Possible Sources of Florida's Spiny Lobster Population

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RESUMEN

El desove de la población de *Panulirus argus* del sur de la Florida se efectua entre Abril y Octubre, pero la mayor actividad se desarrolla durante Mayo-Junio. El reclutamiento de *P. argus* a la población del sur de la Florida se efectúa durante el año. Generalmente alta tasa de reclutamiento ocurre durante la primavera, verano y otoño, y aun ocasionalmente en Enero. La duración de altos niveles de reclutamiento son inexplicables mediante una fuente larval temporalmente restringida como lo es la existencia de comunidades adultas del sur de la Florida.

El desove durante todo el ano de la población del Caribe provee una fuente de la cual puede derivarse el reclutamiento de los juveniles durante todo el año en la Florida. Se ha demostrado la abundancia del tránsito de larvas del Caribe a la Florida por el Estrecho de Yucatan, durante gran parte del año. Langostas del Caribe oriental pudieran ser genéticamente distintas a la población de la Florida, y sus larvas pueden ser conducidas por el Estrecho de Yucatán, por su borde oriental, de donde son arrastradas rumbo noreste y fuera de la Florida. Sin embargo, langostas del norte de Sur América y del Caribe occidental pudieran no ser diferentes a las de las poblaciones de la Florida, y bien pudieran ser fuentes para el reclutamiento en la Florida.

La habilidad de la larva filosoma de *Scyllarides nodifer*, de mantenerse en el Golfo de México durante períodos hasta de ocho o nueve meses, indican que debe existir un sistema de circulación que soporte un reclutamiento local. La presencia de *P. argus* activamente reproductor en el Golfo de México, en las áreas ocupadas por *S. nodifer* pueden indicar que estas poblaciones también pudieran contribuir al reclutamiento en el sur de la Florida. Se ha sugerido que localmente es probable debe existir un sistema de corrientes estacionales que soporten las larvas cerca de los Cayos de la Florida. Sin embargo, tal sistema no pudiera proveer mucho del reclutamiento anual, dado el período restringido del desove de las langostas en los Cayos de la Florida.

Aun cuando no se descarta la contribución local al reclutamiento de la langosta en la Florida, la evidencia disponible indica que mucho del reclutamiento debe derivarse de larvas de desoves en otros parajes, probablemente la región norte de Sur América o el Caribe occidental. La suerte de las larvas de desoves en la Florida permanecen desconocidas. Si no retornan a la Florida, algunas deben ser arrastradas hacia el norte y al olvido, pero otras pudieran entrar en sistemas lejanos de circulación y contribuir al reclutamiento en otros lugares, eg. las Bahamas orientales o las Antillas. Según se desarrolle la pesquería de la langosta espinosa y se expanda por el Atlántico Tropical Occidental, será sumamente importante el que las prácticas administrativas de esta pesquería sean lo suficiente para asegurar una adecuada producción de larvas. Aun cuando tales desoves no contribuyan a poblaciones paternales, si pueden contribuir a otras poblaciones factibles de pesca. La posible, o probable, dependencia de la población de la Florida de reclutamiento externo necesita el que ello sea adoptado como política general administrativa.

