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SEASONALITY AND DEPTH DISTRIBUTION OF LARVAL FISHES IN THE NORTHERN GULF OF MEXICO ABOVE LATITUDE 26°00′N

Justification and Methods

Information on early life stages of fishes is important for a better understanding of recruitment processes and for the proper management of fisheries. Knowledge of seasonal occurrence and depth distribution of larval fishes is essential for planning and scheduling ichthyoplankton cruises (Colton et al. 1979) and juvenile surveys, so that sampling for target species can be concentrated during periods and at depths where effort will be most effective (Saville 1964). In addition, knowledge of the seasonal occurrence of early life stages is an important aid in identifying larvae. Because eggs and yolk-sac larvae are planktonic for only a relatively few days after being spawned, the presence and distribution of early life stages also suggests proximity of adult spawning concentrations (Houde 1974), aiding the definition of spawning areas and seasonal spawning migrations of adults. Since some commercial and recreational fisheries (e.g., red drum, *Sciaenops ocellatus*, and black drum, *Pogonias cromis*) exploit spawning aggregations, encroachment on these aggregations could have an adverse impact on the fishery.

Colton et al. (1979) summarized larval seasonality data and spawning areas for marine continental shelf fishes between Nova Scotia and North Carolina; whereas, Herrema et al. (1985) inferred spawning seasons of coastal fishes off eastern Florida based on examination of enlarged gonads. The seasonal occurrence of larvae of many species from the northern Gulf of Mexico (GOMEX), however, is not well documented. The northern GOMEX is herein defined as waters north of lat. 26°00′N; this area approximates the U.S. Fishery Conservation (i.e., Exclusive Economic) Zone. For discussion, the study area was subdivided into three regions (Fig. 1) based on longitude as follows: eastern GOMEX (waters east of long. 86°00′W), central GOMEX (those between 86°00′W and 94°00′W), and western GOMEX (waters west of 94°00′W). Seasonality data are scattered throughout the grey literature, and many studies have focused on either select taxa or are limited in spatial or temporal coverage. The most comprehensive studies of the larval ichthyofauna community in the northern GOMEX were those of Houde et al. (1979) from continental shelf waters

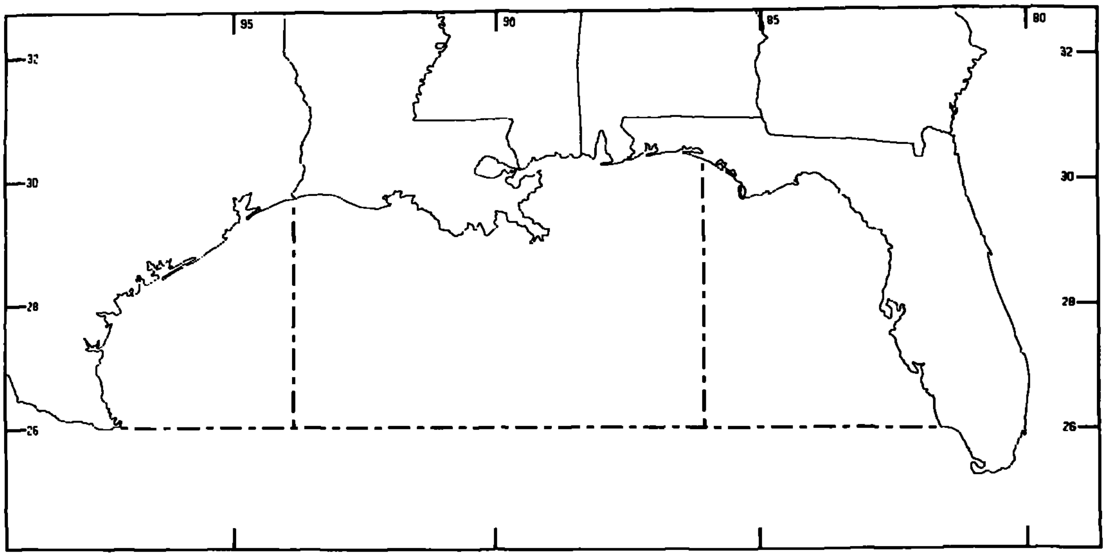

FIGURE 1.—Location of the northern Gulf of Mexico (GOMEX) and its subregions. Studies conducted in waters east of long. 86°00'W are considered northeastern GOMEX, those between 86°00'W and 94°00'W are north-central GOMEX, and west of 94°00'W are northwestern GOMEX.

off west Florida, and Finucane et al. (1977, 1979b) from the south Texas outer continental shelf. Ditty (1986) presented data on seasonality of larval fishes from neritic continental shelf waters off Louisiana that included a discussion of peak seasonal occurrence of abundant taxa; however, those data were limited in areal coverage, and there were significant gaps in the temporal occurrence of many taxa. Therefore, data on larvae of approximately 200 coastal and oceanic fishes from 61 families were compiled from unpublished plankton surveys[1], as well as other published studies from throughout the northern GOMEX, to further clarify the seasonality and peak seasonal occurrence (Table 1), and depth distribution (Table 2) of larval fishes from this area. Since the occurrence of early developmental stages of fishes suggests recent spawning (Colton et al. 1979; Ruple 1984), only studies that primarily collected larvae <10 mm SL were used. Because the taxonomy of larvae of many northern GOMEX fishes (e.g., most exocoetids, blennies, and gobies) are poorly understood, no attempt was made to compile seasonality or depth distribution data for these taxa or for anguilliform, myctophiform, or salmoniform fishes; other poorly understood taxa (e.g., engraulids and cynoglossids) were assigned only to genus.

