Distribution and Abundance of Queen Conch, *Strombus gigas*, Larvae in the Florida Current: Implications for Recruitment to the Florida Keys

DAVID B. HAWTOF [1], KEVIN J. McCARTHY [2],
and ROBERT A. GLAZER[2]
[1] *1037 United St.*
Key West, FL 33040 USA
[2] *Florida Department of Environmental Protection, Marine Research Institute,*
South Florida Regional Lab, 2796 Overseas Hwy., Suite 119
Marathon, FL 33050-3513 USA

ABSTRACT

Identifying the source of recruits to marine fishery stocks is fundamental to developing appropriate management strategies. It has been suggested that the Florida Current serves as a mechanism for transport of queen conch larvae to south Florida from spawning populations elsewhere in the Caribbean. We tested this hypothesis by conducting plankton tows across the Florida Straits from west of the Dry Tortugas towards Cuba in order to determine patterns of queen conch larval abundance and distribution upstream from the Florida Keys. Conch larvae were found exclusively in the Florida Current. Only middle- and late-stage larvae were found. These results are consistent with the hypothesis of an upstream source of larvae, which are transported via the Florida Current towards the Florida Keys.

KEY WORDS: Florida Current, larvae, *Strombus gigas*

INTRODUCTION

The queen conch, *Strombus gigas*, is a significant fishery resource throughout the Caribbean region, with a potential yearly value of $40 million U.S. (Appeldoorn, 1994). Overfishing, habitat degradation, and depleted spawning stocks have reduced conch abundance throughout the region (Appeldoorn, 1987; 1994; Berg and Glazer, 1995). In the Florida Keys, queen conch was a historically important curio and food source (Stevely and Warner, 1978). Stock depletion resulted in closure of the Florida conch fishery in 1985. Despite the moratorium, the population has shown little evidence of recovery (Berg and Glazer, 1991; 1995; Glazer and Berg, 1992; 1994). This lack of recovery is poorly understood, in part because of limited knowledge of larval abundance, larval retention and recruitment processes (Stoner *et al.*, 1996; Stoner and Davis, 1997 a; 1997 b).

Dispersal of planktonic larvae by ocean currents is well described (*vide* Shanks, 1995). Many authors have suggested that localized recruitment to the Florida Keys is controlled by a complex system involving the Florida Current (*i.e.*, Gulf Stream), wind-driven currents, and localized gyres (Lee *et al.*, 1992; 1994; 1995; Criales and Lee, 1995; Stoner *et al.*, 1997). In the Florida Keys, the 18- to 40-day veliger stage of conch larvae (Randall, 1964; D'Asaro, 1965; Brownell, 1977; Davis *et al.*, 1987) facilitates their widespread dispersal. The hypothesis that conch larvae are transported long distances was reinforced by the work of Posada and Appeldoorn (1994), who collected larvae in areas of the Caribbean distant from adult populations. In addition, Mitton *et al.* (1989) and Campton *et al.* (1992) found a high degree of genetic similarity among Caribbean conch populations, suggesting extensive gene flow among those widely dispersed populations.

Previous studies of conch larval abundance were conducted at Lee Stocking Island in the Bahamas (Chaplin and Sandt, 1992; Stoner *et al.*, 1992; Stoner *et al.*, 1996; Stoner and Davis, 1997a; 1997b), the eastern Caribbean Sea (Posada and Appeldoorn, 1994) and the Florida Keys (Stoner *et al.*, 1996; 1997). Stoner *et al.* (1996) suggested that few larvae are produced in the Keys and that the Keys population requires an upstream larval source for maintenance. Yet there is little data demonstrating the presence of conch larvae in the Florida Current, the presumptive conduit of such upstream recruitment. In this study, we sampled the Florida Straits for the presence of conch larvae in order to examine the possibility that conch larvae are recruited to the Florida Keys via upstream transport mechanisms.

