NOAA Technical Memorandum NMFS-SEFSC-566

SEASONAL FOODS, GONADAL MATURATION, AND LENGTH-WEIGHT RELATIONSHIPS FOR NINE FISHES COMMONLY CAPTURED BY SHRIMP TRAWL ON THE NORTHWEST GULF OF MEXICO CONTINENTAL SHELF

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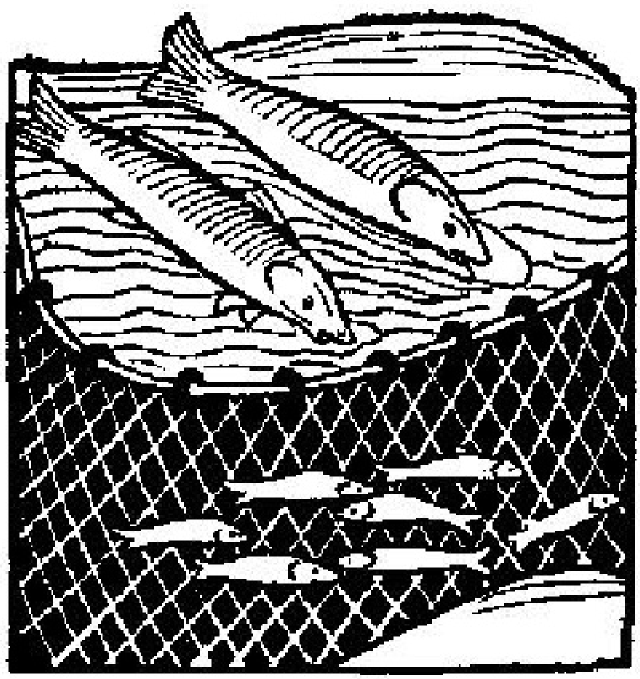

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February 2008

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February 2008

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Sheridan, P. 2008. Seasonal foods, gonadal maturation, and length-weight relationships for nine fishes commonly captured by shrimp trawl on the northwest Gulf of Mexico continental shelf. NOAA Technical Memorandum NMFS-SEFSC-566, 37 p.

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Abstract

Recent emphasis on ecosystem approaches to fisheries management renews interest in, and the need for, trophic information about fish communities. A program was started in 1980 at the National Marine Fisheries Service Galveston Laboratory to develop a trophic database for continental shelf fishes. Collections were made during 1982-1983 that were processed but never published, yet the data remain valid today for historical purposes and for delimiting food web components within ecosystem assessments. I examined spring, summer, and fall foods in offshore populations of nine common species of trawl-susceptible fishes, with particular reference to predation on commercial penaeid shrimps (*Farfantepenaeus* and *Litopenaeus*). Diets were evaluated with the Index of Relative Importance (IRI) which combines the occurrence, number, and weight of each food item. Bank sea bass (*Centropristis ocyurus*) and bighead searobin (*Prionotus tribulus*) primarily consumed crabs, more so by larger than smaller fish. Inshore lizardfish (*Synodus foetens*) was almost entirely piscivorous. Ocellated flounder (*Ancylopsetta ommata*) consumed fishes, crabs, and stomatopods. Dwarf sand perch (*Diplectrum bivittatum*), blackwing searobin (*Prionotus rubio*), rock sea bass (*Centropristis philadelphica*), southern kingfish (*Menticirrhus americanus*), and red snapper (*Lutjanus campechanus*) fed mainly on shrimps. Most fish diets varied with respect to size (age), time of day, area sampled, depth, or season. *Rimapenaeus* and *Sicyonia* were the most frequently identified shrimp genera - only five *Farfantepenaeus* and no *Litopenaeus* were identified in almost 4,300 fish stomachs. I also examined gonadal development and documented fish length-weight relationships. Ripe gonads were most frequently found during summer in dwarf sand perch, during fall in ocellated flounder and bighead searobin, and during spring for other species, except no ripe red snapper or bank sea bass were collected. Rock sea bass was found to be a protogynous hermaphrodite, while dwarf sand perch is a synchronous hermaphrodite. Only ocellated flounder and southern kingfish exhibited sex-related differences in length-weight relationships.

Introduction

The U. S. National Marine Fisheries Service (NMFS) has begun moving towards an ecosystem approach to fisheries management (Sissenwine and Murawski 2004, Murawski 2007). An ecosystem approach entails working knowledge not only of factors that affect natural and fishing mortality rates but also of the food web surrounding and supporting fishery species (Griffis and Kimball 1996, Fluharty 2000). The NMFS Galveston Laboratory initiated a program in the early 1980's that presaged these requirements while conducting research relevant to the Gulf of Mexico Fishery Management Council (GMFMC) shrimp fishery management plan (GMFMC 1981) and the draft GMFMC groundfish management plan (not enacted). At the time, quantitative information concerning foods of continental shelf fishes and fish predation on commercial penaeid shrimps in offshore waters was scant. For example, the shrimp fishery management plan (GMFMC 1981) listed numerous predators of shrimp based solely on the estuarine studies of Gunter (1945) and Darnell (1958).

Several relevant studies were conducted just prior to or following the GMFMC deliberations. Rogers (1977) conducted a study of the trophic relationships of trawl-susceptible bottomfishes off the Texas and Louisiana coasts. He examined 4,550 stomachs from 26 fish species yet did not encounter any *Farfantepenaeus* (brown shrimp, *F. aztecus*, or pink shrimp, *F. duorarum*) or *Litopenaeus* (white shrimp, *L. setiferus*). Sheridan and Trimm (1983) and Sheridan et al. (1984b) reported the offshore foods of the seven most abundant coastal fishes captured by trawl in the same area, finding only hardhead catfish (*Arius felis*), sand seatrout (*Cynoscion arenarius*), and silver seatrout (*C. nothus*) as predators on *Farfantepenaeus*, and then only rarely and not in any particular season. Sheridan et al. (1984a) used the available trophic information to develop an early model of penaeid shrimp - bottomfish interactions and energy flow.

However, two studies (one never published) addressed the potential for increased predation during brown shrimp emigration from estuaries, a time when offshore shrimp are at their smallest sizes. Qualitative examination of over 29,600 stomachs from 168 species of trawl-susceptible fishes collected during the summers of 1981 and 1982 (Divita et al. 1983; NMFS, unpublished data) identified nine additional summertime predators of commercial shrimp from the northwestern Gulf of Mexico. These species were rock sea bass (*Centropristis philadelphica*), bighead searobin (*Prionotus tribulus*), blackwing searobin (*Prionotus rubio*), inshore lizardfish (*Synodus foetens*), ocellated flounder (*Ancylopsetta ommata*), dwarf sand perch (*Diplectrum bivittatum*), southern kingfish (*Menticirrhus americanus*), red snapper (*Lutjanus campechanus*), and lane snapper (*Lutjanus synagris*).

Those species became the focus of this study, in which I examined seasonal aspects of fish diets. Bank sea bass (*Centropristis ocyurus*), while not a known shrimp predator, was included in this study because of its allopatric distribution relative to rock sea bass east of the Mississippi Delta. While sought, no lane snapper were collected during the surveys addressed herein. For each of the nine fish species, I examined: 1) general food habits and relative importance of commercial shrimps (families Penaeidae and Sicyoniidae) in the diet; 2) factors such as size (age), time of day, depth, locale, and season of capture which could influence diets; 3) reproductive periodicity; and 4) length-weight relationships between sexes.

Materials and Methods

Fishes were taken from SEAMAP (Southeast Area Monitoring and Assessment Program) trawl catches made by the NOAA Ship OREGON II and the state vessels R/V WESTERN GULF (Texas), R/V TOMMY MUNRO (Mississippi), and R/V SUNCOASTER (Florida) in 9-91 m waters between Pensacola, Florida and Brownsville, Texas. Day and night collections were made in Florida, Alabama, Mississippi, and Louisiana during October-November (fall) 1982, March-April (spring) 1983, June-July (summer) 1983, and October-November 1983. Collections off Texas were made only at night and only during June-July 1983. Each vessel towed a 12.2-m semiballoon trawl with tickler chain at 5-6 km/h. Fishes were collected according to 1) arbitrary depth strata (9-17 m, 18-36 m, 37-55 m, 56-73 m, and 74-91 m), 2) general locale (Florida, 85° 35' - 87° 20' W longitude; East Delta, 87° 20' - 89° 30' W; West Delta, 89° 30' - 94° 00' W; Texas, 94° 00' - 97° 30' W), and 3) day (0800-1600 h) or night (2000-0400 h) capture. Fishes were chosen haphazardly across the available size ranges. Specimens were preserved in 3.7% formaldehyde-seawater or frozen until analyzed.

Fishes were measured to the nearest mm standard length (SL) and were weighed to the nearest 0.1 g after blotting dry. Length-weight relationships were determined by regression of $\log_{10}$-transformed data. Fishes were presumed to have reached Age I at the following lengths: ocellated flounder, 150 mm (based on a ripe 165 mm male); bank and rock sea basses, 100 mm (Lavenda 1949, and ripe females at 100 mm); dwarf sand perch, 90 mm (ripe females); red snapper, 120 mm (Holt and Arnold 1982); southern kingfish, 190 mm (ripe 192 male and ripe 207 mm female); blackwing and bighead searobins, 110 mm (Richards et al. 1979, Ross 1983); and inshore lizardfish, 200 mm (ripe 192 mm male and ripe 215 mm female).

Stomachs were removed and stored individually in 40% isopropanol. Gonads were examined visually and assigned to one of six maturation stages following Rohr and Gutherz (1977): undeveloped, immature, developing, maturing, ripe, or spent. Chi square analysis was used to detect deviations from expected 1:1 sex ratios.

The contents of each stomach were sorted under a binocular dissecting microscope into broad but exclusive categories, such as polychaetes, amphipods, or crabs. Shrimps were further divided into non-penaeids and genera of penaeids. At the time of the study, commercial penaeids in the Gulf of Mexico included the genera *Penaeus*, *Trachypenaeus*, and *Sicyonia* (as well as others not detected in this study) within the family Penaeidae. Since that time, taxonomic revisions by Pérez Farfante and Kensley (1997) split the Sicyoniidae from the Penaeidae, split *Farfantepenaeus* and *Litopenaeus* from *Penaeus*, and split *Rimapenaeus* from *Trachypenaeus*. My use of the term penaeids hereafter references all genera that were identified: commercial *Farfantepenaeus*, *Litopenaeus*, *Rimapenaeus*, and *Sicyonia* plus the non-commercial *Parapenaeus* and *Penaeopsis*. Animal fragments not distinctly referable to any taxon were categorized as such. Fine organic matter not referable to any other category was termed detritus. Algae, diatoms, seagrasses, seeds, and woody material were grouped as plant matter. All shrimps, crabs, and fishes were identified when possible to family or genus for qualitative analysis. The items in each category were counted, placed in pre-weighed aluminum pans, dried at 80-90°C for 24 h, and re-weighed (0.0001 g). Data from all stomach analyses within each fish species were first pooled to examine overall diets. Diet variation was examined by age, time, locale, depth, season, or arbitrary size class, the latter to examine trophic ontogeny in species with a wide range in sizes collected. For each combination of fish stomach contents, I calculated for each food category its frequency of occurrence (%F = percent of stomachs containing this food type), numerical composition (%N = percent of this food type among the total number of items in the sample), and weight or biomass (%W = percent of this item in the total dry weight of all contents in the sample). These values were then used to calculate the Index of Relative Importance (IRI, Pinkas et al. 1971) for each food type:

$$IRI = (\%N + \%W)(\%F).$$

Since IRI can vary between 0 and 20,000, I normalized IRI values for each food type as percent of the total IRI for the sample (%IRI, Cortés 1997).

