 16 \pm 5$ m) indicate that the pycnocline covered from near the surface to ~40 m. In half of the stations the surface mixed layer depth was 10 m, and in the other half it was 0 m; in the latter, the surface salinity ($S_s = 35.31$) was the highest of the study (Table 2).

In this period, fish larvae of 27 species in 19 families were collected (Appendix). Significant differences between the total larval abundance of the 0- to 50-m and 100- to 150-m strata and between the 0- to 50-m and 150- to 200-m strata were found ($P < .05$) (Table 3). The most abundant species were *Vinciguerria lucetia* (Phosichthyidae) (65%), *Diogenichthys laternatus* (Myctophidae) (11%), and *Opisthonema* spp. (Clupeidae) (7%) accounting for 83% of the fish larvae caught in the cruise. The first two species were distributed over the entire sampled water column, whereas *Opisthonema* spp. larvae were found only in the upper 50 m. The larval abundance of *V. lucetia* was significantly different between the 0- to 50-m and the 100- to 200-m strata ($P < .05$) (Figure 4). Although the highest mean larval abundance of this species was in the 50- to 100-m stratum, it was not

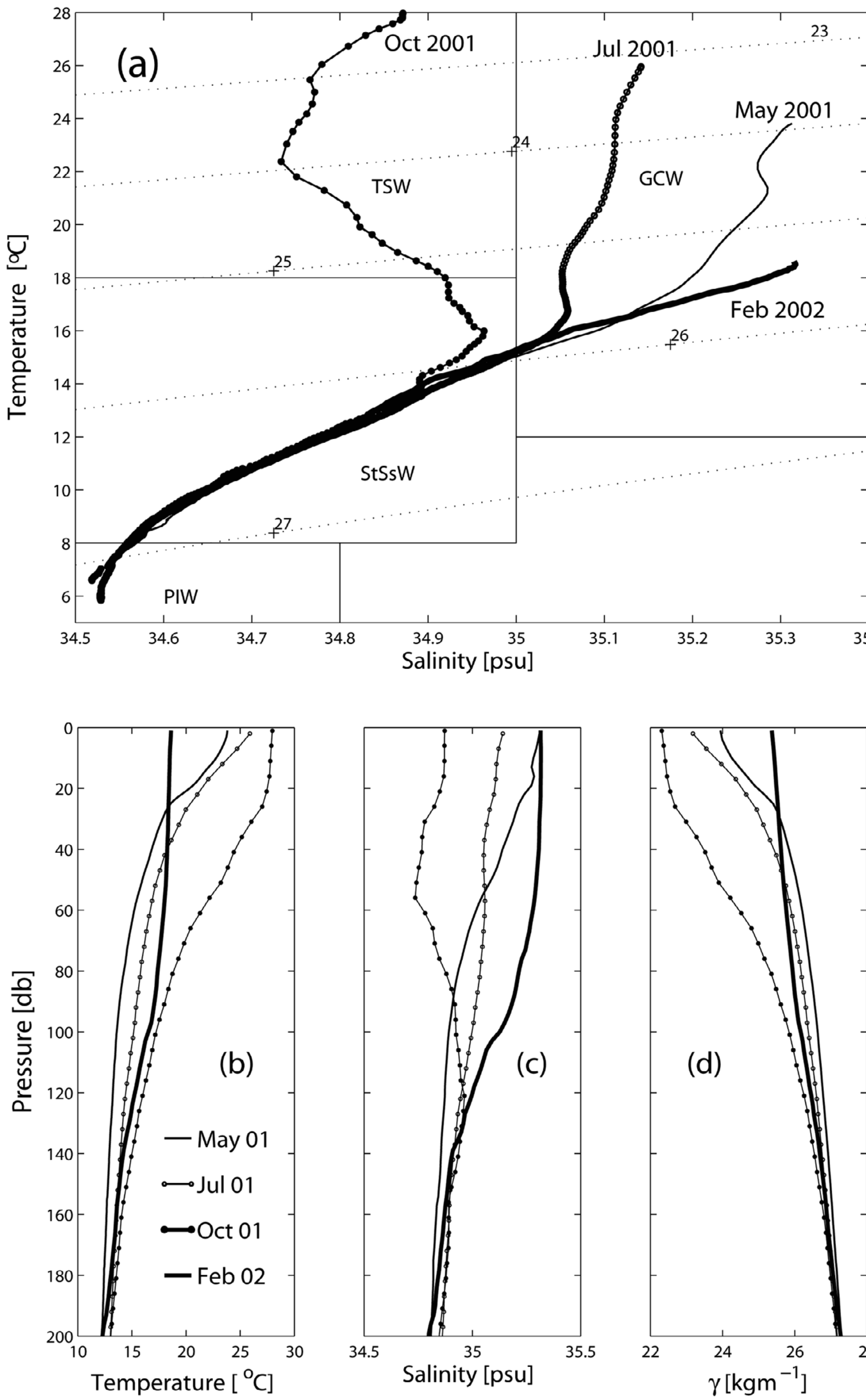

Figure 2. T-S diagram (*a*) and average temperature, salinity, and density profiles (*b*, *c*, and *d*) from conductivity, depth, and temperature data obtained during May, July, and October 2001 and February 2002. GCW, Gulf of California Water; TSW, Tropical Subtropical Water; StSsW, Subtropical Subsurface Water; and PIW, Pacific Intermediate Water.

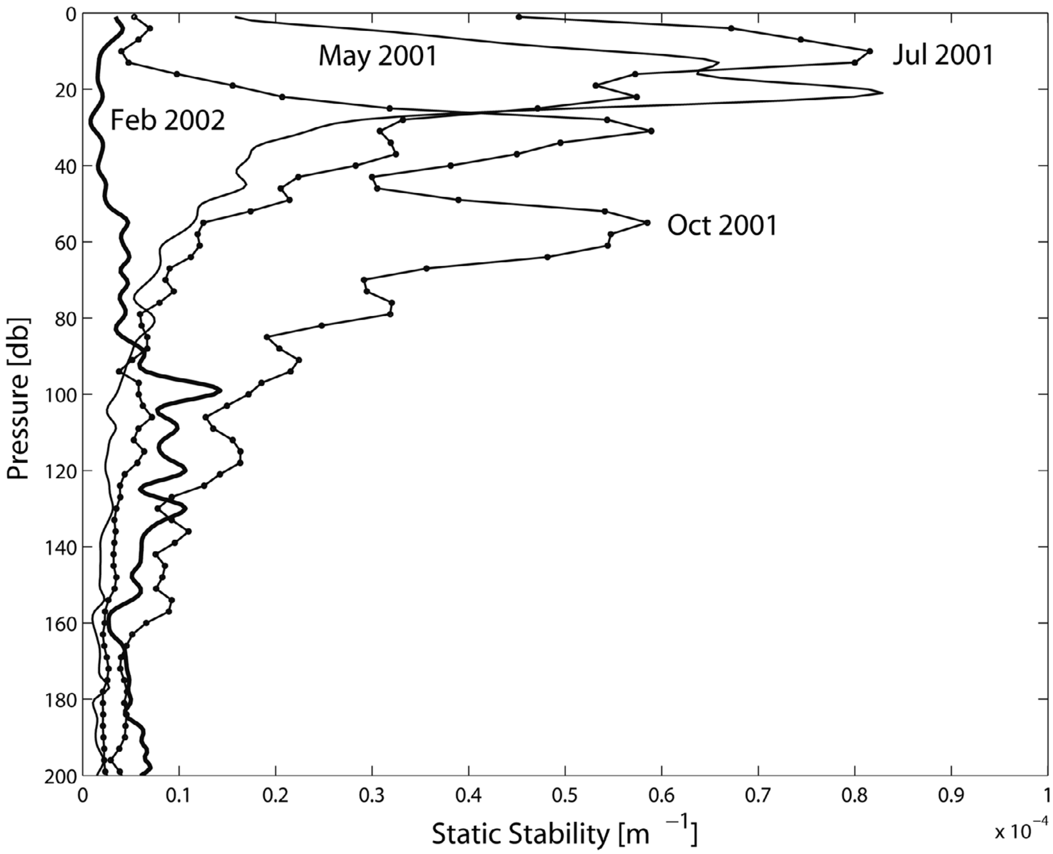

FIGURE 3. Average profiles of static stability from conductivity, depth, and temperature data obtained off Bahía de La Paz (Gulf of California) during May, July, and October 2001 and February 2002.