INTRODUCTION

The State of Florida utilizes a closed spawning season, protection of spawning females during harvest season, and a minimum legal harvest size as management measures intended to assure replenishment of the spiny lobster fishery. Previous information suggested that most, if not all, of Florida's lobster fishery was replenished by larvae recruited from Caribbean spawning stocks, but recent reports have suggested that most recruitment to Florida may depend upon spawn from the Florida population itself, with little contribution from Caribbean stocks (Menzies and Kerrigan, 1979, 1980). Gregory (1979) observed that the present minimum harvest size does not adequately protect Florida reproductive stock, and intense fishery exploitation restricts the major portion of egg production to small, newly mature females which are not as fecund as larger lobsters. He concluded that if Florida's recruitment is dependent upon Florida spawn, present fishery laws not only curtail potential productivity but also jeopardize population stability in the south Florida fishery. Gregory proposed an extension through August of the April-July closed season and an increase in minimum harvest size from 76 mm to 85 mm carapace length (CL). Based upon observations in the Florida Keys fishery during 1978-79, Lyons et al. (1981) concluded that no extension of the closed season seems necessary, but agreed that present minimum size does little to protect spawning stocks. They found the reproductive potential of the Florida Keys population to be reduced approximately 88% from that of an unfished population and stated that a minimum harvest size of 90 mm CL would be necessary to insure that most lobsters had an opportunity to spawn at least once. Despite the fact that effort in the fishery increased approximately five-fold during the past decade (from ca. 100,000 to 500,000 traps), landings have continued to remain relatively stable, averaging approximately 5 million lb (2.3 million kg) per year (Labisky et al., 1980). Stability of landings in the presence of increased effort has encouraged the belief that recruitment is not declining. The fishery harvests virtually all lobsters surviving from recruitment 2 to 3 years earlier (Simmons, 1980; Lyons et al., 1981), and the population is replenished by additional recruitment. Thus, the only cause for concern seems to be declining catch per unit effort, a socioeconomic problem not necessarily related to biology (Prochaska and Cato, 1980). However, when Davis and Dodrill (1980) compared 1976-78 densities of juvenile lobsters in Biscayne Bay with densities observed during 1968-69 by Eldred et al. (1972), they concluded that densities in that major nursery declined by 67% during the 7-10 year period. They suggested that the decline may have been related to reduced recruitment. These reports prompted the Florida Department of Natural Resources (FDNR) to review information pertinent to Florida's recruitment problem.

BACKGROUND

The closely related scyllaridean families Palinuridae (spiny lobsters) and Scyllaridae (shovel-nosed lobsters) possess transparent, leaf-like larvae called phyllosomes. Phyllosomes of most lobsters inhabit oceanic waters where they pass through 10-12 developmental stages before metamorphosing to a distinctive, lobster-like swimming stage collectively termed postlarvae (*sensu* Gordon, 1953; Lyons, 1970, 1980; Little, 1977) or, for spiny lobsters, called a puerulus (plural: pueruli).

Dynamics of larval life for Californian and Western Australian spiny lobsters (*Panulirus interruptus* and *P. cygnus*, respectively) have been summarized by Serfling and Ford (1975) and Phillips et al. (1979). In each species, larvae are hatched from eggs released in deep water. Youngest larvae occur nearest shore, thereafter being transported seaward by prevailing currents so that older larvae may be encountered several hundred kilometers from land. Due to shifts in current direction, phyllosomes are then redirected shoreward toward edges of continental shelves where they undergo metamorphosis and, as pueruli, swim directionally to coastal shallows to take up residence as benthic juveniles. The larval period of the Californian lobster is approximately 8 months, and that of the Western Australian lobster is approximately 10-11 months. Release of larvae and greatest abundance of pueruli occur within well-defined periods, and oceanic currents first transport larvae away from and later back to general areas of origin.

Although diagrammatic models of similar simplistic systems for *Panulirus argus* have been presented by Buesa (1970), Baisre (1977), and Menzies and Kerrigan (1980), the larval strategy of *P. argus* contains several complications rendering its actual definition more difficult. Three species of *Panulirus* (*P. argus, P. guttatus,* and *P. laevicauda*) occur in Florida and, generally, throughout the tropical and subtropical western Atlantic, and no satisfactory method for separating their larvae has been found (Lyons and Little, 1975). However, *P. argus* is by far most abundant, and several studies have assumed, probably justifiably, that most palinurid phyllosomes captured from plankton are those of *P. argus*.