METHODS

We conducted plankton tows in the Florida Straits from the western Florida Keys to the northern boundary of Cuban waters from 6 July 1996 to 9 July 1996 (Figure 1). Samples were collected upstream from known spawning populations of conch to prevent sampling locally produced larvae (Glazer and Anderson, in press). Two stations (RS and DT) were situated between Key West, Florida, U.S.A. and the Dry Tortugas, Florida, U.S.A. Ten additional stations (A to J) were located west and south of the Dry Tortugas. Of these, stations A through E were located north of the Florida Current; station F was near the northern edge of the current; and stations G through J were in the Florida Current, with station I located in the charted axis. The southernmost station (J) was located 46 km north of the coast of Cuba.

Two plankton tows were conducted sequentially at each station during daylight hours (between 0856 and 1926 hours) using a 202-µm-mesh plankton net (0.5 m diameter X 2.5 m long), with a calibrated flowmeter (General Oceanics) suspended in the mouth of the net. The flowmeter was used to determine the volume of seawater sampled. Each tow was conducted for 15 minutes.

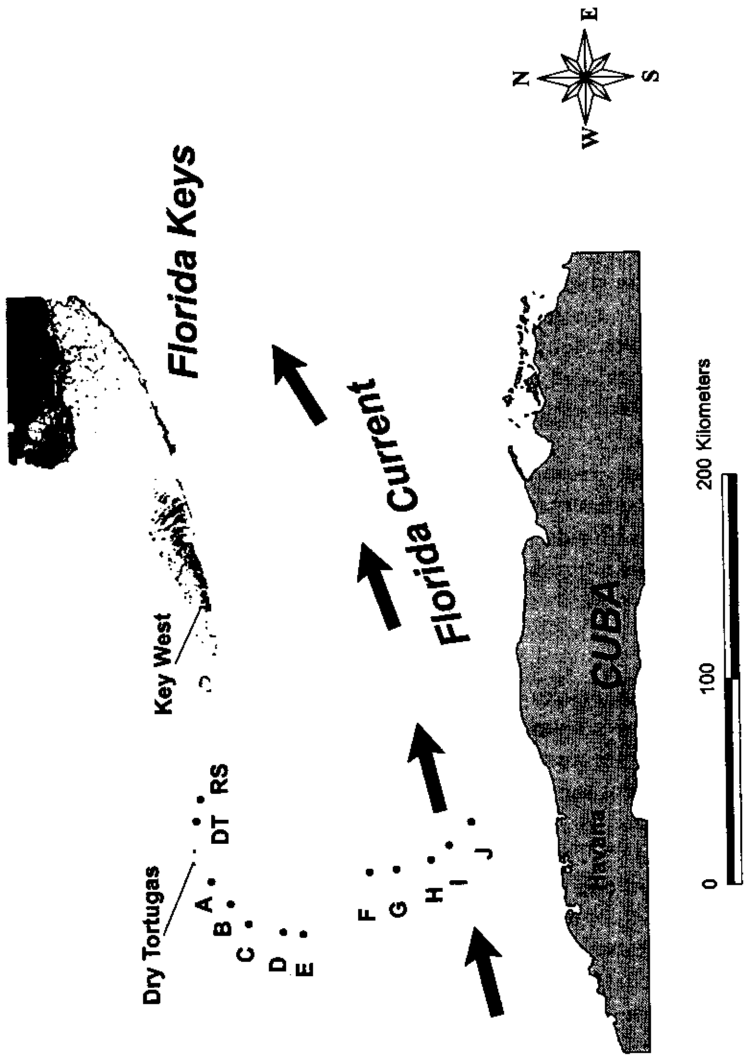

Figure 1. Location of stations where plankton tows were conducted during 1997.