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Discussion

Although not all northern GOMEX ichthyoplankton studies were readily comparable because of differences in gear and tow type, plankton net mesh size, and seasonal and areal coverage (Table 3), few major discrepancies in either seasonality or peak seasonal occurrence of larvae resulted from such differences. For example, Pearson (1929) suggested a secondary spawning from late July to November for black drum off Texas, but these dates have not been reported from elsewhere in the literature. Likewise, Finucane (1976) reported round scad, *Decapterus punctatus*, <6 mm SL in December–January, but based on sampling at the same location in subsequent years (Finucane et al. 1977, 1979b) and the seasonal occurrence of this species as suggested by others (Table 1), these may have been larvae of the rough scad, *Trachurus lathami*, rather than those of round scad. Houde et al. (1979) collected larvae of Spanish sardine, *Sardinella aurita*, during all months of their Florida continental shelf survey; however, their winter occurrences of Spanish sardine were only from the southern part of the survey area (i.e., <26°00'N). This may account for the dis-

TABLE 1.—Seasonality (X) and peak seasonal occurrence (*) of larval fishes (<10 mm SL) in the northern Gulf of Mexico (GOMEX) above lat. 26°00′N. Sources 1–31 and 75 are studies conducted in the northeastern GOMEX (waters east of long. 86°00′W); 33–59 and 74, north-central GOMEX (those between 86°00′W and 94°00′W); 61–73, northwestern GOMEX (waters west of 94°00′W); and 23, 25, 32, 48, 60, and 76–80 are Gulf-wide studies. Assignment of taxa to Families follows Robins et al. (1980) except *Epigonus* sp. and *Symphysanodon typus* which follows Johnson (1984). Numbers in Source, see end of table.

Family	Taxa	J	F	M	A	M	J	J	A	S	O	N	D	Source
Elopidae	*Elops saurus*	X	X	X	X	X		X		X	X	X		1,2,41,54,61,63,66
Albulidae	*Megalops atlanticus*						X	X	X					2,6
	Albula vulpes					X	X							54,66
Clupeidae	*Brevoortia* spp.	X	X	X	X	X					X	X	X	1–3,61–63
	B. patronus	*	*	X	X					X	X	X	*	33,40–42,46,47,49,53,55, 57–59,61–63,66,69,74
	B. smithi	X	X	X									X	5,55
	Etrumeus teres	*	*	*	X	X	X					X	X	2,5,12,29,40,41,43,50–52, 59,61,63,66,68
	Harengula jaguana			X	X	*	*	*	*	X	X	X		1–3,5,30,40,46,47,50–53, 56–59,61–63,66,68,69
	Opisthonema oglinum			X	X	*	*	*	*	X	X	X		2,5,31,40,46,50–52, 56–59,61–63,68,69
	Sardinella aurita			X	X	X	X	X	X	X	X	X		2,22,50–52,56,59,61, 63,68
Engraulidae	*Anchoa* spp.	X	X	*	*	*	*	*	*	*	X	X	X	1–3,23,25,40,41,46,47, 53,56–59,61–64,66,68,69
	Anchoviella / Engraulis	X	X	X	X	X	X	X	X	X	X	X	X	40,41,46,61–63,68
Gobiesocidae	*Gobiesox strumosus*	X	X	*	*	*	X	X	X	X	X	X	X	1,3,40,41,46,47,56,58, 59,66,68
Ogcocephalidae	*Ogcocephalus* sp.					X			X	X				68
Bregmacerotidae	*Bregmaceros atlanticus*	X	X	X	X	X	X	X	X	X	X	X	X	2,4,40,59,61–64,68
	B. cantori	X	X	X	X	X	X	X	*	*	*	*	X	2,4,40,59.64
	B. houdei	X	X			X	X	X	*	*	*	*		2,4,64
	B. macclellandi	X	X			X			X	X	X	X		2,4
Gadidae	*Urophycis* spp.	X	X	X								X	X	2,40,41,57.59,61–63,68
	U. cirrata	X												64
	U. floridanus	X	X											63
Ophidiidae	*Brotula barbata*	X										X	X	40,59,64
	Lepophidium spp.	X	X	X	X	X	X	X	X	X	X	X	X	18,40,59,63,68
	Ophidion spp.	X	X	X	X	X				X	X	X	X	40,59,61–63,68
	O. selenops		X	X	X	X	X	X	X	X	X	X		18,40
	Ophidion Type 1		X	X	X	X	X	X	X	X	X	X		18
	Ophidion Type 2		X	X	X	X	X	X	X	X	X	X		18
	Otophidium omostigmum		X	X	X	X	X	X	X	X	X	X		18,68
Carapidae	*Carapus bermudensis*	X	X			X	X	X	X	X	X	X		2,63
	Echiodon sp.	X	X		X	X	X	X	X	X	X	X		2,64
Exocoetidae	*Hemiramphus balao*		X						X			X		2
	H. brasiliensis					X	X	X						2
	Hyporhamphus unifasciatus	X	X			X	X	X	X	X		X		2,40,69
Belonidae	*Ablennes hians*							X			X			62
Atherinidae	*Membras martinica*				X	X	X	X						2,40,41.46,47,58,69
Holocentridae	*Adioryx vexillarius*											X		2
	Holocentrus sp.					X								40
Caproidae	*Antigonia* spp.		X			X			X			X		2
	A. capros								X					2
Trachipteridae	*Trachipterus* sp.		X											59
Fistulariidae	*Fistularia* sp.					X								2
Centriscidae	*Macrorhamphosus scolopax*	X	X											2,40,41,59,63,64
Serranidae	*Anthias* spp.	X	X	X	X	X	X	X	X	X	X	X	X	2,41,61,63,64
	Centropristis spp.	X	X	X	X	X		X		X	X	X	X	41,53,59,61–64,68
	C. striata	X	X	X		X				X	X	X		2,7
	Diplectrum spp.	X	X	X	X	*	*	*	*	X	X	X	X	53,59,61–64,68
	D. formosum	X	X	X	*	*	X	X	*	*	X	X		2,7
	Epinephelus spp.	X	X			X	X	X	X	X	X	X		2,64,68
	Gonioplectrus hispanus									X				64
	Hemanthias aureorubens	X	X			X	X	X	X			X		2
	H. leptus		X											2,40
	H. vivanus	X	X	X	X	X	X	X	X	X	X	X	X	2,61,63,64
	Holanthias martinicensis										X	X		64
	Liopropoma spp.	X			X	X	X	X	X	X	X	X		2,61,63,64
	Myctoperca spp.				X									64
	Plectranthias garrupellus											X		2
	Serraniculus pumilio					X	*	*	*	*	X	X		2,7,40,61–63
	Serranus spp.	X	X		X	X	X	X	X	X	X	X	X	2,63,64,68