The range of adult *P. argus* encompasses the southwestern Atlantic off the coast of central Brazil; the Caribbean Sea, including the Lesser and Greater Antilles and the north and east coasts of South and Central America; the Bahama Islands; the Gulf of Mexico, including deeper portions of the northern Gulf shelf; southeast Florida; deeper portions of the southeastern United States continental shelf northward to Cape Hatteras; and Bermuda (Williams, 1965). Additionally, a record exists of two specimens captured off western Africa (Marchal, 1968).

The region where most lobsters occur is characterized by numerous gyres, eddies and seasonally varying currents. The North Equatorial Current flows northwestward to the southern Antilles where it divides, one branch sweeping northward past the eastern shores of the Antilles and Bahamas and the other branch entering the Caribbean Sea, exiting via the Yucatan Channel, passing between Florida and the Bahamas (Florida Current), then rejoining the eastern branch and veering northeast past Bermuda (Gulf Stream) to become the upper portion of the North Atlantic Gyre. Waters exiting the western side of the Yucatan Straits during spring and summer often intrude northward into the north-central Gulf of Mexico, veer clockwise and pass near or over the outer west Florida shelf (Loop Current) before rounding Dry Tortugas and joining the Florida Current. During fall and winter of some years, the Loop Current recedes so that waters exiting the Yucatan Straits flow more directly toward the southern edge of the Florida Keys reefs. An anticyclonic countercurrent flowing southward and westward adjacent to the Keys reefs is believed to be the northern side of a small gyre resulting from interfacing of the northerly moving Florida Current with the southern tip of the continental land mass. The countercurrent was recognized during May and June but reportedly may persist for up to 6 months (Brooks and Niiler, 1975). Each of these currents has been suggested as a device for transporting larvae to Florida (Menzies and Kerrigan, 1979).

Spawning. As early as 1922, Crawford and De Smidt observed that female *P. argus* in the Florida Keys moved to deep water to spawn. Although lobsters bearing spawn were landed throughout much of the year, most spawned during spring and early summer, and none spawned during November-January. It is now known that spawning in the Florida Keys occurs principally during early summer, with a peak in

May-June and a marked decline during July (Smith, 1948; Dawson and Idyll, 1951; Lyons et al., 1981). Spawning occurs infrequently as late as October (Smith, 1948; Lewis, 1951) and rarely as late as December (Robinson and Dimitriou, 1963) or as early as March (Lyons et al., 1981). Smith (1958) stated that Florida lobsters may "breed" twice in one season, but this has not actually been demonstrated in Florida stocks. Davis (1974) noted that females emigrated seaward from shallows to deep reefs to spawn; spawning increased markedly during April at Dry Tortugas but Davis observed no autumnal spawning activity. Lyons et al. (1981) confirmed that more than 90% of all spawning in the Florida Keys occurred near seaward reefs, and spawning began during April when water temperatures approached 24°C; no secondary autumnal peak was observed.

Smith (1954) documented occurrence of *P. argus* in the Gulf of Mexico, and Moore (1962) reported that large *P. argus* were often captured by shrimp boats in the northern Gulf. Although neither Smith nor Moore reported spawning, divers commonly encounter spawning lobsters on the continental shelf offshore from Tampa Bay (L. H. Bullock, FDNR, personal communication). Recreational divers have informed FDNR biologists of considerable spawning by large *P. argus* off Cape Canaveral during August and September, and a recent report indicates that large *P. argus* off Georgia may also spawn (Olsson, 1980). These data indicate that spawning occurs northward of the fishery population and may occur later than in the Keys. Delayed spawning may be in response to different seasonal temperatures than those in south Florida. Bottom temperatures off Cape Canaveral in some years remain low until mid-summer, then increase through fall (Kennedy et al., 1977).

