# CEPHALOPODS IN THE DIET OF THE SWORDFISH, *XIPHIAS GLADIUS*, FROM THE FLORIDA STRAITS

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ABSTRACT

An analysis was conducted on the cephalopod remains from the stomachs of 65 swordfish, *Xiphias gladius*, from the Florida Straits. Results indicated that cephalopods contribute a large proportion of the total ration of food items, accounting for over 90% of total weight of contents in 69% of the stomachs. Of these, ommastrephid squid of the genus *Illex* represented the single most important prey items. In total, 15 species of cephalopods were encountered, consisting of 13 teuthoids and 2 octopods. This previously unrecognized diversity confirmed the earlier postulated opportunistic feeding strategy of *X. gladius*. Cephalopod, fish, and crustacean remains are reported in terms of frequency of occurrence and biomass. Analysis of the vertical distribution of cephalopod prey indicated that swordfish feeding is most concentrated in epipelagic and upper mesopelagic waters. Comparisons with feeding studies on billfishes from the western North Atlantic indicated that istiophorids may rely more heavily on finfish prey than squid in contrast with the present findings for *X. gladius*. Also, octopods may contribute a greater proportion of the cephalopod component of total ration in the istiophorids than in *X. gladius*.

Analysis of stomach contents of many marine teleosts, mammals, and birds (Bouxin and Le Gendre 1936; Clarke 1966; Rancurel 1970, 1976; Dragovich and Potthoff 1972; Imber 1973, 1975; Perrin et al. 1973; Clarke and MacLeod 1970, 1976; Mercer 1974) coupled with estimates of cephalopod biomass (Voss 1973) suggest a key role of cephalopods in oceanic food webs. Nevertheless, few thorough studies have been conducted that have analyzed cephalopod remains, both qualitatively and quantitatively (see Voss 1953; Rees and Maul 1956; Jolley 1977; Matthews et al. 1977; Morejohn et al. 1978). Oceanic vertebrates are often more efficient collectors of cephalopods than available oceanographic gear (Clarke 1966). Therefore, information from stomach content analyses can supplement and refine existing knowledge of the biology of both prey and predator.

Cephalopods represent a major element in the diet of the swordfish, *Xiphias gladius* Linnaeus (Maksimov 1969). Yet, investigations of swordfish diet, commencing with Fleming (1828), yield little data concerning the trophic relationship between this predator and cephalopod mollusks. Acquisition of 65 swordfish stomachs allowed investigation of feeding ecology with emphasis on aspects of the biology and systematics of cephalopod prey.

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## HISTORICAL RESUMÉ

The feeding ecology of *X. gladius* is poorly understood, not only because of a general paucity of studies concerning xiphiid predation, but perhaps more importantly, from a lack of studies by invertebrate specialists dealing with invertebrates consumed by swordfish (e.g., mollusks, crustaceans). In contrast, stomach content analyses made by ichthyologists have provided reasonably good specific-level diagnoses of fish remains. A brief summary of studies that contain information on cephalopod remains from *X. gladius* stomachs is provided here.

Goode (1883) cited Fleming's (1828) report of the remains of *Sepiae* from a swordfish stomach. Goode also noted the occurrence of squid mandibles and speculated they were from the loliginid squid, *Loligo Pealii* (= *L. pealei*). In addition, Goode observed that stomach contents of swordfish from the western Atlantic were "...for the most part of the common schooling species of fishes." Rich (1947) noted a set of large beaks ("perhaps *Architeuthis*") from a *Xiphias* harpooned on the northern Georges Banks. Bigelow and Schroeder (1953) noted a specimen of *Ilex* (= *Illex*) from the stomach of a swordfish harpooned off Halifax, Nova Scotia, and commented that squid may, at times, form the chief component of the swordfish diet. Yabe et al. (1959) reported squid (mantle length 20-40 mm) and squid fragments (mantles and beaks) from several swordfish stomachs. They did not assign these cephalopod remains to more specific taxa. Several specimens contained "octopus jaws." Their study demonstrated ontogenetic changes in prey selection, with adult Pacific swordfish feeding principally on squid. Tibbo et al. (1961) examined stomachs of 39 swordfish from Nantucket Shoals and Sable Island Bank, finding fish and the squid *Illex illecebrosus*. In 14 of those swordfish (Sable Island Bank specimens), 22 squid were included among 564 food items.