The plankton net was suspended within one meter of the surface because conch larvae are photopositive and abundant near the surface when wave heights are low (Barile *et al.*, 1994; Stoner and Davis, 1997b; Chaplin and Sandt, 1992). When brought aboard, the contents of the net were washed into a labeled container and preserved with 5% formalin in seawater. Surface water temperature, wind velocity and direction, wave height and direction, and cloud cover were also recorded. Location was determined using the Global Positioning System (GPS). Because water temperatures across the Florida Straits are homogeneous during the summer (T. Lee, personal comm.), we were unable to use surface-water temperature to locate the Florida Current. Therefore, we estimated the location of the Florida Current by looking for a difference between the compass heading (*i.e.*, presumed course) and the course over ground of the vessel (*i.e.* actual course) as determined by the GPS. When we were north of the Florida Current, the vessel's compass heading and the course over ground calculated from GPS data concurred; however, when we entered the Florida Current (flowing toward the northeast), the compass heading remained "south", but the actual course (plotted from the GPS) showed that we were moving (course over ground) to the southeast. This indicated an eastward drift which we concluded was caused by the Florida Current.

Conch larvae were identified and their shell length was measured under a 20X dissecting microscope with an ocular micrometer using the criteria of Davis *et al.* (1993). Conch larval density was calculated as the number of veligers per unit volume of seawater sampled. The numbers of larvae from replicate tows at each location were combined for data analyses.

We used a Mann-Whitney two-tailed test to examine differences in larval abundance between regions north of the Florida Current (Stations RS, DT, A-E) and those within the Florida Current (Stations F - J) and between stations in the northern Florida Current (Stations F-H) and those in the southern Florida Current (I, J). Differences in larval size among stations were examined with a Kruskall-Wallis test.

RESULTS

We collected a total of 29 queen conch veligers. Of these, four (14%) were collected at stations estimated to be in the northern region of the Florida Current. The remaining 25 individuals (86%) were collected at stations estimated to be in the southern region of the current. No larvae were collected at stations north of the estimated Florida Current (Table 1). Mann-Whitney nonparametric analyses indicated significant differences between larval density north of the Florida Current (Stations RS, DT, A - E) and larval density in the Florida Current (Stations F-J) ($U = 3.500$, $p = .007$). There were no significant differences between densities in the northern (stations F-H) and southern (stations I and J) regions within the Florida Current ($U = 0.000$, $p = .083$).

The majority of the larvae found were late stage (*i.e.*, 900 µm SL or larger).

Four of the 29 larvae were less than 900 µm (Table 2). No early-stage larvae (<400 µm) were found. There was no significant difference in larval shell length between stations ($\chi^2 = 3.066$, df = 3, p = 0.382).

Table 1. Abundance and density (ind. /100 m^3) of queen conch larvae by sample station along a transect from the Florida Keys, USA, toward Cuba. Stations DT and RS were between Key West, Florida, and Dry Tortugas, Florida. Stations A - E were north of the Florida Current, stations F - H were in the northern portion of the Florida Current, and stations I and J were in the southern portion of the Florida Current.

Location	Latitude	Longitude	# Conch	Ind./ 100m^3
DT	24 37.1	82 44.1	0	0.00
RS	24 35.8	82 38.2	0	0.00
A	24 33.4	82 59.9	0	0.00
B	24 28.5	83 00.5	0	0.00
C	24 23.7	83 11.6	0	0.00
D	24 14.7	83 13.9	0	0.00
E	24 09.7	83 14.3	0	0.00
F	23 52.3	82 58.3	3	1.43
G	23 45.3	82 57.8	0	0.00
H	23 36.5	82 55.3	1	0.58
I	23 31.7	82 51.7	4	3.15
J	23 36.0	82 45.4	21	9.37

Table 2. Queen conch shell length (mm) by sample station. Stations F and H were in the northern portion of the Florida Current; stations I and J were in the southern portion of the Florida Current between Dry Tortugas, Florida, and Cuba.