Although spawning in south Florida is predominantly a spring-summer phenomenon, spawning occurs throughout the year in the Caribbean. Munro (1974) reported year-round spawning with no apparent peaks at Jamaica; Aiken (1977) confirmed year-round spawning there but discerned peaks during March-June. Year-round spawning with peaks during spring and fall occurs at Venezuela (Cobo de Barany et al., 1972), Puerto Rico (Mattox, 1952), and the Bahamas (Smith, 1951; Kanciruk and Herrnkind, 1976). Very high spawning incidence has been observed during October at Belize (Smith, 1948). Most *P. argus* at Bermuda spawn during June and again during mid-July (Creaser, 1950; Sutcliffe, 1952).

Larvae. Crawford (1921) and Crawford and De Smidt (1922) hatched eggs of *P. argus* at Key West and described first larvae. Lewis (1951) collected *Panulirus* phyllosomes in plankton off Miami and described eleven developmental stages. Baisre (1964) likewise described 11 stages based upon larvae from Cuba.

Lewis (1951) found most very young stages during summer and a few final stages during January off Miami, concluding tentatively that the larval period for *P. argus* might be 6 months. Smith (1958) later estimated the larval period of *P. argus* to be 3-6 months. Sims and Ingle (1967) reviewed the literature concerning larval periods of *Panulirus* and concluded that the period for *P. argus* was probably more than 6 months. Cobo de Barany et al. (1972) also considered the larval period at Los Roques, Venezuela, to be about 6 months, although Buesa (1970) estimated the larval period of *P. argus* to be between 6-8 months.

Ingle et al. (1963) published preliminary findings from many *Panulirus* phyllosomes collected in the Yucatan Straits and Florida Current. Most early stages were found near the shores of Yucatan or Cuba, but later stages were found over much of the sampling area. Sims and Ingle (1967), reporting upon 6931 phyllosomes of *Panulirus* from the same collections, noted that first stage (I) larvae were encountered during April, June, August, September, October and December, and last stage (XI) phyllosomes were taken during January in addition to most previous months, but not during April; stages II-X occurred during all mentioned months. They also reported that plankton near offshore reefs in the Florida Keys contained numerous early larvae during the Florida spawning season, but frequency of larvae declined farther offshore; they noted a few early *Panulirus* larvae collected west of St. Petersburg, Florida. Baisre (1976) also reported that larval development of *P. argus* occurred in offshore oceanic waters, and although stage I larvae occurred mainly at the edge of the shelf, larvae older than stage I were very scarce in coastal waters of Cuba.

Sims and Ingle (1967) used surface and oblique tow (100 m-surface) open-net plankton samples to demonstrate vertical migration of phyllosomes to the surface at night and into deeper waters during day, speculating that differences in current direction between surface and submerged waters, coupled with vertical migration of phyllosomes, could aid in retaining larvae in a given area "and would augment chances for some local recruitment in Florida." Buesa (1970) combined data of Sims and Ingle with unpublished data to reveal that most larvae were concentrated at 50 m depths during daylight, ascending to the surface at dusk and descending at dawn. Soon thereafter, Austin (1972) used closing plankton nets at various depths and confirmed that, as observed previously, phyllosomes ascended to the surface at night, but virtually all occurred in depths less than 50 m during day, and the majority occurred at 10-20 m depths; downward daytime migration was controlled by location of thermoclines which the phyllosomes did not cross. No larvae were collected from waters cooler than 24°C. Baisre (1976) found that *P. argus* phyllosomes around Cuba were concentrated at depths of 25-50 m and were scarce at 100 m; larvae were virtually absent in surface waters, but most samples were collected during daylight.

Smith (1948) observed that the larval period of *P. argus* lasted "for several weeks" during which time they were transported by ocean currents; he believed that local eddies were more important in transporting phyllosomes than were major currents. Lewis (1951) speculated that most larvae from the Florida population were carried north in the Florida Current and later stages taken off Miami were probably spawned either farther south in the West Indies or in the Gulf of Mexico. This, apparently, is the first reference to the "Caribbean recruitment" theory. Smith (1958) maintained that phyllosomes could be transported as far as 1000 miles (1600 km) under favorable conditions, but most were probably not carried so far; he suggested that the currents most likely to affect larval transport were not those of the main Caribbean circulation, but rather the countercurrents nearer shore. Robinson and Dimitriou (1963) concluded that "because of the long distances lobster larvae may be transported by currents it is suggested that most of the locally spawned [Florida] larval lobster population are swept away to the north, playing little or no part in maintaining local adult populations."