De Sylva (1962) analyzed stomachs of seven female swordfish caught in April to May off northern Chile. Of the five specimens containing food remains, 24 squid *Dosidicus gigas* were found. These findings led de Sylva to believe that most swordfish feeding takes place near the surface. Cavaliere (1963) reported swordfish diets from the Straits of Messina and adjacent waters during spring and summer. Cephalopods were found in 80% of the stomachs with *I. coindetii*, *L. todarus* (= *Todarodes sagittatus* ?), and *Todarodes sagittatus* being most common. Guitart-Manday (1964), reporting on an unspecified number of swordfish taken during February and March near Cuba, found teuthoids, including *Thysanoteuthis rhombus* and a single octopod, constituting approximately 30% of the diet by number of items. Scott and Tibbo (1968), utilizing volumetric analysis, examined stomach contents of 514 swordfish from the western North Atlantic between Virginia and Sable Island Banks. They reported that, from March to October, swordfish feed on *I. illecebrosus*, as well as on a variety of fishes. Scott and Tibbo also noted the occurrence of the squid *Ommastrephes*. Interestingly, they reported the infrequent occurrence of the octopod, *Bathypolypus arcticus*, a benthic inhabitant of the continental shelf.

Maksimov (1969) examined stomach contents from 502 swordfish from the tropical Atlantic. Frequency of occurrence and average size of food items were reported. Cephalopods were a major component of the diet in all areas sampled. The following organisms were represented: *Loligo* sp., *Ommastrephes* sp. (3 undetermined spp.), and an undetermined species of sepioid. Ovchinnikov (1970) noted cephalopod and fish remains by percentage from swordfish taken near Cuba. They are identical to those reported by Guitart-Manday (1964) and probably are an uncited repetition of the same data. Beckett (1974) reported swordfish diets from the northwest Atlantic. He indicated that swordfish over deep water usually feed on vertically migrating species including squids, however, no further taxonomic breakdown was given.

## MATERIALS AND METHODS

Food remains from the stomachs of 65 specimens of *X. gladius* from the Straits of Florida were examined. Samples were obtained from three sources: sportfishing tournaments in Miami and Ft. Lauderdale, Fla. (38 specimens), commercial longliners (23 specimens), and other sources (4 specimens). Collection data are given in Appendix Table 1.

Tournament swordfish specimens were measured and weighed at dockside. Weights of longline specimens were estimated using fork length-weight relationships for both males and females (Southeast Fisheries Center[2]). Stomachs were removed and the contents fixed in 10% Formalin.[3] Following fixation, samples were transferred to 70% ethyl alcohol for storage.

Analysis of individual stomachs was conducted as follows. Contents were separated into squid, fish, and other invertebrate components. Total weights were taken for each group. Remains of intact squid were further analyzed for individual weight, dorsal mantle length, sex, state of maturity, and general condition. Based on available morphological features, squid were assigned to the lowest possible taxa. Because of the poor condition of many squid, numerous systematic characters often were destroyed or unrecognizable. Most species-specific diagnoses of teuthoid cephalopods are based on external, soft-tissue characters. It is just those features that are subject to the intial effects of digestion. As a result, identifications were based on a composite of less frequently utilized morphological features that are more resistant to digestive enzymes. These included gladius and spermatophore morphology, internal anatomy, dermal cartilage, mantle musculature, photophore number and distribution, salient beak characters, and radulae. The potential utility of such characters to predator-

[2]Southeast Fisheries Center. 1981. Report of the ICCAT Inter-sessional Workshop on Billfish. Natl. Mar. Fish. Serv., Southeast Fish. Cent., Miami, Fla., Doc. 8, 16 p. Unpubl. manuscr.