TABLE 1.—*Continued.*

Family	Taxa	J	F	M	A	M	J	J	A	S	O	N	D	Source
Grammistidae	*Pseudogramma gregoryi*					X	X	X						2
	Rypticus spp.		X			X	X	X	*	*	X	X		2,7,40,53,61–63,68
	R. saponaceus					X	X	X	X	X				61–63,68
Priacanthidae	*Priacanthus* spp.	X	X	X	X	X	X	X	X			X		2,32,64
	P. arenatus					X								64
	P. cruentatus					X				X				64
	Pristigenys alta						X	X	X	X				2,32
Apogonidae	*Apogon* sp.							X						41
Epigonidae	*Epigonus* sp.											X		64
Malacanthidae	*Caulolatilus* spp.	X	X	X	X	X	X	X	X	X	X	X	X	2,61,63,64
	C. cyanops	X								X				2
Pomatomidae	*Pomatomus saltatrix*				X						X	X	X	40,59,61,63,64,67
Rachycentridae	*Rachycentron canadum*				X	X	X	X	X	X				2,37,62,63
Carangidae	*Alectis crinitus*							X	X	X	X			48,62
	Caranx sp.	X	X	X	X	X	X	X	X	X	X	X	X	2,8,61,63,68,69
	C. crysos			X	X	X	*	*	*	X	X	X		2,8,24,41,50–52,61
	C. hippos/latus				X	X	X	X	X					32,48,60,69
	Chloroscombrus chrysurus				X	X	*	*	*	*	X			1–3,8,40,41,46,47,50–53, 56–59
	Decapterus punctatus			X	*	*	*	*	*	*	X	X		2,8,10,24,40,50–53,59, 61–63,68
	Elagatis bipinnulata					X	X	X	X	X	X			2,56,59
	Hemicaranx amblyrhynchus					X	X	X	X	X	X			48,66
	Oligoplites saurus				X	X	*	*	*	X	X	X		1–3,8,10,32,40,41,46,48, 53,56,59–61,68,69
	Selar crumenopthalmus				X	X	X	X	X	X	X			32,40,48,53,59,60
	Selene spp.					X	X	*	*	*	X	X		2,8,10,32,40,41,48,53, 59–61,63,68
	Seriola spp.	X	X	X	X	X	X	X	X	X	X	X	X	2,8,32,40,48,56,59,60, 63,68
	Trachinotus spp.				X	X	X	X	X	X				2,8,32,47,48,61,63
	T. carolinus					X	X	X	X					32,41,48,60,66
	T. falcatus/goodei				X	X			X					48,60
	Trachurus lathami	*	*	X	X	X						X	X	2,8,23,40,41,50–52,59, 61–63,68
Coryphaenidae	*Coryphaena* spp.					X	X	X	X	X	X	X		2,41,61,64
	C. equisetis				X	X	X	X	X	X	X			2,17,23,25,40
	C. hippurus		X	X	X	X	X	X	X	X	X	X		2,17,23,25
Lutjanidae	*Etelis oculatus*							X	X	X	X	X		62,63
	Lutjanus spp.				X	X	*	*	*	X	X	X		2,40,53,59,61,63,64
	L. campechanus					X	X	X	X	X	X	X		62,64,73
	Pristipomoides aquilonaris		X			X	X	X	X	X	X	X		2,64
	Rhomboplites aurorubens	X				X	X	X	X	X	X	X		2,64
Acropomatidae	*Symphysanodon typus*		X			X						X		2
Gerreidae	*Eucinostomus* spp.				X	X	X	X	X	X	X	X		40,47,53,59,61–63,66
Haemulidae	*Haemulon* spp.					X	X	X	X					61,63
	Orthopristis chrysoptera	X	X	*	X	X								2,40,46,47,59,66,69
Sparidae	*Archosargus probatocephalus*	X	*	*	*	X								1,2,40,47,48,53,59,60, 69,70
	Diplodus holbrooki	X	X	X	X	X								2,68
	Lagodon rhomboides	*	*	X	X						X	X	*	1–3,11,40,41,46–48,53, 56,57,59,60,62,63,66,68, 69
	Pagrus pagrus	X	X			X								2,68
	Stenotomus caprinus	X											X	48,61
Sciaenidae	*Bairdiella chrysoura*			X	*	*	*	*	*	X	X			1–3,32,39–41,46,47,53, 57–59,62,63,66,69,71
	Cynoscion arenarius		X	*	*	X	X	*	*	X	X			1–3,32,34,35,39,40,46, 53,56–59,61,63,68,69,71
	C. nebulosus		X	X	*	*	*	*	*	X	X			1–3,32,35,39–41,46,47, 53,56–59,68–72
	C. nothus					X	X	X	X	*	*	X		2,32,39–41,46,53,56,59, 61–63,68
	Larimus fasciatus				X	X	X	X	X	*	X	X		34,39–41,46,53,56,58,59, 61–63,69
	Leiostomus xanthurus	*	X	X	X						X	X	*	1–3,34,39–41,44,46,47, 53,56–59,61–63,66, 68–71,74