Because considerably more larvae were found along the western and northern sides of the Yucatan Current, Ingle et al. (1963) supported a concept of Caribbean recruitment for Florida's spiny lobster population. Release of drift bottles at sampling stations in the Yucatan Current by Sims and Ingle (1967) resulted in a high incidence of returns from the Keys and southeast Florida coast. Integrating the data on larval occurrence with information on prevailing currents, Sims and Ingle concluded that many larvae in areas they sampled would be transported to areas adjacent to the southeast Florida coast, where they would probably provide recruitment for the south Florida spiny lobster population. Regarding spawn from Florida Keys lobsters, Sims and Ingle speculated that most early phyllosomes enter the Florida Current to be carried toward northern waters; some may re-enter coastal populations via numerous eddies along the eastern United States and Bahamas, but great numbers must drift into the North Atlantic to oblivion. Sims (1968) demonstrated the presence of *Panulirus* phyllosomes across much of the North Atlantic.

Austin (1972) collected phyllosomes from the Florida Middle Ground, the Loop Current, and the Yucatan Straits and Florida Current, but he was unable to identify his phyllosomes and considered all to be *Panulirus* spp. Although there is great probability that many belonged to other scyllaridean genera, some probably were, indeed, *Panulirus*. Like Ingle et al. and Sims and Ingle, Austin found high densities of phyllosomes in the Yucatan Straits. He demonstrated separation of waters exiting the Yucatan Channel during May, those on the eastern side veering eastward to become the Florida Current and those on the western side pushing northward to form the Loop Current; high densities of phyllosomes were entrained in each water mass. Austin also demonstrated occurrence of phyllosomes off the west Florida shelf in the southward sweep of the Loop Current, but it is not known whether any were actually *Panulirus*.

Austin reiterated that phyllosomes spawned in Florida "during late summer, fall or winter" may be transported via the Florida Current and Gulf Stream to northerly regions where temperatures are too cool for survival. He stated that "phyllosomes spawned in Florida do not provide recruitment for any other North American population. . . . if spawned during spring, they can cross the North Atlantic in 6 to 9 months, possibly providing recruitment to the northwest African coast." However, Austin also stated that it was conceivable that phyllosomes spawned in Florida could circumnavigate the North Atlantic and return in 11-13 months, or that phyllosomes could circumnavigate the Sargasso Sea and waters adjacent to Florida, but he thought it doubtful that either route could be traversed during the larval period of *Panulirus*. He concluded that a more logical source for the Florida spiny lobster population would be the southern Antilles and the northeast coast of South America.

Richards (1974, 1975) observed that *Panulirus* phyllosomes in every stage have been found during every month of the year in the western North Atlantic and estimated that the larval period might be as brief as 4 or as long as 12 months. He concluded that "there are very little data to indicate that any one population produces its own recruits, rather the long [larval period] places the phyllosomes at the mercy of oceanic currents and carries them for great distances downstream from their parents. It is possible that some may return to their point of origin some months after their release, however the percentage of these returning or also being held in an area due to local currents seems to be quite remote." Richards and Goulet (1977) reported preliminary computer calculations from a surface drift model indicating possible paths of phyllosome recruitment and dispersal to the Bahamas. Their data showed probability of significant transport of phyllosomes to the Bahamas via the Antilles Current on the east and Florida Current on the west, as well as via large loops in the western portion of the North Atlantic gyre.