Results

General food habits and prey taxa. — The %IRI values (Table 1) pinpoint the primary foods to be crabs for bank sea bass and bighead searobin, fishes for ocellated flounder and inshore lizardfish, and non-penaeid shrimps for rock sea bass, dwarf sand perch, red snapper, southern kingfish, and blackwing searobin. All species except inshore lizardfish had a secondary food type with a relatively high %IRI value, usually either shrimps, crabs, or fishes. Inshore lizardfish was almost completely piscivorous (%IRI = 94.8).

Prey crabs, shrimps, and fishes were identified whenever possible (Table 2). Eight families and 19 genera of crabs were identified among 194 intact crabs taken from fish stomachs. *Portunus*, *Callinectes*, and Portunidae were found most frequently (30% of identified crabs) and were preyed upon primarily by rock sea bass and bighead searobin. *Parthenope*, *Solenolambrus*, and other Parthenopidae formed 13% of the identified crabs, mainly from bank sea bass and blackwing searobin. *Panopeus*, *Micropanope*, and other Xanthidae (13%) were consumed by most predators. Three families and 10 genera of shrimps were identified from 443 intact prey shrimps. Most were *Rimapenaeus* (49%), followed by *Sicyonia* (16%) and Alpheidae (12%). *Rimapenaeus* was the most frequently identified shrimp in all predators except bighead searobin, in which *Sicyonia* predominated. Five families and 24 genera of fishes were identified among 120 intact prey fishes. Twenty-two of the prey fish taxa were eaten by inshore lizardfish. No single group stood out as the primary prey, but carangids (*Trachurus*, *Decapterus*, *Selene*, *Chloroscombrus*; 15% of identified fish), engraulids (*Anchoa*; 12%), and Ophichthidae (8%) were prominent. Ophichthidae was the only prey fish family found in ocellated flounder and the only taxon eaten at least once by all predators.

Diet evaluation by IRI and its components (frequency of occurrence, numerical composition, and dry weight) is presented in Table 3 for primary foods of the nine fish species. In four of nine cases (bank sea bass, dwarf sand perch, bighead searobin, inshore lizardfish), each component and the IRI identified the same primary food. The most extreme disagreement was found for ocellated flounder prey, of which fishes occurred most frequently, nematodes were numerically dominant, and stomatopods contributed the most biomass. In all cases, the most frequently occurring food item had the highest IRI, as did all but one of the most numerous items. Highest biomass contributors more often than not occurred infrequently or were not numerous. The IRI thus moderated results of individual index components.

Factors affecting diet composition. — To determine whether or not fish diets were uniform in time or space, the overall diets were re-analyzed by age, time, locale, depth, and season. Two piscivores were identified: inshore lizardfish and ocellated flounder. The least variable among all nine fish species was that of inshore lizardfish: fish was the primary prey (%IRI $\geq$ 89) no matter how the data were organized (Fig. 1). The other piscivore, ocellated flounder, was more flexible in its diet although this observation is tentative due to the small number (n=13) of full stomachs examined (Fig. 2). After fishes, crabs were the most important diet component in Age 0 ocellated flounder, those from the West Delta and Texas coasts, in 18-36 m waters, or during summer. Alternatively, stomatopods were more important secondary prey for Age 1 ocellated flounder and those collected on the East Delta, in 37-55 m waters, or in spring.

The two fishes classified as crab predators also demonstrated some diet variability. Bank sea bass were only collected during summer surveys, so analyses were limited (Fig. 3). Crabs were the primary prey of both age classes, much more so at Age 1 (%IRI = 72) than at Age 0 (%IRI = 37). Shrimps and polychaetes became important prey on the West Delta and in 9-17 m and 56-73 m depths. For bighead searobin, however, crabs were the primary food by all comparisons except in spring (Fig. 4). At that time, most bighead searobins examined (37/45 individuals) were $\leq$ 75 mm long and were largely epibenthic or planktonic predators consuming mysids, cumaceans, and amphipods.

Based on their overall diets, the remaining five fish species were classified as predators on shrimps. Dwarf sand perch had the least variable diet (Fig. 5). Non-penaeid shrimps were the main food in all cases, although *Rimapenaeus* figured prominently in the dwarf sand perch diet off the West Delta, in spring, or in 37-55 m waters. Blackwing searobin had a similar shrimp-based diet in which *Rimapenaeus* played a larger role (Fig. 6). Blackwing searobin preyed heavily upon *Rimapenaeus* at Age 1, during daylight, off the West Delta, in 37-73 m waters, and during spring. The rock sea bass diet was composed primarily of shrimps and crabs, with shrimps usually having higher %IRI values (Fig. 7). Other foods of occasional importance were fishes (frequent, but only at %IRI = 10-15), stomatopods (fall 1983), and *Rimapenaeus* (74-91 m depths). Southern kingfish were also dependent on shrimps, crabs, and *Rimapenaeus* (Fig. 8), and, in one instance, fishes (at 37-54 m depths). Red snapper had a variable diet based on shrimp (Fig. 9), with occasional %IRI dominance by fishes (37-55 m; day), squids (fall 1983), *Rimapenaeus* (West Delta; spring), mysids (9-17 m), or crabs (Texas; 56-73 m).

Trophic ontogeny was investigated in three species for which relatively large sample sizes over broad length ranges were available (Fig. 10). Inshore lizardfish were piscivorous from the smallest size class (80-119 mm) through the largest (280-359 mm). As length increased, rock sea bass exhibited a decreasing dependence upon shrimps as primary prey coupled with increasing predation on crabs, stomatopods, and fishes. Blackwing searobin retained a dependence on shrimps as prey through all size classes but switched from non-penaeids to *Rimapenaeus* with growth.

Predation on Farfantepenaeus. — As reported above, *Rimapenaeus* and *Sicyonia* were the most frequently observed taxa of prey shrimps. In fact, only five *Farfantepenaeus* and no *Litopenaeus* were identified among the 4,264 fish stomachs examined in this study. Two *Farfantepenaeus* were eaten by rock sea bass (summer), two were eaten by inshore lizardfish (one each in summer and fall), and one was eaten by dwarf sand perch (fall).

Reproductive seasons. — Spawning, as indicated by ripe gonads, primarily took place during spring for rock sea bass, southern kingfish, blackwing searobin, and inshore lizardfish, during summer for dwarf sand perch, and during fall for ocellated flounder and bighead searobin, although most species had extended spawning across more than one season (Table 4). No ripe bank sea bass or red snapper were collected. Ocellated flounder was the only species found to have a reproductive period limited to one season, whereas blackwing searobin and inshore lizardfish were capable of spring through fall spawning. No samples were collected during winter, so I was unable to determine whether any patterns continued into, or were limited to, that season.

Sex ratios were not significantly different from 1:1 for ocellated flounder and red snapper, likely due to small sample sizes (Table 4). Males were significantly more numerous than females in southern kingfish, bighead searobin, blackwing searobin, and inshore lizardfish. Rock sea bass was a protogynous hermaphrodite: initial gonadal development seemed either testicular or ovarian in gross visual appearance, and maturing and ripe ovaries were found, but no ripe testes were recorded. Bank sea bass is probably a protogynous hermaphrodite as well, but no advanced gonadal development was found as fish were only collected during summer. Dwarf sand perch was a synchronous hermaphrodite, since ripe ovarian and testicular tissues were often found together in the gonads. There was some indication that ovarian tissue matured first: among the 373 samples with advanced developmental stages, 73 had testes more advanced than ovaries, 138 samples were equally developed, and 162 samples had ovaries more advanced than testes. Histological studies are needed to confirm or define the hermaphroditic types of these three serranids.

Length-weight relationships. — Length-weight relationships for each species are presented in Table 5. Only ocellated flounder and southern kingfish exhibited significant sex-related differences in this relationship. The significance was marginal ($P = 0.048$) for ocellated flounder and was probably due to a small sample size.

Discussion

Previous studies of predator food habits. — The food habits of the nine species examined in this paper have all been examined to some extent by previous investigators (Table 6). My results agree for some species and disagree for others. All investigators agree that 1) fishes are the primary prey of inshore lizardfish, 2) crabs are the primary prey of bank sea bass, 3) crabs and shrimps are the primary prey of bighead searobin, and 4) shrimps are the primary prey of dwarf sand perch and blackwing searobin. There is some disagreement on the relative compositions of, but not food types in, the diets of rock sea bass, southern kingfish, and red snapper due to a combined effect of different collecting seasons and locations, dissimilar fish size ranges, and different analytical methods. For example, southern kingfish have been reported as consuming primarily fishes, shrimps, clam siphons, or crabs in part because a) Landry and Armstrong (1980) measured diet composition by dry weight, b) McMichael (1981) sampled only in the surf zone and used IRI values based on percent volume, c) Fritzche and Crowe (1981) combined inshore and offshore collections, and d) Divita et al. (1983) sampled only in summer, at night, and off Texas. The only major disagreement in diet composition is for ocellated flounder, for which I report fishes as primary prey and both Topp and Hoff (1972) and Stickney et al. (1974) reported mysids as most important. Part of this disagreement stems from relative rarity of ocellated flounder from offshore waters (I collected 13 fish with food in their stomachs, while Topp and Hoff only had seven), and part stems from Stickney et al. reporting only on estuarine specimens.