TABLE 1.—*Continued.*

Family	Taxa	J	F	M	A	M	J	J	A	S	O	N	D	Source
	Menticirrhus spp.		X	X	X	X	X	X	X	X	X	X	X	1–3,32,34,39–41,46,47, 53,56–59,61–63,66,68,69
	Micropogonias undulatus	*	X	X	X					X	*	*	*	1–3,34,39–41,44,46,47, 53,56–59,61–63,66, 68–71,74
	Pogonias cromis	X	*	*	*	X							X	1–3,34,39,40,46,47,56, 58,59,61,63,66,68–70,72
	Sciaenops ocellatus								X	*	*	X		1,28,39,40,46,47,53,56, 58,59,61,63,66,69,70,72
	Stellifer lanceolatus				X	X	X	X	X	X	X			32,39–41,46,53,56–59, 66,69
Mullidae	*Mullus auratus*					X								2
Kyphosidae	*Kyphosus* spp.	X	X		X	X	X	X				X		2,61,63
Ephippidae	*Chaetodipterus faber*				X	X	*	*	*	X				40,41,46,47,53,56,57,59, 61–64,66,68
Pomacentridae	*Abudefduf saxatilis*							X						63
Mugilidae	*Mugil* spp.	X	X	X	X	X	X	X	X	X	X	X	X	2,61,63,68
	M. cephalus	*	*	X	X						X	X	*	40,41,44,47,53,57,59, 61–64,69,71
	M. curema				X	*	*	*	X					40,46,47,57,59,63,64,68
Sphyraenidae	*Sphyraena* spp.				X	X	*	*	*	X	X	X		40,46,53,57,59,61–64,66, 68
	S. barracuda					X	X	X	X	X				2,64
	S. borealis		X	X	X	X								2,61,68
	S. guachancho					X	X	X	X	X				2,61,63
Polynemidae	*Polydactylus octonemus*				X									64
Opistognathidae	*Lonchopisthus macrognathus*					X								68
	Gnathagnus egregius	X	X											63
Callionymidae	*Callionymus* spp.					X				X				61,68
	C. bairdi	X												59
	C. pauciradiatus									X	X	X		40,59
Microdesmidae	*Microdesmus* spp.			X	X	X	X	X	X	X	X	X		2,40,46,57,59,61–64,68
Acanthuridae	*Acanthurus* spp.	X	X			X			X	X	X	X		2,64
Gempylidae	*Gempylus serpens*				X							X		2,61
	Nealotus tripes	X						X						2,41
	Nesiarchus nasutus	X	X									X		2,59
	Diplospinous multistriatus	X	X	X	X	X	X	X		X		X	X	2,40,41,59,61,63
Trichiuridae	*Lepidopus* sp.							X						61
	Trichiurus lepturus	X	X	X	X	X	X	X	X	X	X	X	X	40,41,56,59,61,63,68
Scombridae	*Acanthocybium solanderi*				X	X	X	X	X	X				2,25
	Auxis spp.	X	X	X	X	*	*	*	*	*	X	X		2,21,23,25,32,40,59,61, 63,64,68,79
	Euthynnus alletteratus				X	*	*	*	*	*	X	X		2,21,23,25,32,40,53,57, 59,61–64,68,79
	E. pelamis				X	X	X	X	X	X	X			2,21,23,25,32,40,61,63, 64,79
	Sarda sarda							X						53
	Scomber japonicus	X	X	X	X	X	X			X	X	X		2,32,40,61,63,68
	Scomberomorous cavalla					X	X	X	*	*	X	X		2,21,23,25,27,32,40, 50–52,59,61–65,68
	S. maculatus				X	X	X	X	*	*	X			2,23,25,27,32,40,50–53, 56,57,59,61–63,65,66,68
	T. albacares				X	*	*	*	X	X				40,63
	T. atlanticus				X	*	*	*	X	X	X	X		2,21,23,25,32,40,61,63, 64,79
	T. thynnus				X	X	X							2,21,23,25,32,40,61,64, 68,76–78,80
Xiphiidae	*Xiphias gladius*	X	X	X	*	*	*	X	X	X	X	X	X	19,23,25,64,79
Istiophoridae	*Istiophorus* sp.				X	X	X	X	X					2,16,23,25,61–64
Stromateidae	*Ariomma* spp.	X	X	X	X	X	X	X	X			X	X	2,40,41,57,59
	Cubiceps pauciradiatus	X	X	X	X	X	X	X	X	X	X	X	X	2,40,41,59,61,63,64
	Hyperoglyphe bythites					X	X	X	X					36
	Nomeus gronovii	X	X											40,41
	Peprilus paru				X	X	*	*	*	X	X	X		2,32,38,40,41,53,56,57, 59,61–63,66
	P. burti	*	*	*	X	X	X	X	X	X	X	*	*	2,32,38,40,41,53,57,59, 61–64,66,68
	Psenes spp.		X						X			X		2
	P. cyanophrys					X								2