Menzies et al. (1978) and Menzies and Kerrigan (1979, 1980) questioned the concept of predominant Caribbean recruitment of Florida's lobster stock. Menzies et al. proposed a study of enzyme systems to determine the genetic composition of various subpopulations and presented preliminary data indicating different allele frequencies between populations at two southeast Florida sites (Boca Raton and Elliott Key) and others in the Bahamas and Belize. Menzies and Kerrigan (1979) expanded their hypothesis of local recruitment loops to other areas: "Thus, Brazilian lobsters return to Brazilian populations, Honduras larvae to Honduran populations . . . [and] larvae spawned around Abaco might return to that area in sufficient numbers to constitute a major contribution to recruitment with little mixing of larvae spawned from Cat Island or other areas; the converse would be true of Cat Island larvae." They presented additional enzyme data from adult populations in the Virgin Islands, Dry Tortugas, and Florida Keys (Marathon and Key West); these data suggested varying differences among subpopulations, depending upon enzyme loci compared. Based upon these, they speculated that "it is unlikely that Belize is a significant contributor to Florida recruitment. Further, if it is assumed that Belize is representative of other Caribbean stocks whose larvae might be carried through the Yucatan Channel then there is little or no contribution from these sources. On the other hand, water circulation directly off Belize may be part of a local gyre mixing little with the main Caribbean water flow passing through the Jamaica and Cayman Islands area. The latter may be more representative of flow from the Lesser Antilles, portions of the Venezuelan coast and further east as well as the southern coast of the Greater Antilles . . . Although few larvae may be directly transported from the Virgin Islands to Florida, intermediate populations might be greatly contributory to Florida recruitment." As an alternative to Caribbean recruitment, Menzies and Kerrigan (1979, 1980) proposed that larvae entrained in a countercurrent and/or eddy identified off Key West by Brooks and Niiler (1975) might be transported westward into the Gulf of Mexico, enter and be maintained in the Loop Current, and then return to the Florida Keys as pueruli. However, Menzies (personal communication) has since developed information which shows few or no differences between south Florida lobster populations and those from Trinidad and eastern Mexico, so the issue of Caribbean recruitment remains open.

Postlarvae. Lewis et al. (1952) described pueruli of *P. argus* captured near Miami during January-March and declared that "it seems certain that this stage is not normally planktonic." However, Ingle et al. (1963) subsequently documented several captures of *P. argus* pueruli in oceanic plankton. Witham et al. (1965) described the widespread occurrence of *P. argus* pueruli in a southeast Florida estuary; later, using "artificial habitat" collectors, Witham et al. (1968) demonstrated that recruitment to estuaries occurred year-round via nighttime arrival of swimming pueruli during dark lunar phases. Year-round recruitment under similar conditions in the Florida Keys was confirmed by Sweat (1968), Little (1977) and Little and Milano (1978, 1980). Significant passage of pueruli through

Keys channels into Florida Bay in surface and mid-depth waters was demonstrated by Sweat (1968). Little and Milano (1980) demonstrated that greatest recruitment to the Keys occurred during late spring, but levels were generally high during spring through fall and even (atypically) during January of one year.

Menzies and Kerrigan (1979) compared allele frequencies of pueruli from Boca Chica Key, Florida, with others they obtained at Elliott Key. They found no difference between any postlarvae and Florida adult populations at one "important locus" but noted a 3% incidence of postlarvae bearing a rare allele not found in any Florida juveniles or adults, concluding that at least 3% of recruitment did not originate in Florida. Menzies and Kerrigan (1980) speculated that the small foreign component may be "selected out" before maturity.