One aspect common to most of the previously mentioned fish food habits studies is the recurrence of only a few taxa as important prey items. All nine fish species that I examined had preyed upon *Rimapenaeus* and at least five preyed on *Sicyonia*, while portunid crabs were common foods of crab predators. *Farfantepenaeus*, however, is rarely a large component of trawl-susceptible predator diets in offshore waters, although Fritzche and Crowe (1981) reported a 25% frequency of occurrence in southern kingfish stomachs (combined inshore and offshore samples). These recurrences are due in part to the composition of the invertebrate fauna on the continental shelf, as these prey taxa are usually ranked among the 10 most numerous taxa collected in trawl surveys. *Rimapenaeus* is the most abundant macroinvertebrate of the Texas and West Delta shelves and is tenth off the East Delta, while *Sicyonia* is the second most abundant off Texas, third off the East Delta, and fourth off the West Delta (Franks et al. 1972, Holland et al. 1980, Bedinger 1981). These authors found *Farfantepenaeus* ranked first off the East Delta and third off the West Delta and Texas. Portunid crabs (including *Callinectes* and *Portunus*) are also quite abundant, ranking fourth off Texas, second off the West Delta, and eighth off the East Delta. In areas where *Farfantepenaeus* outnumbers *Rimapenaeus* or *Sicyonia*, the size factor plays a large role in penaeid prey taken by the fish predators. Divita et al. (1983) reported that the incidence of fish predation on these three shrimp genera was highest for the smallest taxon (*Rimapenaeus*), not for the most abundant.

Two pairs of congeners were considered in this report, and each pair exhibited major differences in diet. Bank sea bass preyed heavily on crabs and less so on shrimps (%IRI = 67 and 14, respectively), while rock sea bass consumed shrimps over crabs (%IRI = 55 and 26, respectively). The same juxtaposition was observed between bighead searobin (%IRI = 77 and 18 for crabs and shrimps, respectively) and blackwing searobin (%IRI = 89 and 6 for shrimps and crabs, respectively). The variation in predominant taxa was also distinctive: Parthenopidae in bank sea bass and blackwing searobin versus Portunidae in rock sea bass and bighead searobin; *Rimapenaeus* in blackwing searobin versus *Sicyonia* in bighead searobin; non-penaeid shrimps in bank sea bass versus *Rimapenaeus* and Alpheidae in rock sea bass. Most likely these were habitat-induced differences related to sandy or hard-bottom substrates nearshore and off the East Delta versus muddy substrates offshore and off the West Delta (Minerals Management Service 1983). Bighead searobin inhabit shallower waters (primarily < 20 m) than blackwing searobin (40-60 m), while rock sea bass are most abundant over mud substrates and bank sea bass are more abundant over sand or hard substrates (Miller 1959, Darnell et al. 1983, Darcy and Gutherz 1984). Substrate preferences for the various prey taxa have not been elucidated, at least for the northern Gulf of Mexico.

Predation on Farfantepenaeus. — *Farfantepenaeus* is not a major prey item for trawl-susceptible fish predators in offshore waters of the northern Gulf of Mexico, as has been reported here and elsewhere (Rogers 1977, Landry and Armstrong 1980, Divita et al. 1983). One exception is recorded by Fritzche and Crowe (1981) in which *Penaeus* sp. (either *Farfantepenaeus* or *Litopenaeus* or both) was identified in 25% of the stomachs examined. However, these data represented a combination of inshore and offshore samples. As Divita et al. (1983) pointed out, *Farfantepenaeus* recruiting to offshore waters tend to be the same average size as the fishes, making successful consumption of intact *Farfantepenaeus* difficult. Instead, other smaller taxa are preyed upon. Because of this, the natural mortality of *Farfantepenaeus* in offshore waters is probably quite low compared with fishing mortality. For example, Klima et al. (1982) estimated that the commercial shrimp fleet landed 876 million *Farfantepenaeus* Gulf-wide just during June-August 1981.

Fish reproduction. — My observations on the reproductive periods of these nine fishes are in general agreement with previous research. I reported a fall spawning peak for ocellated flounder and bighead searobin as did Miller (1965), Topp and Hoff(1972), Landry and Armstrong (1980), and Ross (1983), although spawning may be initiated in summer and carry into winter. Spring spawning for rock sea bass corresponded to data presented by Miller (1959) and Miller (1965), as well as to data for southern sea bass

(*Centropristis melana*) in Roberts et al. (1976). A spring spawning peak for southern kingfish was also reported by Gunter (1938), Moe and Martin (1965), and Smith and Wenner (1985), while Reid (1954), Miller (1965), Landry and Armstrong (1980), Fritzche and Crowe (1981), and Harding and Chittenden (1987) also recorded fall spawning activity. My fall sample size (16 southern kingfish) was perhaps too small to detect fall spawning activity. My results and those of Reid (1954) and Perret (1971) indicated inshore lizardfish exhibited peak spawning in spring, while Miller (1965) postulated a fall peak. Blackwing searobin was previously listed as a fall spawner (Hildebrand 1954, Miller 1965), yet I noted peak gonadal development in the spring. Miller (1965) thought dwarf sand perch was a winter-spring spawner and Erdman (1976) reported spring spawning for pond perch (*Diplectrum radiale*), but ripe gonads were twice as frequent in my summer collections as in my spring samples. I only collected bank sea bass in summer, when no ripe gonads were noticed, but this species is noted to spawn in winter and spring (Miller 1959). No ripe red snapper were collected, probably because they do not mature until Age 2 (Futch and Bruger 1976) or 220-230 mm (Holt and Arnold 1982) and only five specimens exceeding 220 mm were collected. Moseley (1966) and Futch and Bruger (1976) reported summer spawning for red snapper, and I found eight females (135-175 mm) with developing ovaries during summer.

Hermaphroditism has not been reported previously for dwarf sand perch, although other serranids are hermaphroditic. Both sand perch (*Diplectrum formosum*) and pygmy sea bass (*Serraniculus pumilio*) are synchronous hermaphrodites (Bortone 1971, Hastings 1973), as I noted for dwarf sand perch. It remains to be seen whether or not external self-fertilization (rather than cross-fertilization between mating pairs) occurs with dwarf sand perch as it does with belted sand fish (*Serranus subligarius*) (Clark 1959). I suspect that rock sea bass and bank sea bass are protogynous hermaphrodites. Roberts et al. (1976) indirectly indicated southern sea bass was protogynous, in that running ripe males were 17% longer and 55% heavier than ripe females. Black sea bass *(Centropristis striata*) is also a protogynous hermaphrodite (Lavenda 1949, Cupka et al. 1973, Wenner et al. 1986).

Acknowledgments

This project could not have been completed without field and laboratory assistance of David Trimm and Bruce Baker, both of whom have long since moved on to science positions elsewhere. Dr. Ed Klima, Galveston Laboratory Director, and Mr. K. Neal Baxter, Fishery Management Branch Chief, at the time of the study provided financial and personnel support.

Loretta Sullivan DeKay provided data on qualitative observations from fish stomachs collected during June-July 1982. Frank Patella provided mainframe computer support prior to the PC era.

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Table 1. Summary stomach contents for nine species of northern Gulf of Mexico fishes, expressed as percent of total Index of Relative Importance (%IRI). OF = ocellated flounder, BB = bank sea bass, RB = rock sea bass, DP = dwarf sand perch, RS = red snapper, SK = southern kingfish, BW = blackwing searobin, BH = bighead searobin, IL = inshore lizardfish. x = <0.1%. Wgt = g dry weight.

Stomach Contents	Fishes								
	OF	BB	RB	DP	RS	SK	BW	B H	IL
Sand	-	-	x	-	-	-	x	0.4	-
Plant matter	-	-	x	-	-	-	x	x	-
Anemones	-	0.1	-	-	x	-	-	-	-
Corals	-	x	x	-	-	-	-	-	-
Nematodes	4.6	-	-	-	x	-	-	-	-
Polychaetes	-	9.0	2.4	2.3	0.2	7.2	0.2	-	-
Gastropods	-	x	x	-	-	-	-	-	-
Bivalves	-	0.5	x	x	x	-	x	x	-
Squid	-	0.7	x	x	4.3	x	-	-	3.6
Octopi	-	x	-	-	-	-	-	-	-
Calanoid copepods	-	-	-	x	-	-	x	-	-
Barnacles	-	x	-	-	-	-	-	-	-
Stomatopods	16.7	0.3	7.3	x	0.2	0.6	0.3	x	x
Mysids	-	1.2	0.2	1.3	2.8	-	0.2	2.1	-
Cumaceans	-	-	-	-	-	-	x	0.6	-

Isopods	-	x	-	-	-	-	-	-	-
Amphipods	-	0.5	x	x	0.2	1.7	0.6	0.2	-
Farfantepenaeus	-	-	x	x	-	-	-	-	x
Parapenaeus	-	-	-	-	-	-	x	-	-
Penaeopsis	-	-	-	-	0.1	-	-	-	-
Rimapenaeus	-	-	4.5	9.2	5.7	7.2	22.8	0.7	0.3
Sicyonia	0.4	-	1.1	0.8	0.4	0.2	0.3	8.1	x
Non-penaeid shrimps	0.7	13.8	49.2	75.2	62.0	52.0	66.3	9.4	1.3
Crabs	28.1	66.9	25.8	4.5	3.7	26.2	6.1	77.2	X
Crab larvae	-	-	x	x	x	x	2.0	X	-
Lobsters	-	-	x	x	-	-	-	-	-
Ophiuroids	-	0.4	x	-	-	-	-	-	-
Holothurians	-	-	-	x	-	-	-	-	-
Lancelets	-	-	-	-	-	x	-	-	-
Fishes	47.5	6.5	8.3	6.3	19.0	4.3	0.2	0.3	94.8
Animal fragments	1.6	-	0.9	0.2	1.5	0.7	1.0	1.1	X
Detritus	0.4	x	x	x	3.7	-	x	-	-
Stomachs examined	26	102	1021	523	364	180	900	250	898
Stomachs with food	13	56	386	258	192	72	474	154	376

Mean items / stomach	2.8	4.1	2.3	2.2	3.3	3.9	6.0	3.7	1.7
Mean wgt / stomach	0.578	0.081	0.082	0.064	0.099	0.141	0.100	0.129	0.786

Table 2. Occurrence of families and genera of prey fishes and decapods in stomach contents of nine species of northern Gulf of Mexico fishes. a = *Portunus spinicarpus*, b = *Portunus gibbesii*. All *Callinectes* were *C. similis*.