TABLE 1.—*Continued.*

Family	Taxa	J	F	M	A	M	J	J	A	S	O	N	D	Source
	P. pellucidus	X	X							X	X	X		2
	Tetragonurus atlanticus	X												59
Scorpaenidae	*Scorpaena* spp.	X	X	X	X	X	X	X	X	X	X	X	X	2,40,41,53,56,57,61–63, 66,68
Triglidae	*Peristedion* spp.					X								2
	Prionotus spp.	X	X	X	X	X	X	X	X	X	X	X	X	1–3,40,41,46,53,56–59, 61–64,66,68,69
Dactylopteridae	*Dactylopterus volitans*					X								2,40
Bothidae	*Bothus* spp.	X			X	X	X	X	X	X	X	X	X	32,40,41,45,59,61–64,68
	B. ocellatus	X	X	*	*	*	X	X	X	X	X	X	X	61–63,68
	B. robinsi		X	X	X	*	*	*	*	*	*	*		2,9
	Citharichthys spp.	X	X	X	X	X	X	X	X	X	X	X	X	32,40,46,56–59,63,66,68, 69
	C. cornutus	X	X		X	*	*	*	*	X	X	X		2,9,32,40
	C. gymnorhinus	X	X			X	X	X	X	X	X	X	X	2,9,32,40,59
	C. macrops	X	X	X	X	*	X	X	X	X	X	X		2,9,26
	C. spilopterus	X	X	X	X	X		X	X	X	X	X	X	2,26,40,41,45,53,59
	Cyclopsetta spp.	X	X	X		X	X	*	*	*	X	X		32,40,41,45,61–63,68
	C. fimbriata	X	X			X	*	X	X	*	X	X		2,9,62,63
	Engyophrys senta					X	X	X	X	X	X			2,20,32,40,41,45,53,59
	Etropus crossotus				X	X	X	X	X	X	X	X		26,32,40,41,45,46,56,57, 59
	E. rimosus	*	*	*	*	X	X	X	X	X	X	*	*	2,9,26
	Monolene sessilicauda					X	X	X	X	X	X	X	X	2,9,13,32,40,61,62,68
	Paralichthys spp.	*	*	X	X					X	X	X	*	1,2,40,41,45–47, 53,57, 59,61–63,66,68–70
	Syacium spp.				X	X	*	*	*	X	X	X	X	32,40,41,45,53,59,61–64, 68
	S. gunteri						X	*	*	X	X	X	X	32,40,57,61–63,66
	S. papillosum					X	*	*	*	*	X	X		2,9,14,32,40
	Trichopsetta ventralis					X	X	X	X	X	X			2,9,15,32,40,45
Soleidae	*Achirus lineatus*		X	X	X	X	*	*	*	X	X	X		2,3,40,41,45–47,53,56, 57,59,75
	Gymnachirus sp.				X	*	*	X						61,63
	G. melas		X			X	X					X		2
	Trinectes maculatus				X	X	*	X	X	X				1,40,46,53,58,66
Cynoglossidae	*Symphurus* spp.	X	X	X	X	X	X	X	X	X	X	X	X	2,3,40,45–47,53,56–59, 61–64,66,68,69
Balistidae	*Balistes* sp.							X	X					61
	Monacanthus sp.					X				X	X			61,62,68
	M. hispidus					X	X	X		X		X		46,53,69
	M. setifer											X		40
Ostraciidae	*Lactophrys* sp.					X	X						X	66,68
Tetraodontidae	*Lagocephalus laevigatus*					X				X				68
	Sphoeroides spp.	X	X	X	X	X	X	X	X	X	X	X	X	1,2,40,41,46,53,56,57, 59,61–64,66,68,69
Molidae	*Ranzania laevis*										X			64

[1]Blanchet 1979.
[2]Houde et al. 1979.
[3]Phillips et al. 1977.
[4]Houde 1981.
[5]Houde and Fore 1973.
[6]Smith 1980.
[7]Houde 1982.
[8]Leak 1981.
[9]Dowd 1978.
[10]Aprieto 1974.
[11]Caldwell 1957.
[12]Houde 1973.
[13]Futch 1971.
[14]Futch and Hoff 1971.
[15]Futch 1977.
[16]Gehringer 1957.
[17]Gibbs and Collette 1959.
[18]Gordon 1982.
[19]Grall et al. 1983.
[20]Hensley 1977.
[21]Juarez 1976.
[22]Houde 1976.
[23]Kelley et al. 1986.
[24]Montolio 1976.
[25]Richards et al. 1984.
[26]Tucker 1978.
[27]Dwinell and Futch 1973.
[28]Peters and McMichael 1987.
[29]Houde 1977a.
[30]Houde 1977b.
[31]Houde 1977c.
[32]SEAMAP 1983.
[33]Christmas and Waller 1975.
[34]Cowan 1985.
[35]Daniels 1977.
[36]Dawson 1971a.
[37]Dawson 1971b.
[38]Ditty 1981.
[39]Ditty 1984.
[40]Ditty 1986.
[41]Ditty and Truesdale 1984.
[42]Fore 1970.
[43]Fore 1971.
[44]Fruge 1977.
[45]Kuhn 1979.
[46]Ruple 1984.
[47]Sabins 1973.
[48]SEAMAP 1985.
[49]Shaw et al. 1985.
[50]Shaw and Drullinger 1985.
[51]Shaw and Drullinger 1986.
[52]Shaw et al. 1987.
[53]Stuck and Perry 1982.
[54]Thompson and Deegan 1982.
[55]Turner 1969.
[56]Vecchione et al. 1982.
[57]Walker 1978.
[58]Williams 1983.
[59]LDWF 1983 unpubl. data.
[60]SEAMAP 1984.
[61]Finucane et al. 1977.
[62]Finucane et al. 1979a.
[63]Finucane et al. 1979b.
[64]McGowan 1985.
[65]McEachran et al. 1980.
[66]Hoese 1965.
[67]Barger et al. 1980.
[68]Finucane 1976.
[69]Allshouse 1983.
[70]King 1971.
[71]Guillen and Landry 1981.
[72]Pearson 1929.
[73]Collins et al. 1980.
[74]Sogard et al. 1987.
[75]Houde et al. (1970, cited in Phillips et al. 1977).
[76]Richards 1976.
[77]Richards 1977.
[78]Richards and Potthoff 1980a.
[79]Richards and Potthoff 1980b.
[80]McGowan and Richards 1986.

TABLE 2.—Primary depth distribution of larvae (<10 mm SL) of some abundant taxa of fishes from the northern Gulf of Mexico above lat. 26°00′N. Depths are those reported in the literature at which >75% of larvae were collected. Asterisk (*) indicates larvae are estuarine-dependent.