[3]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

prey studies by nonteuthologists has prompted the writers to begin work on a guide to identification of cephalopod remains from predatory species.

Buccal masses were dissected from identified squid remains and retained for future examination of mandibles. Estimates of the number of cephalopods were based solely on soft-tissue remains. Unassociated hard structures such as free mandibles, lenses, and gladii often were encountered in large numbers suggesting extended residence within the stomach. Therefore, inventories of those remains were not utilized in determining total numbers of cephalopod prey.

An attempt was made to assess the vertical migratory behavior of swordfish based on known bathymetric distribution of their squid prey. Other aspects of swordfish feeding ecology were examined using fishing depth and hookup time, as well as sex and size of swordfish specimens.

## RESULTS

Tables 1 and 2 present frequencies and biomasses of prey in stomachs of 65 swordfish. Cephalopods were the most important component, both in numbers and weight. Fish remains were of secondary importance, followed by crustaceans (shrimp). Figures 1-3 depict frequency of occurrence of each group. Cephalopods composed over 90% of the contents by weight in 68% of the stomachs examined. Only 9% of the stomachs contained <50% cephalopod remains. Fish remains accounted for >50% of contents in only 11% of the stomachs. Fish remains were ≤10% of total remains in 69% of all stomachs. Shrimp remains were found in only 9% of the stomachs, accounting for 8% by weight in one stomach and <3% in all other instances. Weights of stomach contents are conservative because swordfish are known to occasionally regurgitate or even evert their stomach when captured (Tibbo et al. 1961).

Cephalopod remains were found to include the following species:

Class: Cephalopoda Cuvier 1798
- Subclass: Coleoidea Bather 1888
  - Order: Teuthoidea Naef 1916
    - Suborder: Oegopsida Orbigny 1845
      - Family: Enoploteuthidae Pfeffer 1900
        - Subfamily: Ancistrocheirinae Pfeffer 1912
          - Genus: *Ancistrocheirus* Gray 1849
            - Species: *A. lesueuri* (Orbigny 1839)
      - Family: Onychoteuthidae Gray 1849
        - Genus: *Onychoteuthis* Lichtenstein 1818
          - Species: *O. banksii* (Leach 1817)
      - Family: Lepidoteuthidae Naef 1912
        - Genus: *Tetronychoteuthis* Pfeffer 1900
          - Species: *T. massyae* Pfeffer 1912
      - Family: Architeuthidae Pfeffer 1900
        - Genus: *Architeuthis* Steenstrup 1857
          - Species: *Architeuthis* sp.
      - Family: Histioteuthidae Verrill 1881
        - Genus: *Histioteuthis* Orbigny 1841
          - Species: *H. dofleini* (Pfeffer 1912)
            *Histioteuthis* sp.
      - Family: Ctenopterygidae Grimpe 1922
        - Genus: *Ctenopteryx* Appellöf 1899
          - Species: *C. sicula* (Verany 1851)
      - Family: Ommastrephidae Steenstrup 1857
        - Subfamily: Ommastrephinae Steenstrup 1857
          - Genus: *Ommastrephes* Orbigny 1835
            - Species: *O. pteropus* Steenstrup 1855
          - Genus: *Ornithoteuthis* Okada 1927
            - Species: *O. antillarum* (Adam 1957)
        - Subfamily: Illicinae Posselt 1890
          - Genus: *Illex* Steenstrup 1880
            - Species: *I. coindetii* ? (Verany 1837)
              *I. oxygonius* Roper, Lu, and Mangold 1969
              *I. illecebrosus* ? Lesueur 1821
      - Family: Thysanoteuthidae Keferstein 1866
        - Genus: *Thysanoteuthis* Troschel 1857
          - Species: *T. rhombus* Troschel 1857
      - Family: Cranchiidae Prosch 1849
        - Subfamily: Cranchiinae Prosch 1849
          - Genus: *Cranchia* Leach 1817
            - Species: *C. scabra* Leach 1817
  - Order: Octopoda Leach 1818
    - Suborder: Incirrata Grimpe 1916
      - Family: Bolitaenidae Chun 1911
        - Genus: *Japetella* Hoyle 1885
          - Species: *J. diaphana* Hoyle 1885

Family: Argonautidae Naef 1912
Genus: *Argonauta* Linnaeus 1758
Species: *Argonauta* sp.