Predator	Prey	Taxa (frequency)
Ocellated flounder	Fishes	Ophichthidae (5)
	Shrimps	*Sicyonia* (1)
	Crabs	None
Bank sea bass	Fishes	*Lepophidium* (1)
	Shrimps	Alpheidae (1)
	Crabs	Paguridae (10), *Parthenope* (8), Xanthidae (5), *Iliacantha* (3), *Pinnixa* (2), *Portunus* [a] (2), *Calappa*, Majidae, *Podochela*, Portunidae (1 ea)
Rock sea bass	Fishes	*Bregmaceros*, *Centropristis*, Ophichthidae (1 ea)
	Shrimps	*Rimapenaeus* (29), Alpheidae (22), *Sicyonia* (16), *Acetes* (14), *Farfantepenaeus* (2), *Leptochela* (1)
	Crabs	Portunidae (12), *Portunus* [a,b] (6), *Parthenope*, *Pinnixa*, *Raninoides*, Xanthidae (4 ea), *Calappa*, *Panopeus* (3 ea), *Callinectes*, *Euryplax*, Grapsidae (2 ea), Goneplacidae, *Hepatus*, *Leiolambrus*, *Micropanope*, Paguridae, *Persephona*, *Solenolambrus* (1 ea)
	Lobsters	Scyllaridae (1)
Dwarf sand perch	Fishes	Ophichthidae (2)
	Shrimps	*Rimapenaeus* (31), *Sicyonia* (12), Alpheidae (7), *Acetes* (3), *Leptochela* (2), *Farfantepenaeus*, Penaeidae (1 ea)
	Crabs	*Raninoides* (3), *Parthenope* (2), *Speocarcinus*, Xanthidae (1 ea)
	Lobsters	Scyllaridae (1)
Red snapper	Fishes	Ophichthidae, *Serranus*, *Sphoeroides*, *Synodus* (2 ea), Bothidae, Clupeidae, Ophidiidae (1 ea)
	Shrimps	*Rimapenaeus* (21), *Leptochela* (13), *Sicyonia* (7), Alpheidae, Hippolytidae (6 ea), *Acetes* (2), *Ogyrides*, *Penaeopsis* (1 ea)
	Crabs	*Albunea*, *Callinectes*, Paguridae, Portunidae, Parthenope (1 ea)
Southern kingfish	Fishes	*Anchoa*, Ophichthidae, *Sphoeroides* (1 ea)

	Shrimps	*Ogyrides*, *Rimapenaeus* (12 ea), *Sicyonia* (2), Alpheidae, *Leptochela* (1 ea)
	Crabs	*Emerita*, *Raninoides* (4 ea), *Callinectes*, Portunidae, *Portunus* [a] (1 ea)
Blackwing searobin	Fishes	*Symphurus* (2), *Micropogonias* (1)
	Shrimps	*Rimapenaeus* (94), *Acetes* (15), *Sicyonia*, Alpheidae (14 ea), *Ogyrides* (6), *Lucifer* (4), *Leptochela*, Penaeidae (3 ea), *Parapenaeus* (2), *Discias* (1)
	Crabs	Portunidae (7), *Parthenope* (6), *Pinnixa* (5), *Calappa*, Xanthidae (4 ea), *Iliacantha* (3), *Callinectes*, Parthenopidae, *Persephona* (1 ea)
Bighead searobin	Fishes	*Etropus*, Ophichthidae (1 ea)
	Shrimps	*Sicyonia* (18), *Rimapenaeus* (13), Alpheidae (3), *Acetes*, *Leptochela* (1 ea)
	Crabs	Portunidae (15), *Calappa* (8), Xanthidae (6), *Portunus* [a,b] (5), *Hepatus*, *Persephona* (4 ea), *Callinectes* (3), *Parthenope* (2), *Ovalipes*, Paguridae, *Pinnixa* (1 ea)
Inshore lizardfish	Fishes	*Anchoa* (14), *Trachurus* (10), *Etrumeus* (9), *Trichiurus* (6), *Decapterus* (5), *Saurida*, *Synodus* (4 ea), Bothidae, Clupeidae, *Polydactylus*, *Selene*, Serranidae, *Stenotomus* (2 ea), *Chloroscombrus*, *Cynoscion*, *Lagodon*, *Larimus*, *Micropogonias*, Ophichthidae, *Prionotus*, *Pristigenys*, *Serranus*, *Sphoeroides*, *Symphurus* (1 ea)
	Shrimps	*Rimapenaeus* (18), *Sicyonia* (3), *Farfantepenaeus* (2), *Acetes* (1)
	Crabs	None

Table 3. Comparison of the primary foods of nine species of fishes by percentage frequency of occurrence (%F), percentage numerical composition (%N), percentage dry weight (%W), Index of Relative Importance (IRI), and percentage of total IRI (%IRI). Only foods with %IRI ≥ 1.0 are presented. Shrimps = non-penaeid genera.

Fish	Food	%F	%N	%W	IRI	%IRI
Ocellated flounder	Fishes	46.2	27.0	33.9	2811.4	47.5
	Crabs	38.5	13.5	29.6	1658.5	28.1
	Stomatopods	23.1	8.1	34.6	986.5	16.7
	Nematodes	7.7	35.1	0.1	270.5	4.6
Bank sea bass	Crabs	62.5	36.7	38.6	4704.5	66.9
	Shrimps	41.1	19.2	4.3	967.9	13.8
	Polychaetes	30.4	10.5	10.4	635.2	9.0
	Fishes	16.1	4.4	24.1	457.7	6.5
	Mysids	5.4	16.2	0.1	87.3	1.2
Rock sea bass	Shrimps	40.4	30.7	15.3	1859.2	49.2
	Crabs	27.5	15.1	20.4	974.4	25.8
	Fishes	14.5	7.2	14.0	308.0	8.1
	Stomatopods	12.4	6.2	15.9	274.9	7.3
	Rimapenaeus	7.5	3.8	18.8	169.5	4.5
	Polychaetes	8.3	9.3	1.8	92.4	2.4
	Sicyonia	4.2	2.0	7.9	40.9	1.1
Dwarf sand perch	Shrimps	55.5	41.3	32.8	4107.9	75.2
	Rimapenaeus	13.0	7.2	31.0	498.0	9.1
	Fishes	14.2	7.2	16.0	341.2	6.3
	Crabs	16.0	7.9	7.6	248.2	4.5
	Polychaetes	11.3	7.9	3.1	124.3	2.3
	Mysids	3.8	18.8	0.5	72.9	1.3

Red snapper	Shrimps	45.3	39.1	21.3	2738.7	62.0
	Fishes	25.0	9.5	23.5	825.2	18.7
	Rimapenaeus	8.9	3.8	24.7	252.7	5.7
	Squid	13.5	6.0	8.1	190.5	4.3
	Crabs	12.5	4.4	8.7	164.5	3.7
	Mysids	5.2	23.3	0.3	122.7	2.8
Southern kingfish	Shrimps	50.0	45.2	14.1	2967.9	52.0
	Crabs	30.6	14.1	34.8	1496.5	26.2
	Rimapenaeus	15.3	5.0	22.1	413.5	7.2
	Polychaetes	25.0	10.6	5.7	408.1	7.2
	Fishes	15.3	4.6	11.1	239.6	4.2
	Amphipods	6.9	13.4	0.1	94.2	1.7
Blackwing searobin	Shrimps	58.7	37.0	27.0	3756.6	66.3
	Rimapenaeus	19.6	9.3	56.7	1293.2	22.8
	Crabs	21.9	12.1	3.7	345.9	6.1
	Crab larvae	4.6	23.2	1.2	113.0	2.0
Bighead searobin	Shrimps	52.9	23.4	48.5	3803.9	77.2
	Crabs	24.2	10.2	8.9	462.5	9.4
	Sicyonia	11.8	5.0	28.7	397.0	8.1
	Mysids	6.5	14.2	1.3	101.7	2.1
Inshore lizardfish	Fishes	77.9	66.6	82.0	11493.5	94.8
	Squid	16.9	12.5	13.0	432.4	3.6
	Shrimps	9.8	15.2	0.9	158.5	1.8

Table 4. Seasonal occurrence of ripe gonads and overall sex ratios in nine species of bottomfishes. N = number examined, %R = percentage ripe gonads, D = number examined with sexually distinct gonads, M = male, F = female, ** = significant difference from a 1:1 ratio (chi-square, P<0.01).

	Spring		Summer		Fall		Sex Ratio	
Species	N	%R	N	%R	N	%R	D	M:F
Ocellated flounder	5	0.0	11	0.0	10	60.0	16	1.29:1
Bank sea bass	-	-	102	0.0	-	-	0	-
Rock sea bass	143	6.3	528	0.0	350	1.1	542	-[a]
Red snapper	31	0.0	82	0.0	251	0.0	35	1:1.92
Southern kingfish	68	14.7	96	3.1	16	0.0	169	2.52:1**
Blackwing searobin	190	16.8	333	3.3	377	4.5	568	1.33:1**
Bighead searobin	47	0.0	164	1.2	39	30.8	167	1.88:1**
Inshore lizardfish	118	22.0	419	7.4	361	0.6	649	2.82:1**
Dwarf sand perch	77	35.1	254	74.8	192	0.0	373	-[b]

-[a] Protogynous hermaphrodite

-[b] Synchronous hermaphrodite

Table 5. Length-weight relationships for nine species of fishes. Regression equations: Log_{10} weight = a + b Log_{10} length. Analysis of variance (ANOVA) tests for differences between male and female regressions. M = male, F = female, U = undeveloped. Bank sea bass, rock sea bass, and dwarf sand perch are hermaphrodites.

			Length (SL)		Weight (g)		Regression			ANOVA	
Species	Sex	N	Mean	Range	Mean	Range	a	b	r^2	F	P
Ocellated flounder	M	9	163	105-218	111.6	29.5-282.7	-4.15	2.80	0.97	3.961	0.048
	F	7	181	118-249	151.5	29.8-440.4	-5.95	3.60	0.99		
	MFU	26	160	57-249	129.7	3.9-440.4	-4.64	3.02	0.97		
Red snapper	M	12	157	111-238	124.5	41.9-451.9	-4.02	2.79	0.98	1.025	0.371
	F	23	155	104-218	120.6	36.1-357.6	-4.43	2.79	0.99		
	MFU	364	102	42-238	38.0	3.9-451.9	-4.04	2.79	0.99		
Southern kingfish	M	121	169	114-227	95.8	27.4-243.8	-4.70	3.00	0.98	5.187	0.007
	F	48	198	127-262	159.7	44.9-363.9	-4.51	2.93	0.98		
	MFU	180	170	77-262	102.3	10.1-363.9	-4.64	2.98	0.99		
Blackwing searobin	M	323	108	43-212	33.7	2.2-270.8	-4.39	2.91	0.96	0.173	0.841
	F	243	123	63-250	49.6	7.2-511.6	-4.45	2.94	0.97		
	MFU	900	91	23-250	21.4	0.1-511.6	-4.04	2.74	0.97		
Bighead searobin	M	107	94	50-196	26.5	5.1-121.9	-3.71	2.60	0.92	2.582	0.079
	F	58	115	73-168	46.7	12.2-170.6	-4.18	2.84	0.97		

	MFU	250	89	40-196	22.9	2.6-230.5	-4.07	2.78	0.97		
Inshore lizardfish	M	479	204	116-351	83.4	13.8-486.0	-5.34	3.14	0.95	1.099	0.334
	F	170	254	129-355	168.6	18.6-444.7	-5.42	3.18	0.96		
	MFU	898	200	82-355	77.6	4.2-486.0	-5.28	3.12	0.98		
Bank sea bass	MFU	102	112	58-192	43.7	6.4-178.2	-4.21	2.85	0.97		
Rock sea bass	MFU	1021	102	35-221	28.2	1.4-325.1	-4.36	2.90	0.99		
Dwarf sand perch	MFU	523	93	23-123	20.9	0.3-59.1	-4.59	3.01	0.95		

Table 6. Prey of nine bottomfish species as reported by previous investigations. Size ranges are mm SL. + = upper boundary not specified, FO = frequency of occurrence, NC = numerical composition, %V = percentage volume, %W = percentage dry weight, %I = percentage of index of relative importance. Percentages not available from Moseley (1966).