TABLE 2

Mean Features of Water Column Structure off Bahía de La Paz (Gulf of California) during May, July, and October 2001 and February 2002

Cruise	May 2001	July 2001	October 2001	February 2002
H_{mix} (m)	0 (5.6 ± 5)	0 (4.4 ± 9)	17 ± 8.3	79 ± 18
S_s (psu)	35.31 ± 0.08	35.14 ± 0.06	34.87 ± 0.2	35.31 ± 2.2
T_s (°C)	23.79 ± 0.92	25.90 ± 1.4	28.0 ± 0.2	18.6 ± 0.3
Z_{Emax} (m)	16.5 ± 4.9	12.4 ± 7.3	48 ± 17	100 ± 27
Range of pycnocline (m)	0–40	0–40	30–80	100–110

Note: S_s and T_s, respectively, are salinity and temperature at 1-m depth; H_{mix} is the surface mixed layer depth; Z_{Emax} is the depth of the maximum value of the stability parameter. All ±SD of the estimates from the individual profiles.

TABLE 3

Total Larval Abundance among the Different Depth Sampling Strata off Bahía de La Paz (Gulf of California) (Nonparametric Mann-Whitney Test [Mann and Whitney 1947])

	Water Column Level (m)					
Cruise	0–50/ 50–100	0–50/ 100–150	0–50/ 150–200	50–100/ 100–150	50–100/ 150–200	100–150/ 150–200
May 2001	30 (8/34)	30* (6/29)	15* (0/14)	23 (5/25)	9 (0/12)	5 (0/10)
July 2001	47 (15/48)	32 (12/42)	47* (12/42)	13 (8/34)	27 (8/34)	28 (7/29)
October 2001	49 (21/60)	55 (21/60)	37* (9/36)	46 (21/60)	37* (9/36)	27 (9/36)
February 2002	16 (5/25)	18 (5/25)		11 (4/21)		

Note: Numbers within parentheses represent critical values (minimum/maximum). Asterisks indicate values outside the critical range that were significantly different ($P \leq .05$).

significantly different from those of the other strata due to high variance. The Bray-Curtis index clearly defined two groups of strata: the surface stratum (0- to 50-m depth) and the strata from 50- to 200-m depth (Figure 5), in line with the significance test.

In July, the stratification again reached to the surface ($H_{mix} \sim 0$ almost everywhere) and was present down to 100-m depth. The strongest stability (that is, the pycnocline) was found in the upper 40 m ($Z_{Emax} = 12 \pm 7$ m) (Table 2).

In this period, fish larvae of 46 species in 31 families were collected (Appendix). Significant differences between the total larval abundance of the 0- to 50-m and 150- to 200-m strata were found ($P < .05$) (Table 3). The most abundant species were *V. lucetia* (33%), *Triphoturus mexicanus* (Myctophidae) (30%), and *D. laternatus* (16%). These three species were found over the entire sampled water column. The abundance of *V. lucetia* larvae was significantly different between the 0- to 50-m and 50- to 100-m levels and between the 0- to 50-m and 150- to 200-m levels ($P < .05$) (Figure 4). The Bray-Curtis index did not define strata groups as in the other periods, but most of the 0- to 100-m strata were separated from the 100- to 200-m strata (Figure 5).

In October, the surface mixed layer was 20 m deep, a mean pycnocline was present from 30-m to 80-m depth (although there was some stratification down to 125 m), and there were two stability peaks, at 30 and 54 m. The lowest S_s (34.87) was observed in this period, with minimum salinity cores (~34.74) at 40- to 60-m depth as marked by the two peaks in $E(z)$ (Table 2).

Fish larvae of 88 species in 47 families were collected (Appendix). Significant differences were found between the total larval abundance of the 0- to 100-m and 15- to 200-m strata ($P < .05$) (Table 3). The most abundant species were *V. lucetia* (23%), *Benthosema panamense* (Myctophidae) (20%), and *D. laternatus* (5%). These species were found over the entire sampled water column. The abundance of *B. panamense* and *V. lucetia* larvae was significantly different between the 0- to 100-m and the 150- to 200-m strata ($P > .05$) (Figure 4). The Bray-Curtis index defined a large group for the strata from 0- to 100-m depth (Figure 5), and most of the strata from 150- to 200-m depth were not clustered.

In February, stratification was weak in the top 200 m, and the density step across the pycnocline was very small. The surface mixed layer was 100 m deep, and the maximum stability was located at the base of the mixed layer. The lowest T_s and a S_s as high as in May 2001 (35.31) were recorded in this period (Table 2).