			Size (mm)	
Site	N	Mean ± SD	Minimum	Maximum
F	3	1141 ± 128	1000	1250
H	1	1200	1200	1200
I	4	988 ± 275	750	1250
J	21	1033 ± 129	750	1200

DISCUSSION

This study was designed to assess larval distribution and abundance in a transect perpendicular to the axis of the Florida Current in areas without contributions from localized spawning. We found pronounced patterns in the spatial and size distributions of larvae in the Florida Straits. All larvae were found in the Florida Current and all were mid- to late-stage. These results strongly imply that larvae entrained in this region of the Florida Current originated from sources upstream of the Florida Keys, consistent with the conclusions of Stoner *et al.* (1996). Alternatively, the observed spatial patterns of larval abundance may be related to the patchy distribution of larvae, limited recruitment to this region, or the small sample size; however, the clear pattern of larval distribution being coincident with the Florida Current suggests that the current is important for the transport of *Strombus gigas* larvae.

Queen conch veligers collected in the Florida Keys have been either early stage (< 400 μm SL) or late stage (>900 μm SL); no intermediate-size veligers have been collected, suggesting that the late-stage larvae were not spawned in the Florida Keys (Stoner *et al.*, 1996). Lee *et al.* (1992) identified local processes for conveyance of marine larvae to the Florida Keys via mesoscale gyres. These gyres, when coupled with the prevailing southeast summer wind, may facilitate larval transport from offshore to the reefs of the Florida Keys (Smith and Stoner, 1993; Lee *et al.*, 1994; Pitts, 1994; Stoner *et al.*, 1996, 1997). Our results confirm the presence of conch larvae in the Florida Current; however, cross-shelf transport of larvae from the Florida Current to nearshore or reef tract areas remains unproven.

Queen conch hatching size is about 300 µm (Davis, 1994) and they have a growth rate of 50 µm/day (Ballantine and Appeldoorn, 1983). Assuming the flow of the Florida Current is 1.5 m/s (Lee *et al.*, 1992), the larvae we collected may have originated in western Cuba or even further upstream (*e.g.*, the Yucatan peninsula, Belize, or Jamaica). This scenario is likely if immediately after hatching, the veligers are entrained in advecting currents. Alternatively, larvae could have originated from the north shore of Cuba, if larvae were retained in the localized countercurrents that flow east to west along the north coast of Cuba (R. Claro, personal comm.). Retention in this region could account for the late stage of development of larvae collected in the Florida Current.

In our samples, the larval densities were substantially lower than those reported in the Exuma Cays, Bahamas, but they are consistent with the larval densities in areas of the Florida Keys with no breeding aggregations (Stoner *et al.*, 1996) (Table 3). Stoner *et al.* (1996) concluded that the limited availability of larvae may be hindering the recovery of Florida's conch population. If this is true, further examination of larval supply via the Florida Current and cross-shelf transport processes, and of the retention of locally spawned larvae will be necessary to determine bottlenecks to conch recruitment in the Florida Keys.

Table 3. Queen conch larval densities in Florida, the Exuma Cays, Bahamas, the Straits of Florida and the Florida Current.

Location	Density (Ind./100 m)
Florida[1]	0.0 to 1.40
Florida excluding the Looe Key breeding aggregation [1]	0.0 to 2.6
Florida Straits north of Florida Current [2]	0.0
Florida Current [2]	0.0 to 9.37
Exuma Cays [1]	2.3 to 32.50

[1] Stoner *et al.*, 1996
[2] Present Study

Ultimately, conservation of the spawning source for local recruits is paramount to sustaining a fishery. Therefore, identifying larval sources is critical in determining effective management strategies. Because queen conch larvae have the potential to recruit across multiple national boundaries, effective management of queen conch will require international cooperation.

ACKNOWLEDGMENTS

We wish to thank M. Ray and N. Mehta for assistance in larval identification and The Caribbean Marine Research Center, Vero Beach, Florida and A.W. Stoner for encouragement and the loan of equipment. This work was supported in part by funds provided by the Florida Department of Environmental Protection. J. Leiby, L. French, J. Quinn, J. H. Hunt and W. C. Sharp provided valuable editorial comments on the manuscript.