Species	Sizes	Primary Animal Prey (%)	Method	Source
Ocellated flounder	25-199	Mysids 52, Crabs 13, Shrimps 9	FO	Stickney et al. 1974
	125-255	Mysids 41, Crabs 28, Stomatopods 10	NC	Topp and Hoff 1972
	76-233	Crabs 27, *Rimapenaeus* 12, Shrimps 11	FO	NMFS, unpublished data
Inshore lizardfish	18-233	Fishes 91, “Penaeids” 18	FO	Reid 1954
	50-200+	Fishes 56, Squid 41	%V	Rogers 1977
	48-444	Fishes 69, Shrimps 16, Squid 7	FO	Divita et al. 1983
	59-328	Fishes 66, Squid 26	FO	NMFS, unpublished data
Bighead searobin	17-150	Crabs 62, *Sicyonia* 8	%W	Landry and Armstrong 1980
	100+	Crabs 46, Shrimps 39, Mysids 31	FO	Ross 1983
	100-145	Shrimp 67	FO	Divita et al. 1983
	55-255	Crabs 35, Shrimps 26, *Sicyonia* 20	FO	NMFS, unpublished data
Blackwing searobin	26-175	Shrimps 48, Fishes 14, Crabs 13	%V	Rogers 1977
	72-163	*Rimapenaeus* 33, Shrimps 9, Crabs 4	FO	Divita et al. 1983
	36-233	Shrimps 33, *Rimapenaeus* 21, Crabs 11	FO	NMFS, unpublished data

Dwarf sand perch	26-125	Shrimps 48, Fishes 25	%V	Rogers 1977
	87-115	Shrimps 44, Crabs 4	FO	Divita et al. 1983
	60-282	Shrimps 27, Crabs 27, *Rimapenaeus* 15	FO	NMFS, unpblished data
Bank sea bass	92-175	Crabs 31, Fishes 12, Shrimps 6	FO	Divita et al. 1983
	24-190	Crabs 47, Fishes 8, Shrimps 6	FO	NMFS, unpublished data
Rock sea bass	26-225	Fishes 26, Shrimps 23, Crabs 21	%V	Rogers 1977
	85-224	*Rimapenaeus* 13, Crabs 11, *Sicyonia* 10	FO	Divita et al. 1983
	45-226	Crabs 14, Shrimps 12, Fishes 6	FO	NMFS, unpublished data
Southern kingfish	53-288	Fishes 41, Shrimps 27, Crabs 13	%W	Landry and Armstrong 1980
	99-270	Shrimps 38, *Penaeus* 26, Polychaetes 25	FO	Fritzsche and Crowe 1981
	10-225	Clam siphons 38, Cumaceans 18, Crabs 16	%I	McMichael 1981
	112-282	Shrimp 20, Crabs 20, Fishes 6	FO	Divita et al. 1983
	125-266	Crabs 36, Shrimps 25, *Rimapenaeus* 14	FO	NMFS, unpublished data
Red snapper	25-280	Shrimps, Stomatopods, Fishes	%V	Moseley 1966
	100-700	Fishes, Tunicates, Shrimps	%V	Moseley 1966
	160-572	Fishes 57, Crabs 21, Stomatopods 12	FO	Futch and Bruger 1976
	65-200	Fishes 13, Shrimps 13, Crabs 10	FO	Divita et al. 1983

65-320	Fishes 33, Squid 19, Crabs 18	FO	NMFS, unpublished data

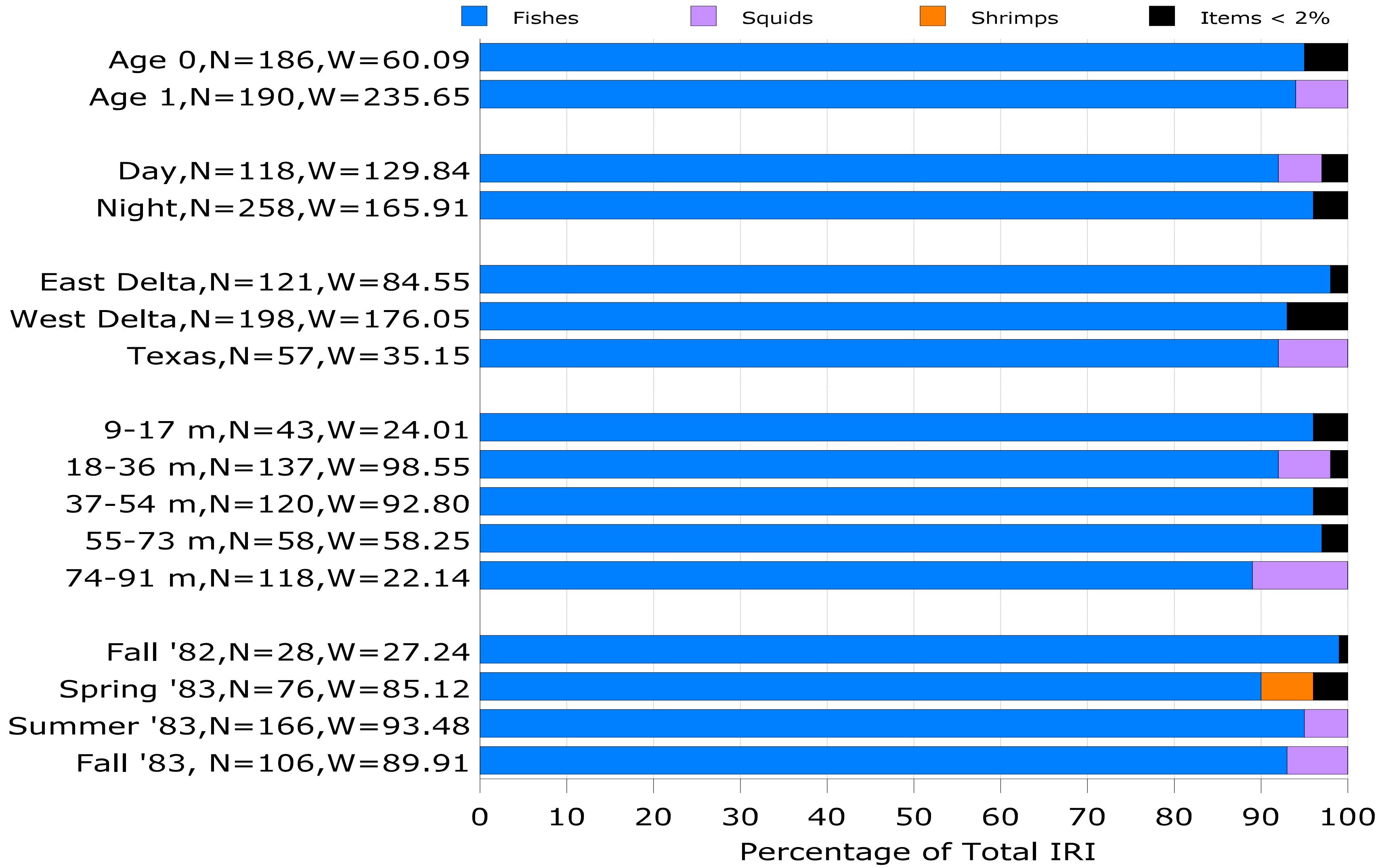

Figure 1. Stomach contents of inshore lizardfish by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

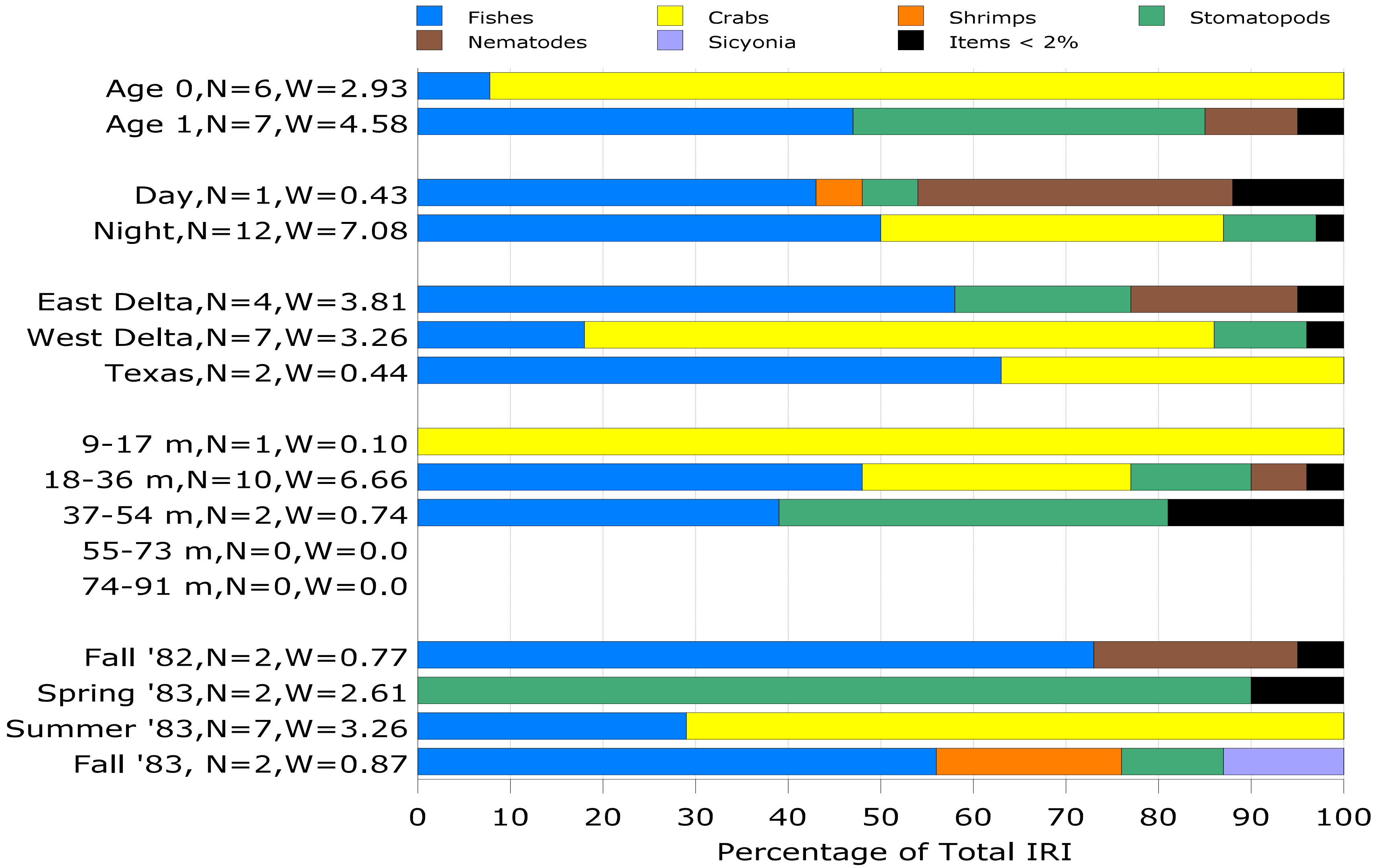

Figure 2. Stomach contents of ocellated flounder by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