Taxa	Depth (m) <25	<50	<100	50–200	>150	Source
Chloroscombrus chrysurus	X					1,2,3,4,5,6,8,10
Orthopristis chrysoptera	X					1
Cynoscion nebulosus *	X					1,9,10
C. arenarius	X					1,2,9,10,11
Pogonias cromis *	X					11
Archosargus probatocephalus *	X					1
Chaetodipterus faber	X					2
Peprilus paru	X					1,25,26
Anchoa spp.		X				1
Harengula jaguana		X				1,4,5,6,13
Opisthonema oglinum		X				1,4,5,6,10,29
Brevoortia patronus *		X				14,15,16,17,32
Sardinella aurita		X				1,4,6,18
Diplectrum formosum		X				1
Serraniculus pumilio		X				1
Centropristis striata		X				1
Lagodon rhomboides *		X				1
Leiostomus xanthurus *		X				1,11,19,32
Micropogonias undulatus *		X				1,11,19,20,32
Scomberomorus maculatus		X				1,4,21,22,23,24
Decapterus punctatus			X			1,3,4,6
Peprilus burti			X			25,26
Etrumeus teres				X		1,5,6,11,12,27,28,30
Caranx crysos				X		1,3,4,6
Trachurus lathami				X		1,2,3,5,30
Hemanthias vivanus				X		1
Auxis sp.				X		1,21,22,23
Euthynnus alletteratus				X		1,21,22,30
Scomberomorus cavalla				X		20,23,24
Lutjanus campechanus				X		31
Xiphias gladius					X	7,21,22
Istiophorus spp.					X	21,22
Euthynnus pelamis					X	1,21,22,23

[1]Houde et al. 1979.
[2]Ditty and Truesdale 1984.
[3]Leak 1981.
[4]Shaw et al. 1987.
[5]Shaw and Drullinger 1986.
[6]Shaw and Drullinger 1985.
[7]Grall et al. 1983.
[8]Montolio 1976.
[9]Daniels 1978.
[10]Walker 1978.
[11]Cowan 1985.
[12]Houde 1977b.
[13]Houde 1977c.
[14]Shaw et al. 1985.
[15]Fore 1970.
[16]Turner 1969.
[17]Christmas and Waller 1975.
[18]Houde 1976.
[19]Fruge 1977.
[20]Finucane et al. 1977.
[21]Richards et al. 1984.
[22]Kelley et al. 1986.
[23]Dwinell and Futch 1973.
[24]McEachran et al. 1980.
[25]Ditty 1981.
[26]SEAMAP 1983.
[27]Fore 1971.
[28]Houde 1973.
[29]Houde 1977a
[30]Finucane et al. 1979b.
[31]Collins et al. 1980.
[32]Sogard et al. 1987.
[33]Richards and Potthoff 1980b.

crepancy in Spanish sardine seasonal occurrence reported by Houde and Fore (1973) (September–February) and that found by Shaw and Drullinger (1985, 1986), Shaw et al. (1987), and this review (March–November). Finally, seasonality data reported in Ditty (1986) for larvae of finescale menhaden, *Brevoortia gunteri*, was based on specimens subsequently believed to be a morph of gulf menhaden (*B. patronus*).

In general, the seasonal occurrence of many taxa of larval fishes (i.e., scaled sardine, *Harengula jaguana*, and Atlantic thread herring, *Opisthonema oglinum*) began both earlier and extended later in studies conducted on the Florida continental shelf and southern parts of the study area than those in the northern-most GOMEX. Likewise, in studies involving bays (e.g., Phillips et al. 1977; Blanchet 1979; Williams 1983), tidal passes (e.g., King 1971; Sabins 1973; Allshouse 1983), and barrier islands (e.g., Guillen and Landry 1981; Ruple 1984), peak seasonal occurrence of larvae of some fishes was usually later than in studies conducted offshore, primarily because of the time delay necessary for shoreward migration of estuarine-dependent larvae such as Atlantic croaker (*Micropogonias undulatus*), striped mullet (*Mugil cephalus*), pinfish (*Lagodon

TABLE 3.—Location and sampling characteristics for northern Gulf of Mexico (GOMEX) ichthyoplankton studies. For months sampled: Q = quarterly, M = monthly, S = synoptic, B = biweekly. Numbers in columns with asterisk (*) refer to footnotes. Numbers separated by semicolons refer to specific gear types.