Octopod remains were limited to a single occurrence of each of two species, both taken from the same stomach. Remaining cephalopods consisted of squid of the suborder Oegopsida. Of these, the genus *Illex* was predominant (Figure 4). *Histioteuthis* was second most common based on number of individuals, followed by equal numbers of *Ommastrephes pteropus* and *Onychoteuthis banksii*. Following these, in decreasing frequency of occurrence were *Thysanoteuthis rhombus* and *Cranchia scabra*. There were single records of *Ornithoteuthis antillarum*, *Tetronychoteuthis massyae*, *Ancistrocheirus lesueuri*, *Ctenopteryx sicula*, and *Architeuthis* sp. Because *Ommastrephes pteropus* and *Thysanoteuthis rhombus* reach large sizes, their contribution to prey biomass was more important than reflected by number of individuals.

Comparison of prey composition and quantity relative to swordfish sex, size, capture method, hookup time, and time of year did not reveal any correlations.

TABLE 1.—Diversity and abundance (number of individuals) of cephalopod remains in the stomach contents of *Xiphias gladius*.

| | Order Teuthoidea | | | | | | | | | | | | Order Octopoda | | Other cephalopod remains | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fish no.[1] | *Illex* spp.[2] | *Ommastrephes pteropus* | *Ornithoteuthis antillarum* | *Ancistrocheirus lesueuri* | *Onychoteuthis banksii* | *Tetronychoteuthis massyae* | *Architeuthis* sp. | *Histioteuthis dofleini* | *Histioteuthis* sp.[3] | *Ctenopteryx sicula* | *Thysanoteuthis rhombus* | *Cranchia scabra* | *Japetella diaphana* | *Argonauta* sp. | Soft-tissue fragments | Buccal masses[4] | Mandibles[4] | Gladii (Ommastrephidae)[4] | Lenses[4] | Total |
| 1 | 15 | | | | 1 | | | | | | | | | | 1 | | | | | 17 |
| 2 | 7 | | | | | | | | | | | | | | 2+ | 1 | 42 | 18+ | 32 | 9+ |
| 3 | 10 | | | | | | | | | | | | | | | | 1 | | | 10 |
| 4 | 2 | | | | | | | | | | | | | | 5+ | | 32 | 19+ | | 7+ |
| 5 | 3 | 1 | | | | | | | | | | | | | 2+ | | 40 | | | 6+ |
| 6 | 13 | 1 | | | | | | | | | | | | | | | 14 | | | 14 |
| 7 | 1 | | | | | | | | | | | | | | | | | | | 1 |