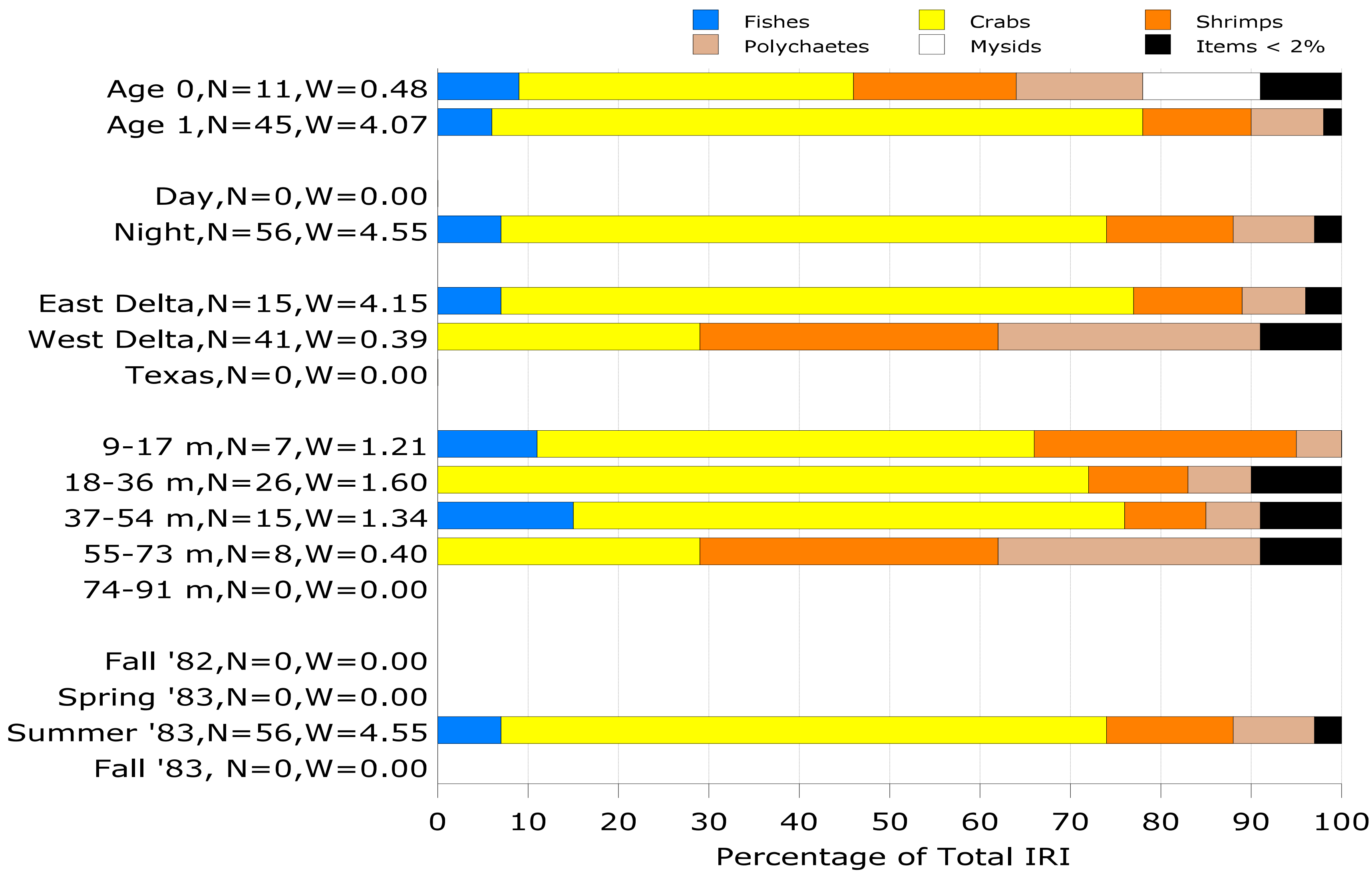

Figure 3. Stomach contents of bank sea bass by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

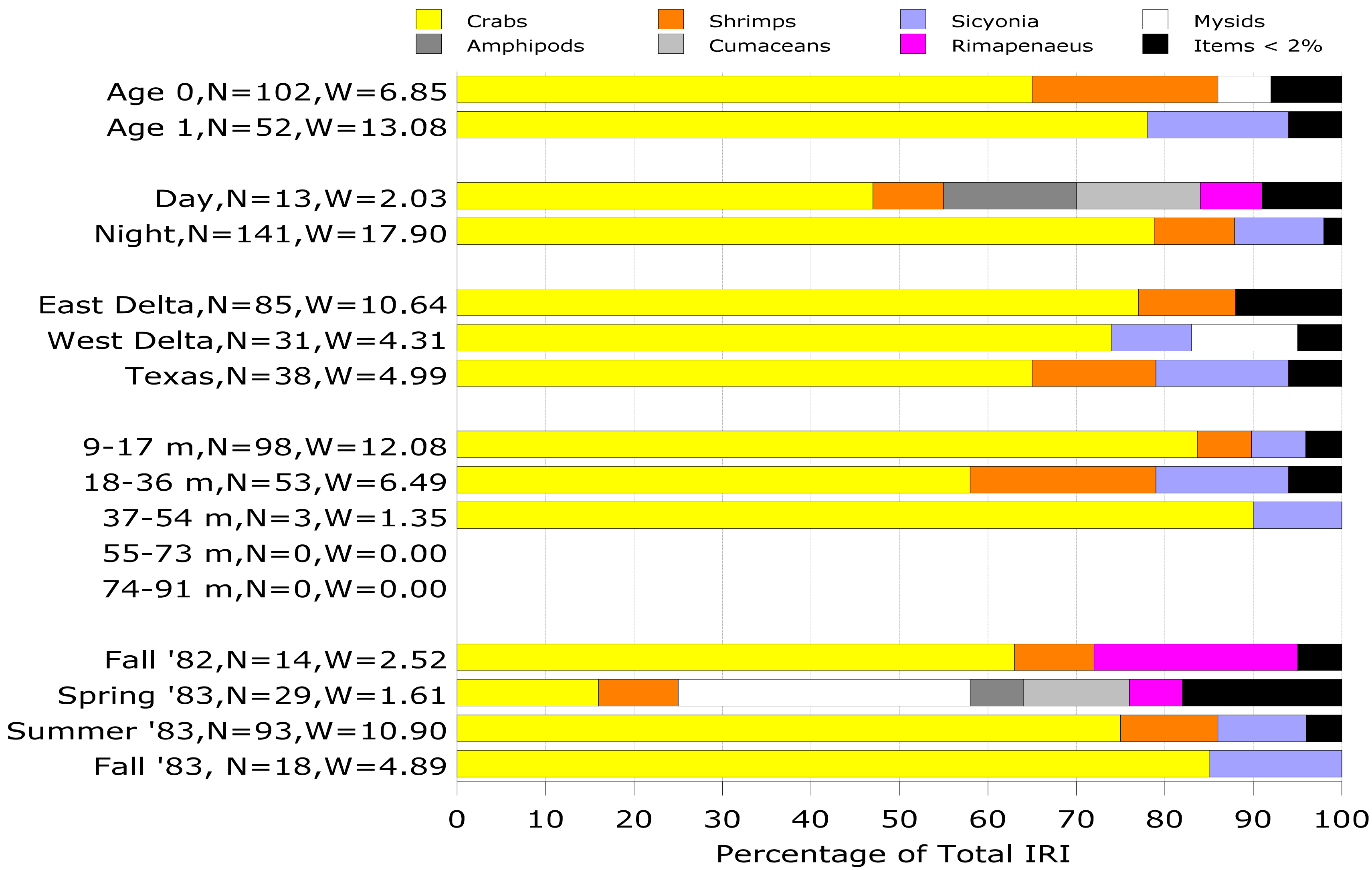

Figure 4. Stomach contents of bighead searobin by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