Fish larvae of 15 species in 11 families were collected (Appendix). No significant differences among total larval abundance of the sampled strata were found ($P > .05$) (Table 3). The most abundant species were *Sardinops sagax* (29%) (Clupeidae), *D. laternatus* (24%),

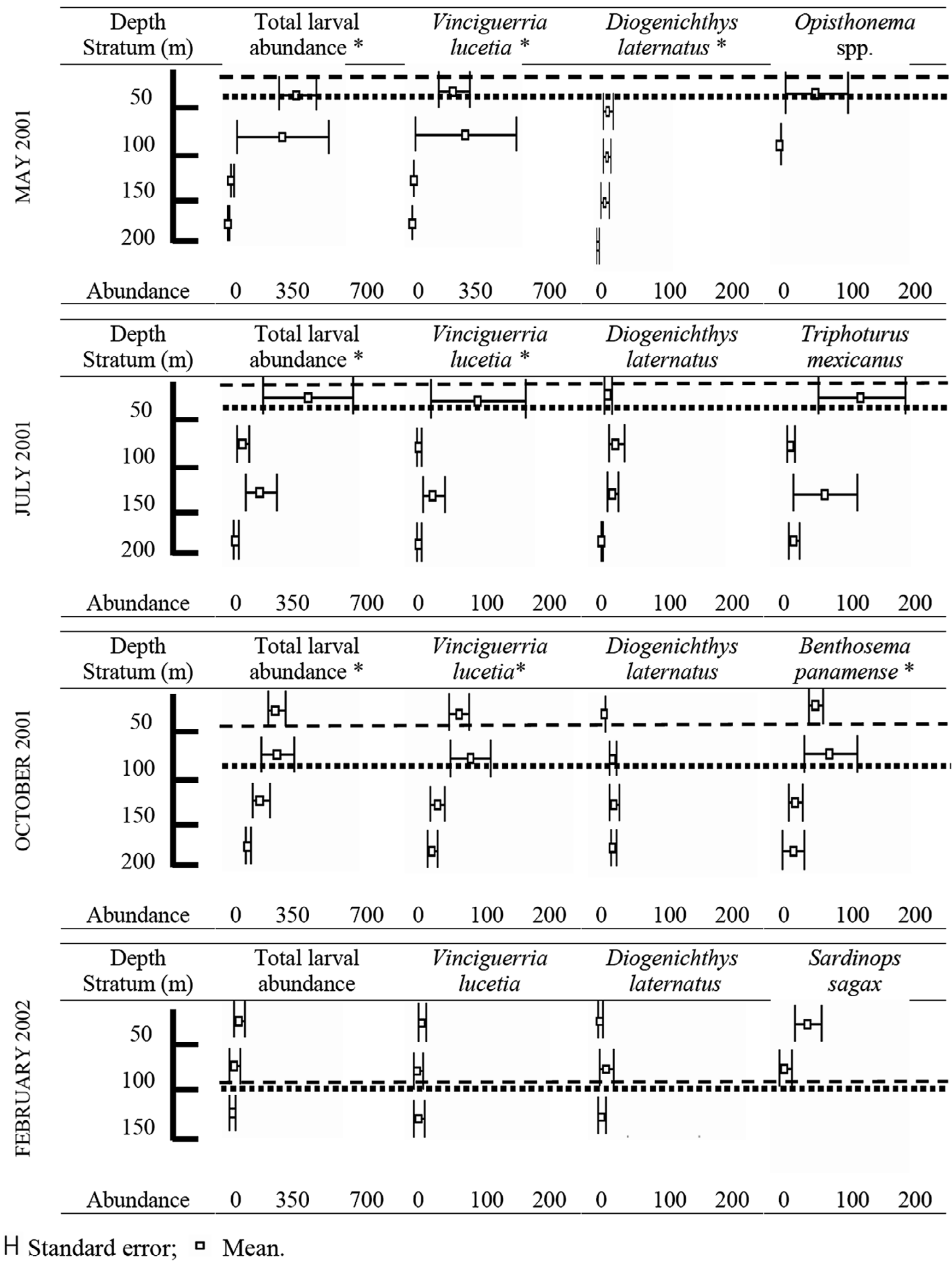

FIGURE 4. Vertical distribution of total larval abundance (larvae per 10 m^2) and the most abundant species off Bahía de La Paz (Gulf of California) during May, July, and October 2001 and February 2002. Asterisks indicate significant differences; dashed line represents depth of the maximum stability; dotted line represents depth of the maximum pycnocline.