| 8 | 27 | 1 | | | 1 | | 1 | | | | | | | | 5+ | 5 | 23 | 2 | 4 | 35+ |
| 9 | 28 | | | | | | | | | | | | | | 2+ | | | | | 30+ |
| 10 | 1 | | | | | | | | | | | | | | 2+ | | | | | 3+ |
| 11 | 1 | | | | | | | | | | | | | | | | 23 | | | 1 |
| 12 | 2 | | | | | | | | | | | | | | | 6 | 19 | | | 2 |
| 13 | 1 | | | | | | | | | | | | | | 1+ | | 8 | | | 2+ |
| 14 | | | | | | | | | | | | | | | 2+ | 2 | 2 | | | 2+ |
| 15 | 1 | 1 | | | | | | | | | | | | | | 4 | 4 | | 3 | 2 |
| 16 | 2 | | | | | | | | | | | | | | 1+ | 1 | 6 | | | 3+ |
| 17 | | | | | | | | | | | | | | | 1+ | 1 | 66 | 14+ | | 1+ |
| 18 | | 1 | | | | | | | | | | | | | 4+ | 4 | | | | 5+ |
| 19 | 15 | | | | | | | | | | 1 | | | | 2+ | 2 | | | | 18+ |
| 20 | 8 | | | | | | | | | | | | | | 5+ | | 46 | 25 | 29 | 13+ |
| 21 | | | | | | | | | 1 | | | | | | | 5 | 4 | 5 | 6 | 1 |
| 22 | | | | | | | | | | | | | | | 13+ | 3 | | 10 | 24 | 13+ |
| 23 | 13 | | | | | | | | | | | | | | 1 | | | | 17 | 14 |
| 24 | 9 | | | | | | | | | | | | | | | | | | | 9 |
| 25 | 14 | | | | | | | | | | | | | | 6+ | | 11 | | 11 | 20+ |
| 26 | 12 | | | | | | | | | | | | | | | | | | | 12 |
| 27 | 2 | | | | | | | 1 | | | | | | | 16+ | 6 | | 16 | 15 | 19+ |
| 28 | 5 | | | | 3 | | | | | | | | | | | 5 | 63 | 53 | 78 | 8 |
| 29 | | | | | | | | | | | | | | | | | | | 51 | 0 |
| 30 | | | | | | | | | | | | | | | 13+ | 4 | 35 | 34 | 12 | 13+ |
| 31 | 10 | | | | | | | | | | | | | | 19+ | | 16 | 18 | 31 | 29+ |
| 32 | 5 | | | | | | | | | | | | | | 4+ | 7 | 8 | 7+ | | 9+ |
| 33 | | | | | | | | | | | | | | | 1 | | | | | 1 |
| 34 | 2 | | | | | | | | | | | | | | 7+ | 2 | 25 | 6+ | | 9+ |
| 35 | 13 | 1 | | | | | | | | | | | | | 9+ | 8 | 96 | 25+ | | 23+ |
| 36 | | | | | 2 | | | | | | | | | | 2+ | | | 13 | 24 | 4+ |
| 37 | | | | | | | | | | | | | | | 1+ | 1 | 12 | 6 | 3 | 1+ |
| 38 | 17 | | | | | | | | | | | | | | | | | | | 17 |
| 39 | 7 | | | | | | | | | | | | | | 3+ | | | | 4 | 10+ |
| 40 | 10 | | | | | | | | | | | | | | 4+ | | 42 | 15 | 41 | 14+ |
| 41 | | | | | | | | | | | | | | | 1+ | | 38 | 22 | 12 | 1+ |
| 42 | | | | | | | | | | | | | | | 9+ | 8 | 23 | 18 | | 9+ |
| 43 | 1 | | | | | | | | | | | | | | 4+ | 3 | 2 | 10 | 13 | 5+ |