Study	Gear type*	Mesh size (mm)	Station depths (m)	Months/freq. sampled*	Study type/ taxa studied	Tow type*	Study location
Phillips et al. 1977	2	0.363	<10	10, B	Survey	13	Tampa/Hillsborough Bay, FL
Blanchet 1979	2	0.505	2–6	11, M	Survey	14	Lower Apalachicola Bay, FL
Houde et al. 1979	1, 2	0.505	10–200	9, Q	Survey	13	Florida continental shelf
Turner 1969	4	0.571	<58	9, Oct.–Apr.	*Brevoortia*	15, 19	Eastern and central GOMEX
Williams 1983	5	0.505	<10	11, M	Survey	14, 17	Lower Mobile Bay, AL
Struck and Perry 1982	2	1.050	10	9, M	Survey	14, 17	Off Mississippi Sound
Ruple 1984	4; 6	0.505, 0.571	4–7; 0.5	12, M	Survey	14, 19; 21	Horn Island, MS
Juarez 1976	2	0.505	>183	Q, Apr.–Nov.	Scombrids	13	Central GOMEX
Montolio 1976	2	0.505	>183	Q, Apr.–Nov.	Carangids	13	Central and western GOMEX
Fore 1971	—	—	27–108	M, Dec.–Apr.	*Etrumeus*	—	Central GOMEX
Sabins 1973	8	0.480	<1.5	11, M	Survey	19, 21	Caminada Pass, LA
Fruge 1977	1, 2	0.505	<91	Nov.	*Micropogonias*	13	Mississippi River Delta to Atchafalaya Bay, LA
Kuhn 1979	1	0.505	10–91	Nov., Jan., July	Bothids	13	Mississippi River Delta to Atchafalaya Bay, LA
Ditty and Truesdale 1984	1	0.505	10–91	Jan., July	Survey	13	Mississippi River Delta to Atchafalaya Bay, LA
Walker 1978	2	0.505	10–45	July, Aug., Dec.	Survey	15, 19	Mississippi River Delta to Timbalier Bay, LA
Ditty 1986	1; 2	0.363	10; 30	11, M; 9, Q	Survey	14, 16, 17; 14	Off Caminada Pass, LA
Vecchione et al. 1982	1	0.333, 0.505	10	11, M	Survey	14, 16, 17	Southwest Louisiana off Calcasieu Lake
Cowan 1985	1	0.335	6–130	M, Dec.–Apr.	Sciaenids	18	Southwest Louisiana
Shaw et al. 1985	1	0.335	6–130	M, Dec.–Apr.	*Brevoortia*	18	Southwest Louisiana
Guillen and Landry 1981	8	1.000	<1.5	M, Jan.–Aug.	Survey	19, 21	Galveston Island, TX
McGowan 1985	1	0.333	Over reef	9, Q	Survey	13, 20	Flower Gardens Reef, TX
King 1971	4	1.000	<5	9, M	Survey	14, 16, 17	Cedar Bayou Pass, TX
Hoese 1965	2	0.086	6–50	9, M	Survey	14	Off Port Aransas, TX
Allshouse 1983	4	0.505	3–12	11, M	Survey	13	Aransas Pass, TX
Finucane 1976	2	0.250	18–135	Dec., Apr., Aug.	Survey	13	South Texas continental shelf
Finucane et al. 1977, 1979b	1	0.333, 0.505	18–182	9, M	Survey	13	South Texas continental shelf
Finucane et al. 1979a	1	0.333, 0.505	17	July, Oct., Feb.	Survey	13	Off Galveston, TX
Fore 1970	7	—	7–75	M, Sept.–Apr.	*Brevoortia*	18	Central and western GOMEX
Christmas and Waller 1975	2; 4	0.505; 1.000	2–110	9, Oct.–Apr.	*Brevoortia*	13; 14	Gulf-wide
Richards and Potthoff 1980a, b	1; 3	0.505; 0.946	>183	9, Apr.–May	Scombrids	13; 14	Gulf-wide
SEAMAP 1983–1985	1; 3	0.333; 0.946	>10	9, S	Survey	13; 14	Gulf-wide

[1]60 cm bongo.
[2]1 m net.
[3]1 × 2 m neuston.
[4]0.5 m net.
[5]1 × 0.5 net.
[6]2 × 0.5 m.
[7]Gulf-V sampler.
[8]Renfro beam trawl.
[9]Multiyear.
[10]15 months.
[11]12 months.
[12]14 months.
[13]Oblique.
[14]Surface.
[15]Subsurface.
[16]Middepth.
[17]Bottom.
[18]Stepwise oblique.
[19]Horizontal.
[20]Oblique at select depth intervals.
[21]Surf zone.

rhomboides), black drum, red drum, and gulf menhaden.

The seasonal occurrence of several taxa are known only from a few scattered specimens (e.g., cornetfish, *Fistularia* sp.; ribbonfish, *Trachipterus* sp.; cowfish, *Lactophrys* sp.; slender mola, *Ranzania laevis*; threadfish, *Polydactylus* sp.; and cobia, *Rachycentron canadum*) or a single monthly record (Table 1). Larvae of other taxa (e.g., searobins, *Prionotus* spp.; anchovies, *Anchoa* spp.; tonguefishes, *Symphurus* spp.; and pufferfishes, *Sphoeroides* spp.) were collected during all months (Table 1), reflecting the many species that comprise each genus. In general, larvae of most scombrids were collected beyond the 50 m depth contour, except Spanish mackerel, *Scomberomorus maculatus*, which occurred primarily within 50 m. Finucane et al. (1979b) collected 50% of their king mackerel, *S. cavalla*, larvae off Texas during September and found this species relatively more abundant and over greater water depths (35–183 m) than Spanish mackerel (<35 m). In the north-central GOMEX, larvae of

Spanish mackerel were more abundant than those of king mackerel, and spawning of this latter species probably occurs over shallower depths than in the northwestern GOMEX (Shaw et al. 1987). Only six larvae of king mackerel were collected by Houde et al. (1979), suggesting that this species does not use the northeastern GOMEX as a major spawning area. Larvae of cero, *S. regalis*, have not been reported from the study area. Larvae of sciaenids and engraulids occurred primarily within the 50 m depth contour, with several species of sciaenids primarily collected inside the 25 m contour (Table 2). Both sciaenids and engraulids are relatively more abundant in the north-central and northwestern than in the northeastern GOMEX (Finucane et al. 1977, 1979b; Houde et al. 1979; Richards et al. 1984; Kelley et al. 1986) (Table 4). Most larvae of clupeids occur in shelf waters of <50 m depth, except those of round herring, *Etrumeus teres*, which primarily occur beyond the 50 m contour (Table 2). Larvae of gulf menhaden are more abundant in the north-central than either the northeastern or northwestern GOMEX and occur primarily around the Mississippi River Delta (Fore 1970; Christmas and Waller 1975; Sogard et al. 1987; and others). Scaled sardine and Atlantic thread herring larvae are abundant in all three subregions of the northern GOMEX; Spanish sardine are rare in the north-central but relatively abundant in the northeastern and northwestern GOMEX (Shaw and Drullinger 1985, 1986; Shaw et al. 1987). Larvae of gulf butterfish, *Peprilus burti*, and harvestfish, *P. paru*, are most common in the north-central GOMEX (SEAMAP 1983), with only a few of their larvae (8 and 25, respectively) having been collected by Houde et al. (1979) in the northeastern GOMEX. Although gulf butterfish larvae have been collected during every month (Table 1), larvae are most common from November to March with very limited spawning during the summer (Ditty 1981; SEAMAP 1983). Houde et al. (1979) also collected >90% of both sparid and haemulid larvae inside the 50 m contour during their Florida continental shelf survey and found that although lutjanids occurred at all depths, they were most abundant from 30 to 100 m. Unlike larvae of other speciose families which primarily occurred either within (e.g., clupeids, engraulids, and sciaenids) or beyond (e.g., scombrids) the 50 m depth contour, those of bothids, carangids, and serranids were widely distributed and occurred at all depths. Larvae of swordfish, *Xiphias gladius*, and sailfish, *Istiophorus* sp., are oceanic and occurred primarily outside the 200 m depth contour; leptocephali of tarpon, *Megalops atlanticus*, and bonefish, *Albula vulpes*, were seldom collected in the study area. Of those taxa whose larvae were most abundant within the 25 m contour (Table 2), several were most commonly collected at considerably shallower depths (e.g., pigfish, *Orthopristis chrysoptera* <20 m; black drum <18 m; and spotted seatrout, *Cynoscion nebulosus* <15 m). Larvae of other taxa which occurred primarily within the 25 m contour includes leatherjacket, *Oligoplites saurus* (<20 m; Houde et al. 1979); kingfish, *Menticirrhus* spp. (<20 m; Walker 1978; Houde et al. 1979; Cowan 1985); and spottail pinfish, *Diplodus holbrooki* (<15 m; Houde et al. 1979). Larvae of hogchoker, *Trinectes maculatus*, and silver perch, *Bairdiella chrysoura*, were occasionally collected in neritic offshore studies, but were most abundant in pass/estuarine studies (e.g., Sabins 1973; Allshouse 1983).