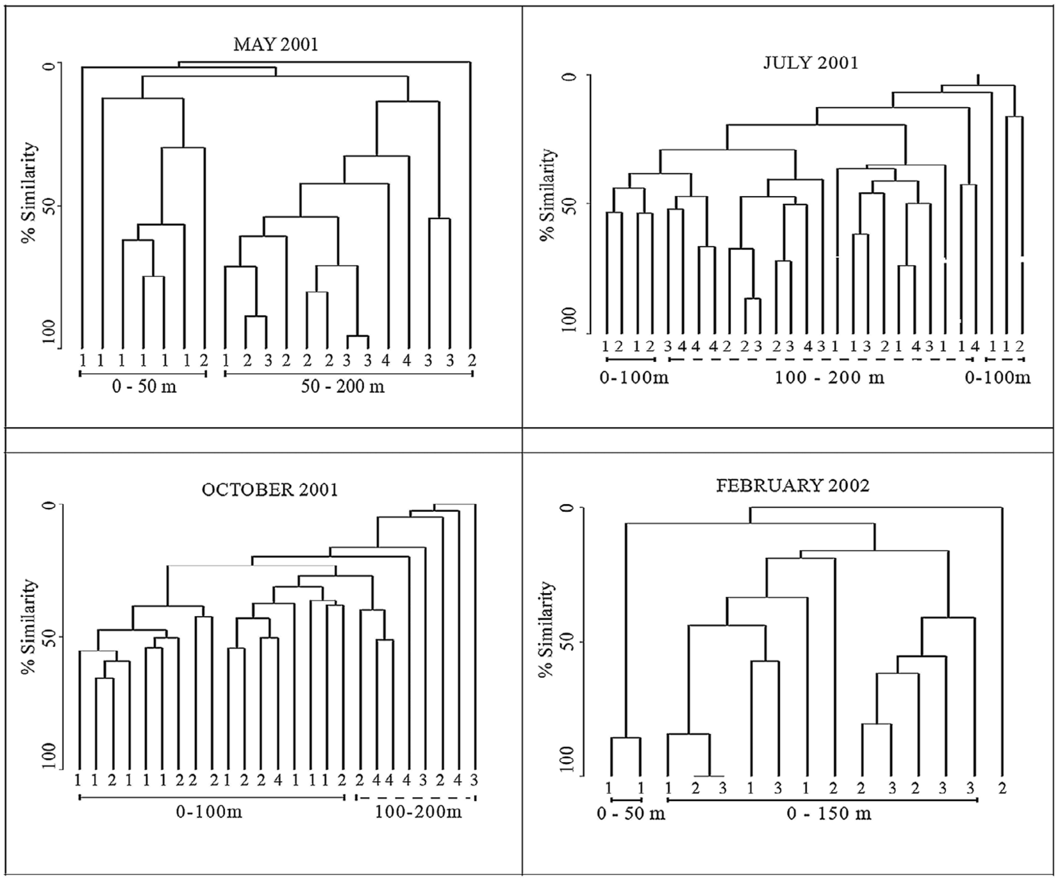

FIGURE 5. Dendrograms of groups of strata defined by the Bray-Curtis index and flexible agglomerative method off Bahía de La Paz (Gulf of California) during May, July, and October 2001 and February 2002. 1, sampling stations of the stratum of 0- to 50-m depth; 2, stratum of 50- to 100-m depth; 3, stratum of 100- to 150-m depth; 4, stratum of 150- to 200-m depth.

and *V. lucetia* (20%). Larvae of *D. laternatus* and *V. lucetia* were found over the entire sampled water column, and most of the sardine larvae were in the upper 50 m. No significant differences were found among the sampled strata ($P > .05$) (Figure 4). The Bray-Curtis index defined a large group including strata from 0- to 150-m depth, in line with the significance test (Figure 5).

DISCUSSION

Results show that vertical distribution of the fish larvae in the area just outside the main entrance to Bahía de La Paz is related to seasonal evolution of the vertical structure of the water column. Total larval abundance and the most abundant and frequent species were significantly higher in the most stable stratum of the water column than below the pycnocline.