TABLE 1.—*Continued.*

| | Order Teuthoidea | | | | | | | | | | | | Order Octopoda | | Other cephalopod remains | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fish no.[1] | *Illex* spp.[2] | *Ommastrephes pteropus* | *Ornithoteuthis antillarum* | *Ancistrocheirus lesueuri* | *Onychoteuthis banksii* | *Tetronychoteuthis massyae* | *Architeuthis* sp. | *Histioteuthis dofleini* | *Histioteuthis* sp.[3] | *Ctenopteryx sicula* | *Thysanoteuthis rhombus* | *Cranchia scabra* | *Japetella diaphana* | *Argonauta* sp. | Soft-tissue fragments | Buccal masses[4] | Mandibles[4] | Gladii (Ommastrephidae)[4] | Lenses[4] | Total |
| 44 | 1 | | | | | | | | | | 1 | | | | 3+ | 1 | 4 | 4 | | 5+ |
| 45 | 1 | | | | | | | | | | 1 | | | | 4+ | 3 | 18 | 13 | 16 | 5+ |
| 46 | | | | | | | | | | | | | | | 10+ | 7 | 16 | 22 | 19 | 10+ |
| 47 | | | | | | | | | | | | | | | 8+ | 2 | | 2 | 5 | 8+ |
| 48 | 7 | | | | | | | | | | | | | | 4+ | 10 | | 4 | 12 | 11+ |
| 49 | 2 | | | | | | | | | | | | | | 6+ | 1 | 20 | 10+ | 44 | 8+ |
| 50 | 6 | | | | | | | | | | | | | | 2+ | 3 | 4 | 2 | 1 | 8+ |
| 51 | | | | | | | | | | | | | | | 9+ | 2 | 12 | 18 | 13 | 9+ |
| 52 | 6 | | | | | | | | | | | | | | 1 | | | | | 7 |
| 53 | 1 | | | | | | | | | | | | | | | | | | | 1 |
| 54 | 4 | | | | | | | | | | | | | | 3+ | | | | | 7+ |
| 55 | 1 | | | | | | | | | | | 1 | | | | | | | | 2 |
| 56 | | | 1 | | | | | | | | | | | | | | | | | 1 |
| 57 | | | | | | 1 | | | | 1 | | 1 | | | | | | | | 3 |
| 58 | | | | | | | | 1 | | | | | 1 | 1 | | | | | | 3 |
| 59 | | 1 | | | | | | | | | | | | | | | | | | 1 |
| 60 | 4 | | | | | | | | 4 | | | | | | 1+ | | 8 | | | 9+ |
| 61 | | | | | | | | 1 | | | | | | | | | | | | 1 |
| 62 | 4 | | | | | | | | | | | | | | 1+ | 2 | 22 | 12 | | 5+ |
| 63 | 8 | | | | | | | | | | | | | | | | 56 | 28 | | 8 |
| 64 | 7 | | | | | | | | | | | | | | 2+ | 2 | 5 | 8 | 13 | 9+ |
| 65 | | | | 1 | | | | | 1 | | | | | | 1+ | | 2 | 2 | | 3+ |

[1]See Appendix Table 1.
[2]Includes *I. coindetii*, *I. illecebrosus*, and *I. oxygonius* (see Discussion).
[3]May include more than one species.
[4]Not included in total cephalopods (see Materials and Methods).

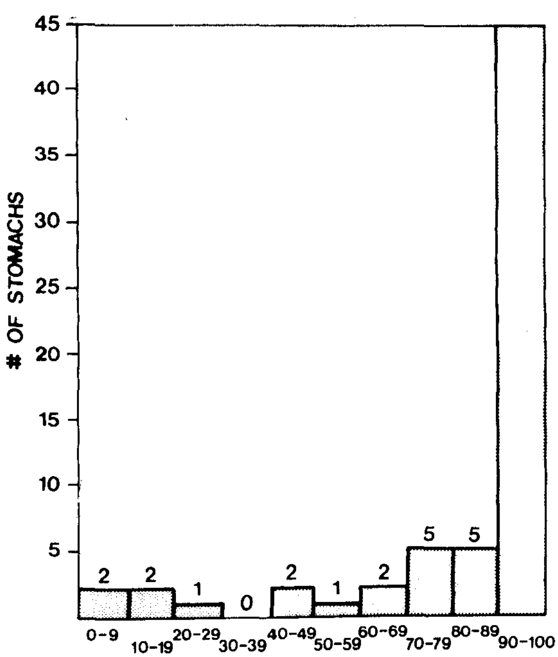


FIGURE 1.—Cephalopod remains as percent of total stomach contents by weight.

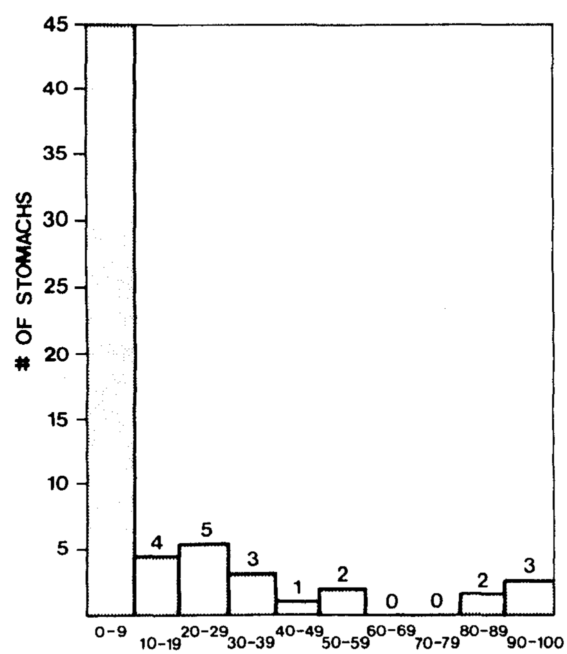


FIGURE 2.—Fish remains as percent of total stomach contents by weight.