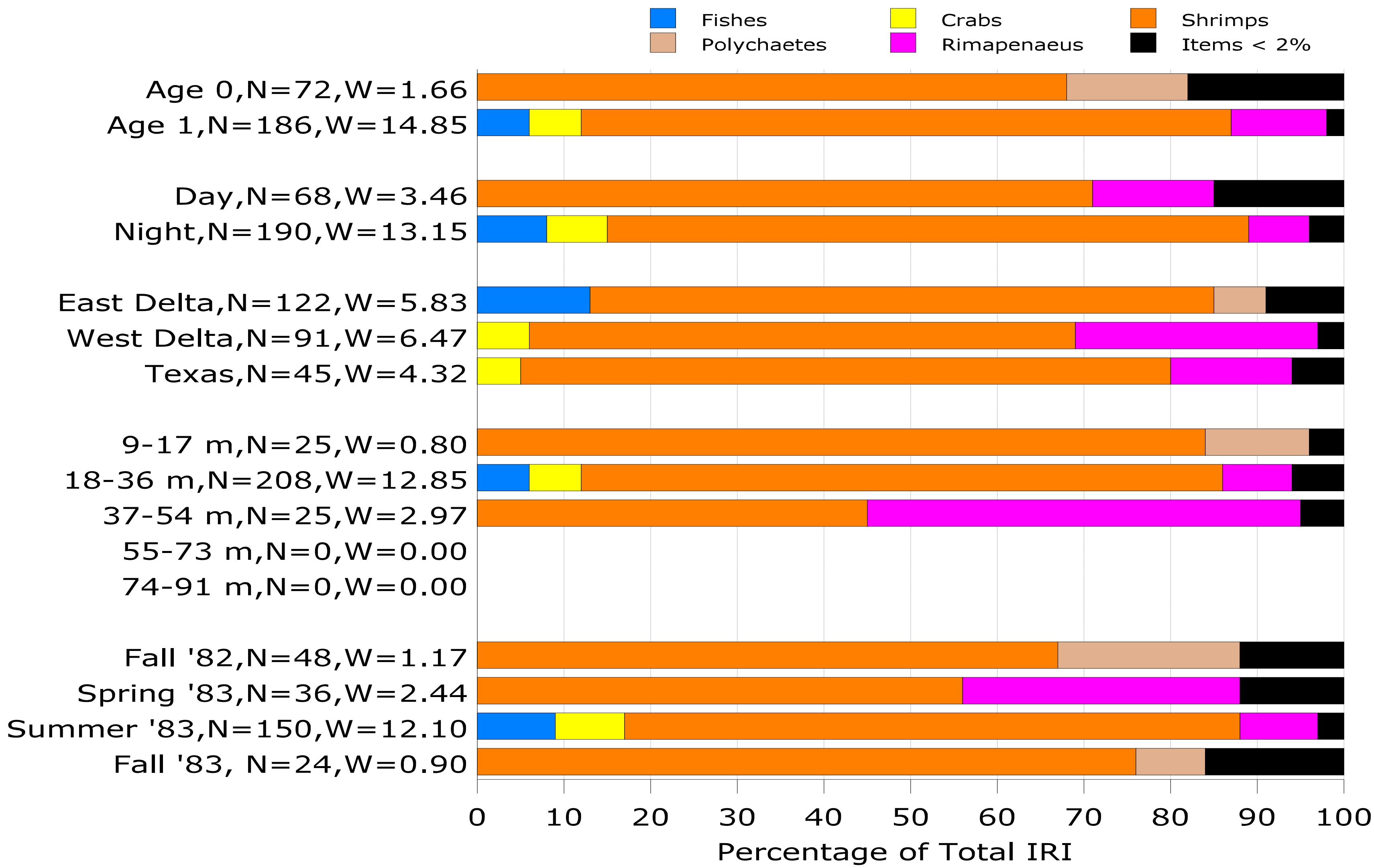

Figure 5. Stomach contents of dwarf sand perch by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

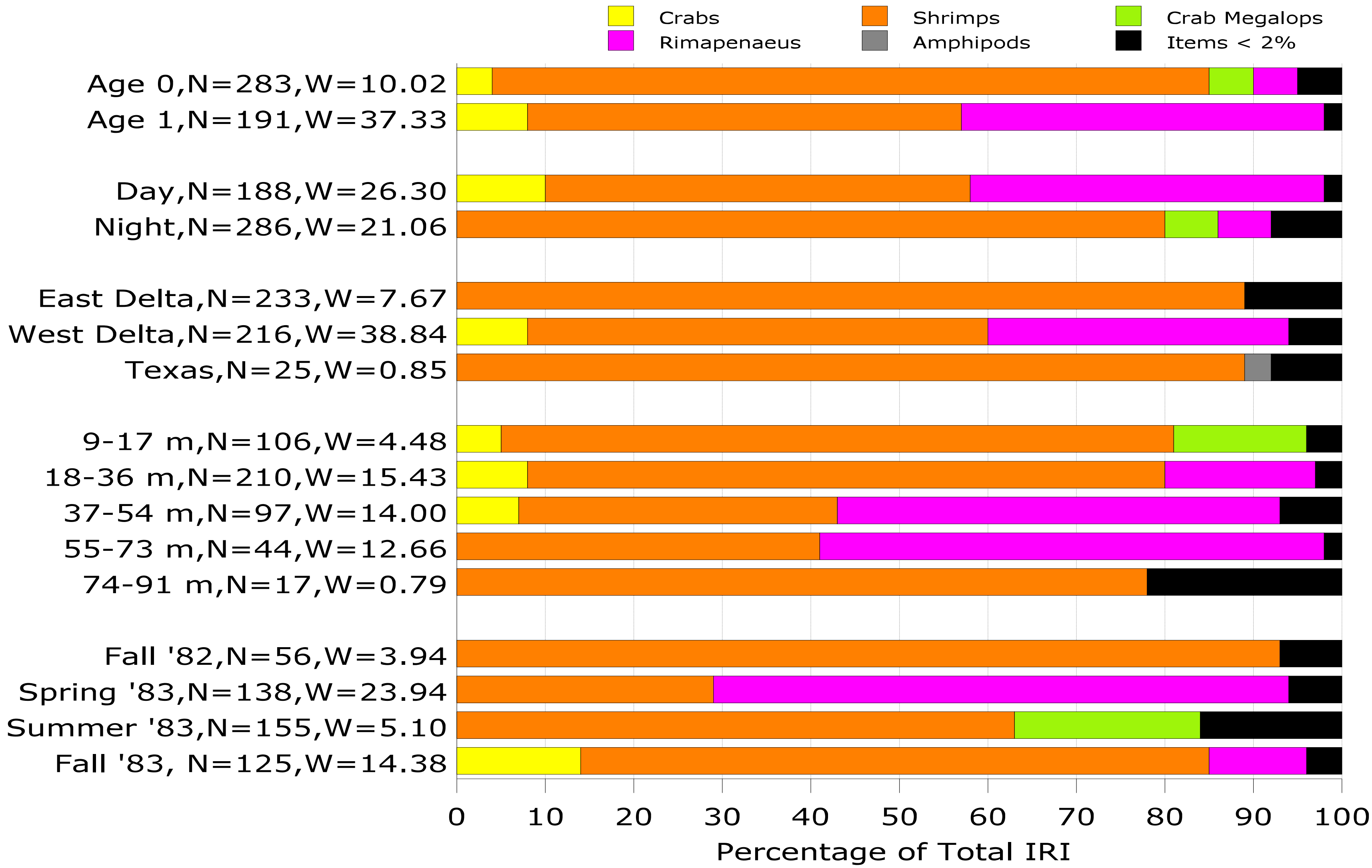

Figure 6. Stomach contents of blackwing searobin by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

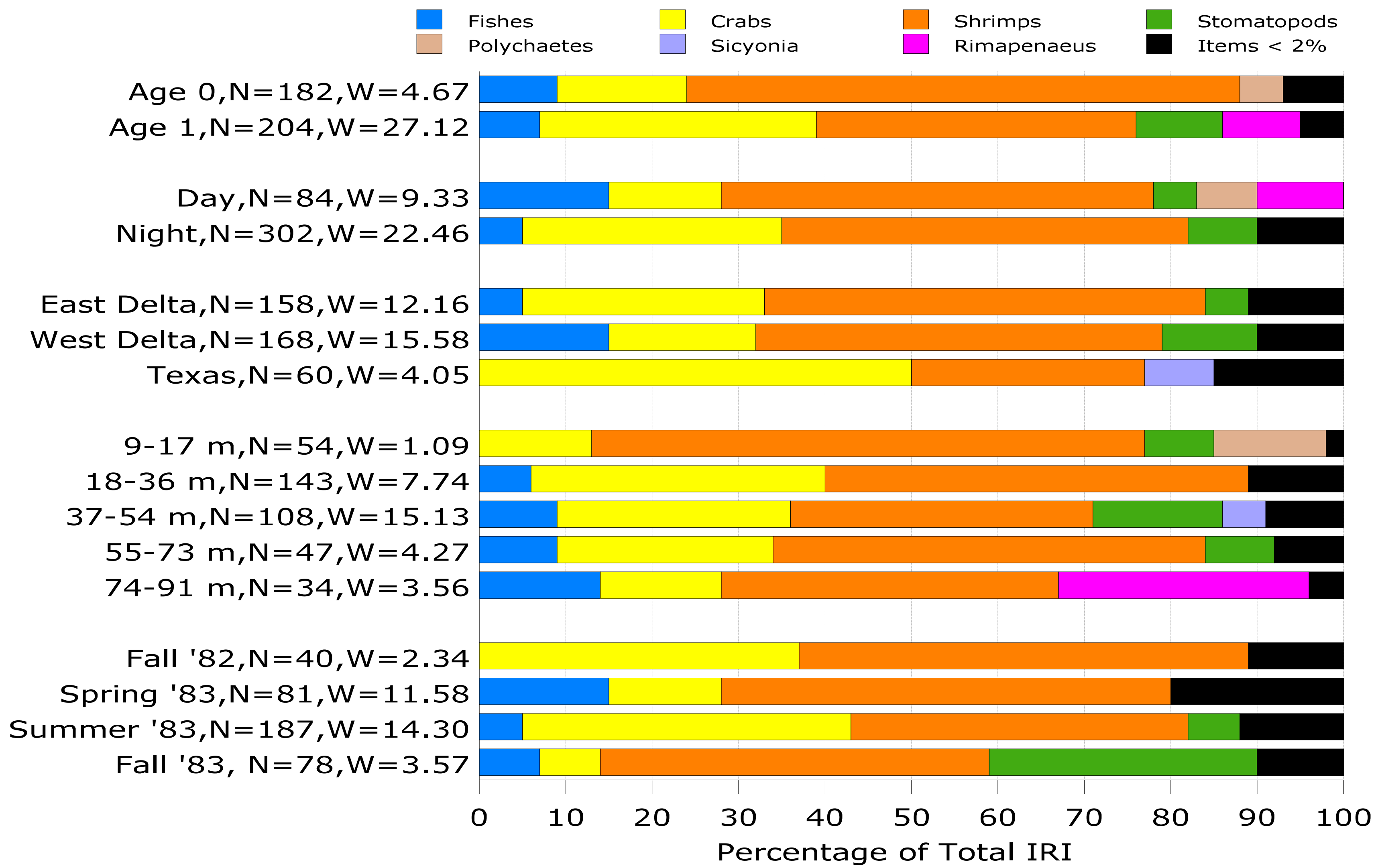

Figure 7. Stomach contents of rock sea bass by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