LITERATURE CITED

Appeldoorn, R.S. 1987. Practical considerations in the assessment of queen conch fisheries and population dynamics. *Proc. Gulf Carib. Fish. Inst.* **38**:314 - 331.

Appeldoorn, R.S. 1994. Queen conch management and research: status, needs and priorities. Pages 301-319 in: Appeldoorn and B. Rodriquez, (eds.). *Queen Conch Biology, Fisheries and Mariculture.* Fundacion Cientifica Los Roques, Caracas, Venezuela. 356 p.

Ballantine, D. L. and R. S. Appeldoorn. 1983. Queen conch culture and future prospects in Puerto Rico. *Proc. Gulf Carib. Fish. Inst.* **35**:57 - 63.

Barile, P.J., A.W. Stoner and C.M. Young. 1994. Phototaxis and vertical migration of the queen conch (*Strombus gigas* Linne) veliger larvae. *J. Exp. Mar. Biol. and Ecol.* **183**:147 - 162.

Berg, C.J., Jr. and R.A. Glazer. 1991. Current research on queen conch (*Strombus gigas*) in Florida waters. *Proc. Gulf Carib. Fish. Inst.* **40**:303 - 306.

Berg, C.J., Jr. and R.A. Glazer. 1995. Stock assessment of a large marine gastropod (*Strombus gigas*) using randomized and stratified towed diver censusing. *ICES Mar. Sci. Symp.* **199**:247 - 258.

Brownell, W.N. 1977. Reproduction, laboratory culture and growth of *Strombus gigas*, *S. costatus* and *S. pugilis* in Los Roques, Venezuela. *Bull. Mar. Sci.* **27**:668 - 680.

Campton, D.E., C.J. Berg, L.M. Robinson and R.A. Glazer. 1992. Genetic patchiness among populations of queen conch *Strombus gigas* in the Florida Keys and Bimini. *Fish. Bull. U. S.* **90**:250 - 259.

Chaplin, J. and V.J. Sandt. 1992. Vertical migration and distribution of queen conch veligers. *Proc. Gulf Carib. Fish. Inst.* **42**:158 - 160.

Criales, M.M. and T.N. Lee. 1995. Larval distribution and transport of penaeoid shrimps during the presence of the Tortugas gyre in May-June 1991. *Fish. Bull.* **93**: 471 - 482.

D'Asaro, C.N. 1965. Organogenesis, development and metamorphosis in the queen conch, *Strombus gigas*, with notes on breeding habits. *Bull. Mar. Sci.* **15**:359 - 416.

Davis, M. 1994. Mariculture techniques for queen conch (*Strombus gigas* L.): egg mass to juvenile stage. Pages 231-252 in: Appeldoorn, R. S. and B. Rodriquez, (eds.). *Queen conch biology, fisheries and mariculture*. Fundacion Cientifica Los Roques, Caracas, Venezuela. 356 p.

Davis, M., C.A. Bolton and R.A. Stoner. 1993. A comparison of larval development, growth and shell morphology in three Caribbean *Strombus* species. *Veliger* **36**:236 - 244.

Davis, M., C. Hess and G. Hodgkins. 1987. Commercial hatchery produced queen conch, *Strombus gigas*, seed for research and grow-out market. *Proc. Gulf Carib. Fish. Inst.* **38**:326 - 335.

Glazer, R. A. and L. A. Anderson. Long-term monitoring of Florida's queen conch (*Strombus gigas*) spawning stock. *Proc. Gulf Carib. Fish. Inst.*, **48**: In press.

Glazer, R.A. and C.J. Berg, Jr. 1992. Growth and mortality of the queen conch, *Strombus gigas*, in Florida. *Proc. Gulf Carib. Fish. Inst.* **42**:152 - 157.