Related Species. The large scyllarid lobster, *Scyllarides nodifer*, occurs only in the Gulf of Mexico, the Florida Keys, the southeast coast of the United States northward to North Carolina, and Bermuda (Williams, 1965; Lyons, 1970). Like *P. argus*, *S. nodifer* has large, ocean-dwelling phyllosomes which occur in approximately 11 stages (Robertson, 1969). Sims (1965) found stage I phyllosomes of *S. nodifer* in the Gulf of Mexico during June, and Robertson observed final phyllosomes during January and February. Although Robertson examined extensive series of phyllosomes from many Caribbean and North Atlantic localities, *S. nodifer* larvae were found only in the Gulf of Mexico and in that half of the Florida Current nearest Florida. Lyons (1970) determined that *S. nodifer* in the Gulf of Mexico spawned only during mid-May through early August, with virtually all females spawning during June and July, and observed that *S. nodifer* postlarvae arrived in the eastern Gulf and southeast Florida during late February through early April, concluding that the larval period of the species was 8-9 months.

Austin (1972) challenged these conclusions, stating "it is inconceivable that [larvae] could remain within the northeastern Gulf of Mexico during winter. Hence they cannot provide recruitment for the northeastern [sic] Florida scyllarid population." Austin cited as evidence his demonstrated absence of larvae in waters over the Florida Middle Ground between January and May. However, the Florida Middle Ground is located virtually in the center of the northern west Florida shelf, so absence of larvae there does not preclude their occurrence in deeper waters of the Gulf of Mexico. Furthermore, only relatively rare final larvae would be expected by January-March, and none would be expected thereafter until very late May, when larvae from the first spawn of the next season might appear. Because *Scyllarides nodifer* does not occur south of the Gulf of Mexico and because the Gulf of Mexico population is obviously maintaining itself successfully, it must follow that mechanisms exist to maintain phyllosomes for as long as 8-9 months in the Gulf of Mexico, and it is probable that *S. nodifer* recruited to the Keys, the southeastern coast of the United States, and Bermuda result from larvae originating in the Gulf of Mexico.

DISCUSSION

Virtually all spawning in the south Florida *Panulirus argus* population occurs during only 7 months (April-October), and by far the greatest portion of that activity takes place during April-July. Intensive spawning at Dry Tortugas may begin during April, but peak spawning in the greater portion of the fishery (Florida

Keys) population occurs during May and June. Recruitment of *P. argus* to the south Florida population occurs throughout the year. Generally high recruitment occurs during summer, fall, and even occasionally during January, but greatest recruitment occurs during spring. Such extended high levels of recruitment are difficult to explain using a spawning source as temporally restricted as that of south Florida stocks. Menzies and Kerrigan (1980) observed that maximum recruitment of postlarvae to Florida occurs 8-10 [actually 8-12] months after maximum spawning, leading them to conclude that either the larval period is longer than generally believed (6 months) or the bulk of Florida recruitment is "from populations having intense breeding activity in October and November." Intensive autumnal spawning does not occur in Florida but does occur in the Caribbean.

Year-round spawning by Caribbean stocks provides a source from which Florida's year-round recruitment of pueruli can be derived. Abundance of larvae in transit from the Caribbean to south Florida via the Yucatan Channel during much of the year has been demonstrated. Although lobsters in the Virgin Islands and other eastern Caribbean areas may be genetically dissimilar from Florida's stocks, preliminary evidence indicates that those from Trinidad and southeast Mexico are not dissimilar, so these and other localities in northern South America and the western Caribbean may prove to be sources of much of Florida's recruitment. Such areas may provide all larvae recruited to Florida during months when larvae spawned in Florida would not be expected to return; larvae from the Caribbean may join recruits originating in Florida, should such exist, during the remainder of each year.

Presence of a local, seasonal current system which may support larvae near the Florida Keys must be recognized. However, even if such a system were demonstrated to exist throughout the year, it probably could not provide much of Florida's year-round recruitment because the spawning period of Florida lobsters is so restricted.