In May, when the pycnocline and Z_{Emax} were both found in the top 50 m, total larval abundance and abundance of *V. lucetia* larvae were significantly higher in the 0- to 50-m depth stratum than in the 100- to 150-m and 150- to 200-m strata. In July, when stratification was similar to that in May, total larval abundance and abundance of *V. lucetia* larvae were significantly higher in the 0- to 50-m stratum than in the 150- to 200-m stratum. In October, when the pycnocline extended from 30- to 80-m depth and the two Z_{Emax} were present in the upper 100 m, there was a coincident significant difference in total larval abundance and in abundance of *B. panamense* and *V. lucetia* larvae between the 0- to 100-m interval and the 150- to 200-m stratum. In February, when the mixed layer was 100 m deep and the pycnocline was very weak, no significant differences were found in total larval abundance nor in the larvae of the most abundant species in the sampled strata (0- to 150-m depth).

Although there are no previous studies that relate vertical distribution of fish larvae to evolution of the structure of the water column in the Gulf of California, relationships between the pycnocline and high abundance of fish larvae recorded in this study tend to be in agreement with previous work elsewhere. Loeb and Nichols (1984), who analyzed the vertical distribution of zooplankton in general at one site in the eastern tropical Pacific during summer, noted that maximum ichthyoplankton abundance and diversity occurred in the pycnocline; the studies of Moser and Smith (1993) in the California Current found the highest density of fish larvae to be associated with the interface between the mixed layer and the pycnocline in summer; and Röpke (1993), in the northern Arabian Sea during an intermonsoon period (March–June), reported that fish larvae of the most abundant mesopelagic species were closely associated with the pycnocline but less abundant mesopelagic species were found below it.

Those previous works did not take into account relationships between Z_{Emax} and larval fish distribution, but we suggest with our results that there are favorable conditions for most fish larvae through the pycnocline and particularly in the strata where Z_{Emax} was registered. The fundamental reason for this result cannot be investigated with the data presented here. Among the possible hypotheses that can be tested are Sverdrup's critical depth hypothesis (Sverdrup 1953) and Lasker's stability hypothesis (Lasker 1975, 1981), which suggest the importance of water column stability in the life cycles of planktonic species. In the most stable zone of the water column, interaction of optimal concentrations of nutrients, oxygen, and solar radiation results in phytoplankton blooms and promotes prey-predator aggregations: in this case, fish larvae with their prey, a prime requisite for larval survival. We hope that future work will address the subject.

In particular, vertical distribution of the sardine larvae in this study, *Ophisthonema* spp. in May and *S. sagax* in February, indicates that even though these species were above or in the steepest gradient of the pycnocline, they were concentrated in the uppermost stratum of the water column ($\leq$50-m depth), apparently unaffected by the position or thickness of the pycnocline or the mixed layer depth. Ahlstrom (1959) and Moser and Smith (1993) found that *S. sagax* larvae occur predominantly in the upper part of the mixed layer during periods of strong winds in the California Current region. Armenta-Martínez (2004) observed great abundance of sardine larvae (*Ophisthonema* spp. in summer and *S. sagax* in winter) at 10-m depth inside Bahía de La Paz. This suggests that the larvae of *S. sagax* and *Ophisthonema* spp. consistently inhabit the upper meters of the water column, at least until the larval postflexion phase.

The fact that larval movements in relation to the daily cycle were not evident in this study may be related to the thickness of the sampled strata (i.e., intervals of 50 m). Brewer and Kleppel (1986), Leis (1986), and Fortier and Harris (1989), who made studies of vertical distribution of fish larvae in narrower strata (<10-m depth) in shallow areas, detected variations in relation to the daily cycle. But in all of those studies the water column did not present substantial vertical thermal or salinity gradients, in contrast with the strong stratification of the water column observed in the Gulf of California. It is possible that significant larval movements would be detected in relation to the daily cycle if narrower strata had been sampled.

The intrusion of Tropical Surface Water (TSW) that was recorded in the study area in October 2001 coincided with the highest specific richness of fish larvae of all cruises, being almost six times richer than in February. This intrusion of TSW is part of the seasonal pattern of the gulf's hydrography, being evident in summer months due to the poleward intrusion of TSW, probably through the poleward Costa Rica Coastal Current or Mexican Current (Kessler 2006, Lavín et al. 2006).