TABLE 4.—Comparison of 10 most abundant families of larval fishes collected during major ichthyoplankton surveys of the Gulf of Mexico. Rank is based on number of individuals collected. Numbers are % of total collection.

Taxa	Finucane 1976	Finucane et al. 1977	Finucane et al. 1979b	Houde et al. 1979	Kelley et al. 1986
Engraulidae	17.4	13.5	6.2		14.6
Gobiidae	16.6	20.6	15.8	15.1	6.2
Bregmacerotidae	14.5	12.5	7.3	2.7	5.4
Clupeidae	8.5	5.0	8.1	20.5	9.6
Sciaenidae	5.3	2.1			3.1
Carangidae	4.8	3.1	3.7	3.9	4.1
Bothidae	4.6	8.4	6.1	6.4	4.4
Synodontidae	4.5	3.6	10.9	3.0	
Myctophidae	3.0	5.0	4.9	5.1	11.2
Serranidae	2.0		2.2	4.9	
Cynoglossidae			3.4		
Scombridae		1.9			
Ophidiidae				2.9	
Labridae				2.3	
Gonostomatidae					3.3
Mugilidae					2.5
Totals	81.2	75.7	68.6	66.8	64.4

In conclusion, these data represent the current knowledge of the seasonality, peak occurrence, and primary depth distribution of larval fishes in the northern GOMEX. This information provides a foundation upon which sound management decisions concerning both the commercial and recreational exploitation of spawning aggregations of fishes and the potentially adverse impact on these fisheries resulting from such exploitation can be based.

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UTILIZATION OF A WASHINGTON ESTUARY BY JUVENILE ENGLISH SOLE, *PAROPHRYS VETULUS*

The use of west coast estuaries and protected bays as nursery grounds by English sole, *Parophrys vetulus* Girard, a significant component of Pacific coast groundfish landings, has been well documented (Westerheim 1955; Kendall 1966; Smith and Nitsos 1969; Misitano 1970). From data collected off Oregon, Laroche and Holton (1979) showed that English sole also utilize nearshore areas along the open coast as nursery grounds. Krygier and Pearcy (1986) determined that estuarine dependence for juvenile English sole was indeed significant relative to the open coastal area off Oregon, although their survey design made it difficult to compare absolute abundance in these areas. In addition, the estuaries studied by Krygier and Pearcy were much smaller than the Washington estuaries of Grays Harbor and Willapa Bay, making it difficult to extrapolate their results.

In the present study our objectives were to 1) compare relative density and estimates of abundance of 0-age English sole between a Washington estuary, Grays Harbor, and the adjacent area along the open coast; 2) compare fish density between several subareas (strata) of each system; and 3) note timing of immigration to and emigration from the estuary. Specific gear was developed to efficiently sample small benthic organisms and was used in both the estuary and open coast survey areas, eliminating the need for gear selectivity intercalibration. In addition, the statistical design of the survey enabled population estimates with confidence intervals to be made for each area.

Methods and Materials

Survey Design

For this study, we specifically developed a plumb staff beam trawl with an effective width of 2.3 m. We designed it for a quantitative assessment of juvenile fishes and crustaceans closely associated with the bottom. Its fine mesh (4 mm) cod end liner retained newly settled flatfish (15–25 mm total length). A complete account of its construction, method of deployment, and field testing was given by Gunderson and Ellis (1986).

We selected two separate survey areas for the study, the Grays Harbor estuary and the adjacent nearshore area along the open coast. The estuarine survey was based on a stratified random statistical design and the open coast survey on a systematic trackline. Both areas were surveyed in 1983 and 1984.

The estuary was stratified into four geographic areas (Fig. 1). Each stratum was divided into 1 × 1 km grids (1 km intervals in the case of narrow channels), and several stations were then randomly selected with the constraint that no two be adjacent. Additional stations were added in both STR (stratum) 1 and 2 for the 1984 survey.

For the open coastal survey, three tracklines oriented perpendicular to the bathymetry were located off Copalis Head, Westport, and Willapa Bay (Cape Shoalwater) (Fig. 2). We established a systematic series of stations along each trackline at 9 m depth intervals from 9 to 64 m. Whenever wave conditions permitted, we sampled an additional station at 5.5 m. In 1984, the 64 m stations were dropped on each trackline because of consistent gear damage in 1983. Also in 1984, replicate tows were made at the 27 and 37 m stations.

Sampling Schedule

We sampled the estuary twice monthly from April through September 1983 and 1984, and a single trip was made in January 1984 for continuity. The two