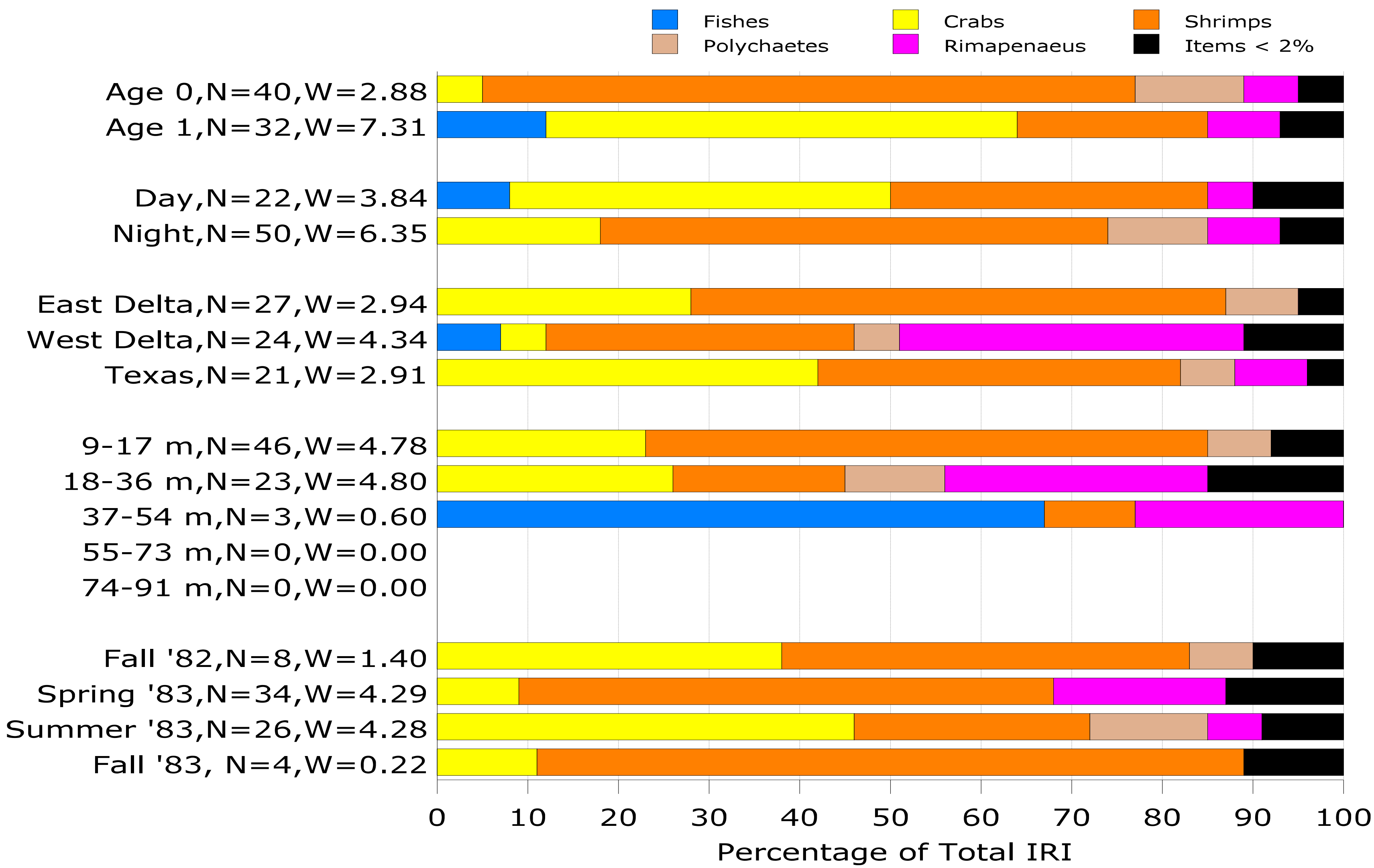

Figure 8. Stomach contents of southern kingfish by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

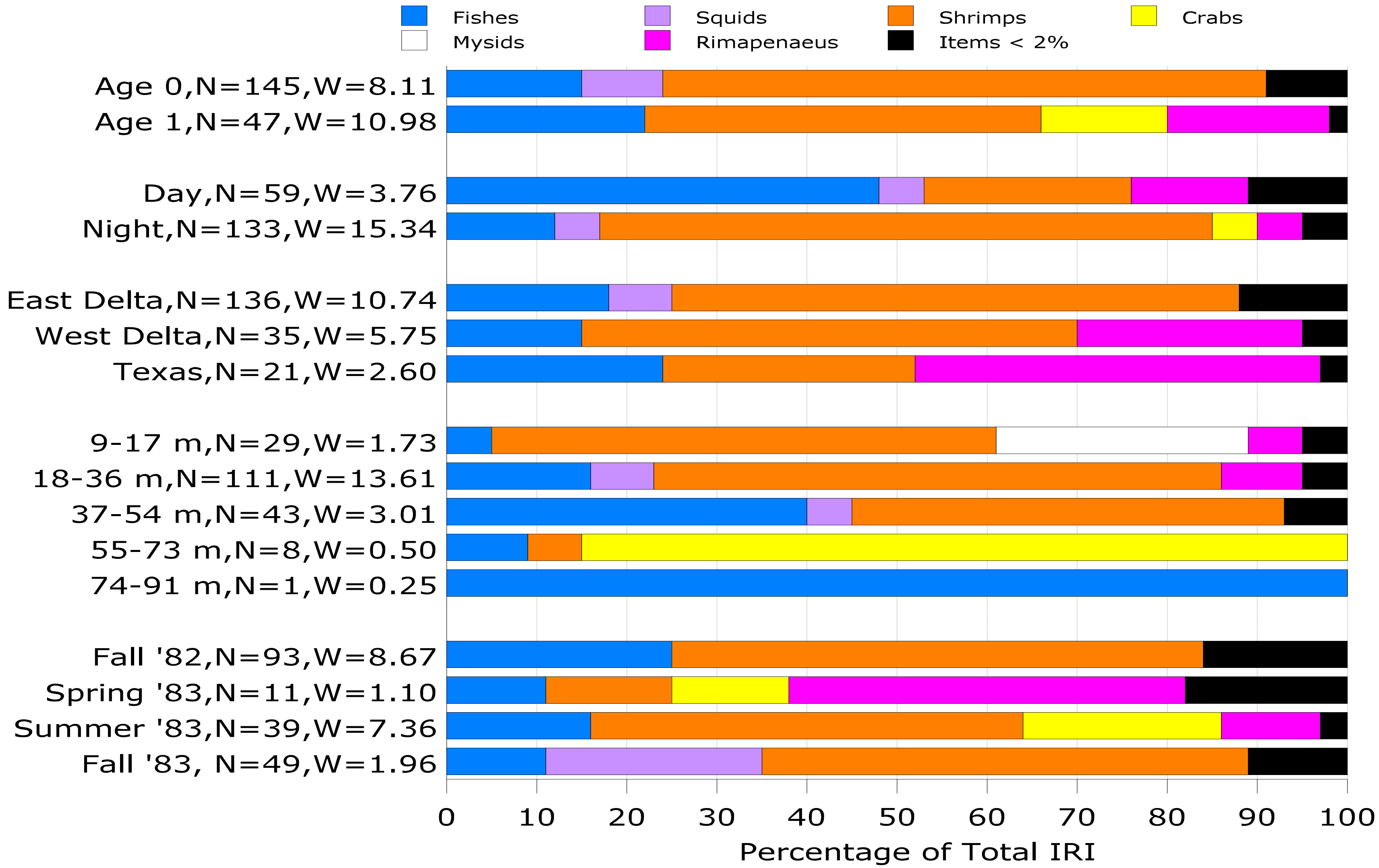

Figure 9. Stomach contents of red snapper by age, time, locale, depth, and season. IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).

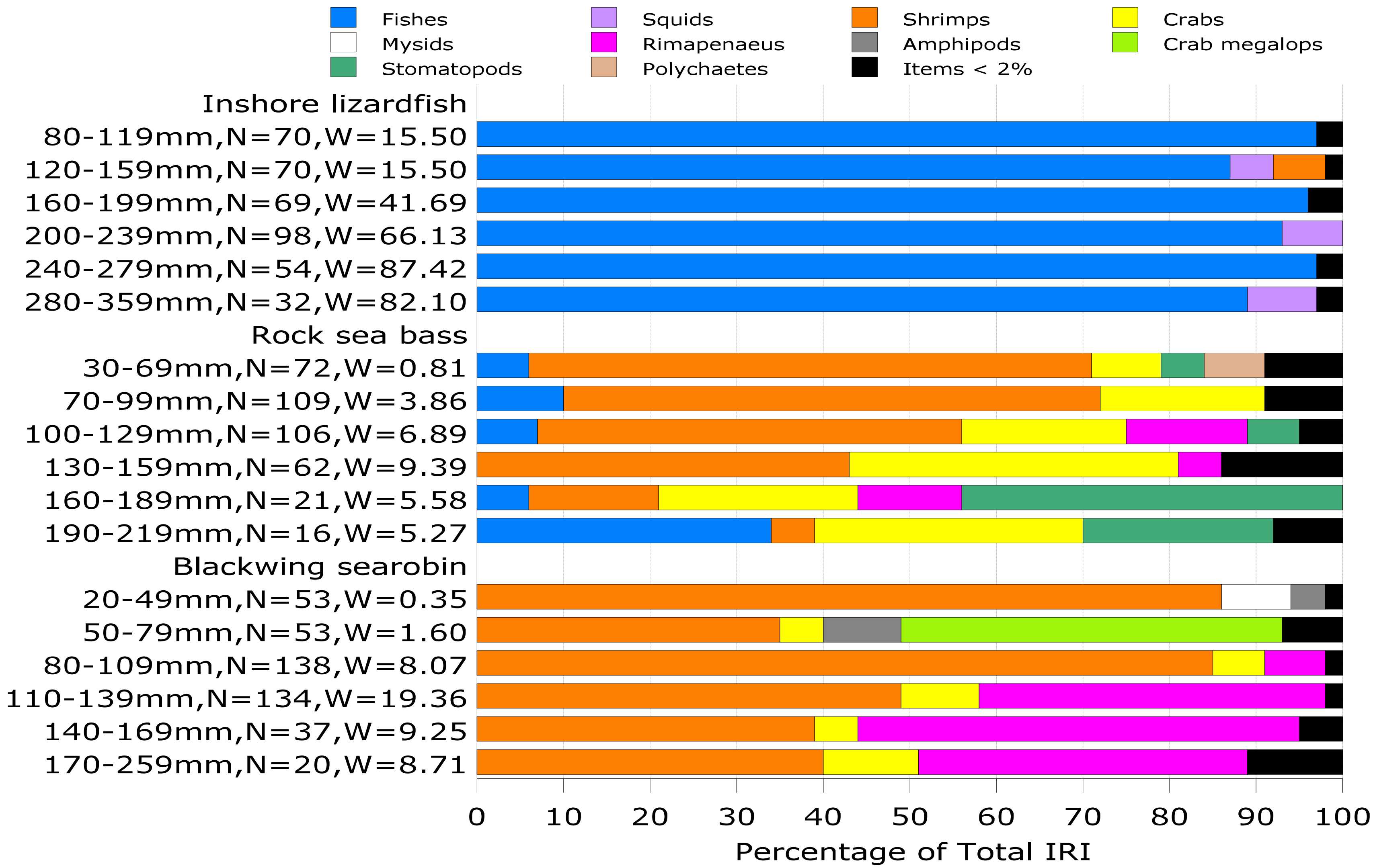

Figure 10. Trophic ontogeny of inshore lizardfish, rock sea bass, and blackwing searobin by arbitrary length bins (SL). IRI = Index of Relative Importance, N = stomachs with food, W = total dry weight (g).