Glazer, R.A. and C.J. Berg, Jr. 1994. Queen conch research in Florida: an overview. Pages 79-95 in: Appeldoorn, R. S. and B. Rodriquez, (eds.). *Queen conch biology, fisheries and mariculture*. Fundacion Cientifica Los Roques, Caracas, Venezuela. 356 p.

Lee, T.N., C. Rooth, E. Williams, M. McGowan, A. F. Szmant and M.E. Clarke. 1992. Influence of Florida Current, gyres and wind driven circulation on transport of larvae and recruitment in the Florida Keys coral reefs. *Cont. Shelf Res.* **12**:971 - 1002.

Lee, T.N., M.E. Clarke, E. Williams, A.F. Szmant and T. Berger. 1994. Evolution of the Tortugas gyre and its influence on recruitment in the Florida Keys. *Bull. Mar. Sci.* **54**:621 - 646.

Lee, T.N., K. Leaman, E. Williams, T. Berger and L. Atkinson. 1995. Florida Current meanders and gyre formation in the southern Straits of Florida. *J. Geophysical Res.* **100**:8607 - 8620.

Mitton, J.B., C.J. Berg, Jr. and K.S. Orr. 1989. Population structure, larval dispersal and gene flow in the queen conch, *Strombus gigas*, of the Caribbean. *Biol. Bull.* **177**:356 - 362.

Pitts, P.A. 1994. An investigation of near-bottom flow patterns along and across Hawk Channel, Florida Keys. *Bull. Mar. Sci.* **54**:610 - 620.

Posada, J. and R.S. Appeldoorn. 1994. Preliminary observations on the distribution of *Strombus* larvae in the eastern Caribbean. Pages 191-199 in: R.S. Appeldoorn and B. Rodriquez, eds. *Queen Conch biology, fisheries and mariculture*. Fundacion Cientifica Los Roques, Caracas, Venezuela.

Randall, J.E. 1964. Contributions to the biology of the queen conch, *Strombus gigas*. *Bull. Mar. Sci.* **14**:246 - 295.

Shanks, A.L. 1995. Mechanisms of cross-shelf dispersal of larval invertebrates and fish. Pages 323-367 in: L. McEdward (ed.). *Ecology of marine invertebrate larvae*. CRC Press. Boca Raton, FL. 464 p.

Smith, N.P. and A.W. Stoner. 1993. Computer simulation of larval transport through tidal channels: role of vertical migration. *Estuarine Coastal Shelf Sci.* **37**:43 - 58.

Stevely, J.M. and P.E. Warner. 1978. The biology and utilization of queen conch, *Strombus gigas* L., in the Florida Keys and throughout its geographic range. Marine Resource Inventory Monroe County Cooperative Extension service. 48 p.

Stoner, A.W. and M. Davis. 1997a. Abundance and distribution of queen conch veligers (*Strombus gigas* Linne) in the central Bahamas. I. Horizontal patterns in relation to reproductive and nursery grounds. *J. Shellfish Res.* **16**:7 - 18.

Stoner, A.W. and M. Davis. 1997b. Abundance and distribution of queen conch veligers (*Strombus gigas* Linne) in the central Bahamas. II. Vertical patterns in nearshore and deep-water habitats. *J. Shellfish Res.* **16**:19 - 29.

Stoner, A.W., R.A. Glazer and P.J. Barile. 1996. Larval supply to queen conch nurseries: relationships with recruitment process and population size in Florida and the Bahamas. *J. Shellfish Res.* **15**:1 - 14.

Stoner, A.W., N. Mehta and T.N. Lee. 1997. Recruitment of *Strombus* veligers to the Florida Keys reef tract: relation to hydrographic events. *J. Shellfish Res.* **16**:1 - 6.

Stoner, A.W.,V.J. Sandt and I.F. Boldron-Metairon. 1992. Seasonality in reproductive activity and larval abundance of queen conch *Strombus gigas*. *Fish. Bull. U.S.* **90**:161 - 170.