CONCLUSIONS

The vertical distribution of fish larvae off Bahía de La Paz is closely related to the seasonal changes of the water column structure, with most fish larvae concentrated in the stratum of maximum stability, which covered from the surface to ∼40 m in the spring and summer of 2001 (no surface mixed layer), from 30 to 80 m in the fall of 2001, and was very weak and deep (∼100 m) in winter of 2001–2002. In addition, the fall 2001 data showed the seasonal invasion of TSW, both in the thermohaline characteristics and in the high specific richness of fish larvae.

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Appendix

List of Species Identified off Bahía de La Paz (Gulf of California) during May, July, and October 2001 and February 2002

	May		July		October		February	
Taxa	Abundance	%F	Abundance	%F	Abundance	%F	Abundance	%F
Elopidae								
Elops affinis					20	11.1		
Albulidae								
Albula type 1					14	11.1		
Muraenidae								
Muraenidae type 1					4	11.1		
Ophichthidae								
Ophichthidae type 2					21	22.2		
Ophichthus zophochir					25	11.1		
Ophichthus type 1					8	11.1		
Myrophis vafer					12	11.1		
Derichthyidae								
Derichthyidae type 1					6	11.1		
Nemichthyidae								
Nemichthyidae type 2					4	11.1		
Congridae								
Congridae type 1					8	11.1		
Heteroconger digueti					4	11.1		
Ariosoma gilberti					18	22.2		
Chiloconger obtusus					8	11.1		
Paraconger californiensis					14	11.1		
Nettastomatidae								
Hoplunnis sicarius	13	12.5						
Serrivomeridae								
Serrivomeridae type 1					5	11.1		
Cyematidae								
Cyematidae type 1					52	33.3		
Cyematidae type 2					17	11.1		
Clupeidae								
Etrumeus teres							20	11.1
Harengula thrissina	134	37.5	5	11.1	15	11.1		
Opisthonema spp.	433	62.5	113	66.7				
Sardinops sagax							486	44.4
Engraulidae								
Engraulidae			8	11.1				
Engraulis mordax							56	11.1
Bathylagidae								
Leuroglossus stilbius							188	44.4
Phosichthyidae								
Vinciguerria lucetia	4,100	75	2,060	77.8	1,648	100	343	77.8
Stomiidae								
Stomias atriventer							6	11.1
Aulopodidae								
Aulopus bajacali					154	55.6	48	22.2
Scopelarchidae								
Scopelarchoides nicholsi	11	12.5	9	11.1	25	22.2		
Synodontidae								
Synodus lucioceps					43	22.2		
Myctophidae								
Diaphus pacificus					88	33.3	9	11.1
Lampanyctus parvicauda	7	12.5			7	11.1		
Triphoturus mexicanus	136	75	1,833	88.9	421	88.9	29	22.2
Benthosema panamense					1,451	100		

Appendix (continued)

	May		July		October		February	
Taxa	Abundance	%F	Abundance	%F	Abundance	%F	Abundance	%F
Diogenichthys laternatus	684	75	962	77.8	340	77.8	397	88.9
Hygophum atratum			5	11.1			35	22.2
Hygophum reinhardtii	11	12.5			29	22.2		
Ophidiidae								
Ophidiidae type 1			26	22.2	104	66.7		
Lepophidium type 1					14	22.2		
Ophidion scrippsae							11	11.1
Bregmacerotidae								
Bregmaceros bathymaster					337	88.9		
Bregmaceros type 1			8	11.1				
Lophiidae								
Lophiodes spilurus			24	11.1	68	66.7		
Antennariidae								
Antennarius avalonis					6	11.1		
Mugilidae								
Mugil cephalus	22	25	16	11.1				
Hemiramphidae								
Hemiramphidae type 1	7	12.5						
Hemiramphus saltator			10	11.1				
Hyporhamphus rosae	0	0	8	11.1				
Holocentridae								
Holocentridae type 1					155	77.8		
Myripristis leiognathos					59	44.4		
Syngnathidae								
Doryrhamphus excisus excisus			8	11.1				
Syngnathus californiensis					6	11.1		
Fistulariidae								
Fistularia corneta					22	44.4		
Scorpaenidae								
Pontinus sierra					23	22.2		
Pontinus type 1			60	33.3	49	44.4		
Scorpaena guttata			9	11.1	32	33.3	17	22.2
Sebastolobus altivelis					7	11.1		
Triglidae								
Prionotus ruscarius			16	11.1	30	33.3		
Serranidae								
Serranidae type 1	7	12.5	8	11.1				
Diplectrum type 1					142	77.8		
Paralabrax maculatofasciatus					90	55.6		
Paralabrax type 1	7	12.5						
Paralabrax type 2	28	25						
Serranus type 1					36	22.2		
Pronotogrammus multifasciatus					57	66.7		
Paranthias colonus					16	22.2		
Apogonidae								
Apogonidae type 1					39	44.4		
Apogon atricaudus					12	11.1		
Apogon guadalupensis			26	33.3	12	11.1		
Malacanthidae								
Caulolatilus princeps	11	12.5						
Coryphaenidae								
Coryphaena hippurus			9	11.1				
Carangidae								
Carangidae type 1			216	44.4				
Caranx caballus			11	11.1	192	44.4	11	11.1