The evident ability of *Scyllarides nodifer* phyllosomes to be maintained in the Gulf of Mexico for 8-9 months indicates that circulation systems must exist to support local recruitment for that species. Presence of a population of large, reproductively active *P. argus* in the Gulf of Mexico in much the same areas occupied by *S. nodifer* suggests that these stocks could also contribute to south Florida recruitment. Genetic composition of Gulf stocks should be investigated.

The fate of larvae spawned in Florida remains unknown. If not returned to Florida, they may be swept north to oblivion or become entrained in distant circulation systems and contribute to recruitment elsewhere. Some Florida larvae could contribute to observed recruitment in the eastern Bahamas and Antilles from the western North Atlantic. However, discrete eastern and western Caribbean lobster subpopulations or a westerly flow of larvae from the eastern Caribbean without a larval return system, as suggested by Menzies and Kerrigan (1979, 1980), would preclude recruitment of Florida larvae to the eastern Caribbean.

Lyons and Little (1975) discussed implications of Florida's dependence upon Caribbean recruitment sources, noting that "as spiny lobster fisheries develop and expand throughout the tropical western Atlantic, it will become increasingly important to understand whether management practices in these fisheries are sufficient to insure adequate production of larvae destined for recruitment into

Florida." Concurrently, Jones (1975) concluded that there are sufficient uncertainties regarding the hypothesis of Caribbean recruitment of Florida lobsters that "it is imperative to manage lobster populations so that they include a reproductively active component. Even if spawning from these animals does not contribute to the parent population, it may contribute to other fishable populations. Also, because of the possible dependence of the Florida population on external recruitment, it is important that this be adopted as a general management policy."

Whatever the source of recruitment, several studies (Sims and Ingle, 1967; Little, 1977; Davis, 1980; Lyons et al., 1981) have speculated that density-independent factors acting on planktonic larvae appear to be more important than density-dependent factors acting on juveniles in the Florida fishery. Davis (1980) noted that in lobster fisheries where definite stock-recruitment relationships are known, minimum harvestable size is set above the size of maturity; where definition of this relationship is lacking, it would still seem prudent to consider size of maturity in setting a minimum harvest size.

The closed harvest season in Florida has been established as the period of maximum spawning activity (April-July), but the necessity for a closed season comes into question if it can be demonstrated that Florida's stock depends little upon Florida spawn. At present, it appears that spiny lobster larvae are transported from the Caribbean to Florida, and these probably contribute to postlarval recruitment there. Whether they survive to join the adult population is unknown. Some contribution to recruitment by larvae spawned from the unfished Gulf of Mexico population is also probable, and some direct return of larvae spawned from the Florida Keys fishery population has not been disproved. Evidence does not overwhelmingly favor any of the foregoing mechanisms, and it may be shown ultimately that each source is important. Until irrefutable evidence indicates protection of Florida spawn is unnecessary, prudent management requires that a closed season should be continued.

Finally, Crawford and De Smidt (1922), Smith (1948), Dawson and Idyll (1951), Robinson and Dimitriou (1963), Beardsley et al. (1975), Warner et al. (1977), Lyons et al. (1981), and others have each remarked upon the impact of increased fishing pressure on the south Florida lobster population. As stated by Robinson and Dimitriou: "There is strong evidence that the problems of the Florida spiny lobster fishery are economic in nature. The reduced returns to the fishermen are the result not of reduced total abundance, but of smaller catches per man resulting from sharply increasing numbers of fishermen." The upward trend in effort has accelerated during the past decade. The great majority of lobsters landed in the Florida Keys are caught during August-November (Warner et al., 1977), and many fishermen thereafter abandon the fishery for more profitable employment. Those who stay are mostly engaged in a clean-up operation for the few lobsters not removed earlier. The 4-month closed season allows replenishment by growth of the next emerging year class such that stocks recover to a much higher level by the time the season reopens. This allows considerably more efficient harvest than would result if the population was allowed no respite. It also, of course, sets an example of protecting some spawn for other nations who may depend upon Florida for larvae and upon whose larvae Florida may depend.

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