Appendix (continued)

	May		July		October		February	
Taxa	Abundance	%F	Abundance	%F	Abundance	%F	Abundance	%F
Selar crumenophthalmus	95	37.5	31	33.3				
Selene peruviana					7	11.1		
Trachurus symmetricus					42	55.6		
Lutjanidae								
Lutjanus peru					39	44.4		
Gerreidae								
Eucinostomus dowii			16	11.1				
Diapterus peruvianus	6	12.5	42	33.3				
Haemulidae								
Haemulidae type 1			9	11.1				
Anisotremus davidsonii			55	44.4				
Calamus brachysomus	68	12.5						
Sciaenidae								
Sciaenidae type 1			19	11.1				
Roncador stearnsii					26	44.4		
Mullidae								
Mulloidichthys dentatus					41	44.4		
Chaetodontidae								
Chaetodon humeralis					83	77.8		
Cirrhitidae								
Cirrhitichthys oxycephalus					17	33.3		
Pomacentridae								
Pomacentridae type 1	11	12.5			20	22.2		
Pomacentridae type 2			24	33.3				
Chromis punctipinnis					15	11.1		
Abudefduf troschelii	162	37.5	63	33.3	4	11.1		
Hypsypops rubicundus					12	22.2		
Stegastes rectifraenum	97	25	38	22.2				
Labridae								
Halichoeres semicinctus					24	33.3		
Iniistius pavo					8	11.1		
Thalassoma type 1			5	11.1				
Xyrichtys mundiceps					18	11.1		
Bleniidae								
Blenniidae type 1			5	11.1				
Ophioblennius steindachneri	15	12.5			23	22.2		
Labrisomidae								
Labrisomus xanti	43	25						
Eleotridae								
Eleotris picta			32	22.2	70	55.6		
Erotelis armiger					4	11.1		
Gobiidae								
Ctenogobius sagittula					15	22.2		
Gobulus crescentalis	43	12.5			7	11.1		
Lythrypnus dalli			8	11.1	14	22.2		
Microdesmidae								
Clarkichthys bilineatus					8	11.1		
Sphyraenidae								
Sphyraena ensis			17	22.2				
Trichiuridae								
Lepidopus fitchi					109	44.4		
Scombridae								
Scomber japonicus							22	22.2
Auxis spp.	130	37.5	183	44.4	46	55.6		

Appendix (continued)

	May		July		October		February	
Taxa	Abundance	%F	Abundance	%F	Abundance	%F	Abundance	%F
Nomeidae								
Cubiceps pauciradiatus					7	11.1		
Paralichthyidae								
Citharichthys platophrys					15	11.1		
Citharichthys sordidus			9	11.1				
Etropus crossotus	8	12.5	24	33.3	12	22.2		
Etropus type 1					8	11.1		
Syacium ovale			24	33.3	68	77.8		
Hippoglossina stomata					16	11.1		
Bothidae								
Bothus leopardinus			46	22.2	30	33.3		
Monolene asaedai					12	22.2		
Cynoglossidae								
Symphurus type 1			24	33.3				
Symphurus type 2					21	22.2		
Symphurus williamsi			10	11.1	17	22.2		
Balistidae								
Balistes polylepis			28	22.2	8	11.1		
Monacanthidae								
Aluterus scriptus					8	11.1		
Tetraodontidae								
Sphoeroides annulatus	21	12.5						
Sphoeroides lobatus				0				
Diodontidae								
Diodon holocanthus					94	66.7		

Note: %F, percentage of occurrence; abundance is expressed as number of larvae per 10 m^2; type is used to denote larvae not described in the literature.