TABLE 2.—Weights (grams) of cephalopod, fish, and other invertebrate remains in the stomach contents of *Xiphias gladius*.

| | Order Teuthoidea | | | | | | | | | | | | Order Octopoda | | Total | | | Percent of total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fish no.[1] | *Illex* spp.[2] | *Ommastrephes pteropus* | *Ornithoteuthis antillarum* | *Ancistrocheirus lesueuri* | *Onychoteuthis banksii* | *Tetronychoteuthis massyae* | *Architeuthis* sp. | *Histioteuthis dofleini* | *Histioteuthis* sp.[3] | *Ctenopteryx sicula* | *Thysanoteuthis rhombus* | *Cranchia scabra* | *Japetella diaphana* | *Argonauta* sp. | Cephalopods | Fish | Other invertebrates (shrimp) | Cephalopods[4] | Fish | Other invertebrates (shrimp) | Total of all components |
| 1 | 1,033 | | | | 36 | | | | | | | | | | 1,088 | 1 | 0 | >99 | <1 | 0 | 1,089 |
| 2 | 421 | | | | | | | | | | | | | | 477 | 24 | 1 | 95 | 4 | <1 | 502 |
| 3 | 1,062 | | | | | | | | | | | | | | 1,062 | 0 | 0 | 100 | 0 | 0 | 1,062 |
| 4 | 88 | | | | | | | | | | | | | | 213 | 0 | 0 | 100 | 0 | 0 | 213 |
| 5 | 178 | 334 | | | | | | | | | | | | | 614 | 0 | 0 | 100 | 0 | 0 | 614 |
| 6 | 1,316 | 319 | | | | | | | | | | | | | 1,635 | 0 | 0 | 100 | 0 | 0 | 1,635 |
| 7 | 73 | | | | | | | | | | | | | | 73 | 10 | 0 | 88 | 12 | 0 | 83 |
| 8 | 3,023 | 155 | | | 70 | | 107 | | | | | | | | 3,730 | 72 | 0 | 98 | 2 | 0 | 3,802 |
| 9 | 2,726 | | | | | | | | | | | | | | 2,812 | 0 | 0 | 100 | 0 | 0 | 2,812 |
| 10 | 61 | | | | | | | | | | | | | | 145 | 0 | 4 | 97 | 0 | 3 | 149 |
| 11 | 177 | | | | | | | | | | | | | | 177 | 1 | 0 | >99 | <1 | 0 | 178 |
| 12 | 155 | | | | | | | | | | | | | | 155 | 0 | 0 | 100 | 0 | 0 | 155 |
| 13 | 80 | | | | | | | | | | | | | | 141 | 0 | 0 | 100 | 0 | 0 | 141 |
| 14 | | | | | | | | | | | | | | | 141 | 20 | 0 | 88 | 12 | 0 | 161 |
| 15 | 49 | 475 | | | | | | | | | | | | | 524 | 0 | 0 | 100 | 0 | 0 | 524 |
| 16 | 263 | | | | | | | | | | | | | | 263 | 0 | 23 | 92 | 0 | 8 | 286 |
| 17 | | | | | | | | | | | | | | | 4 | 88 | 1 | 4 | >95 | <1 | 93 |
| 18 | | 661 | | | | | | | | | | | | | 859 | 77 | 0 | 92 | 8 | 0 | 936 |
| 19 | 2,471 | | | | | | | | | | 75 | | | | 2,642 | 214 | 0 | 93 | 7 | 0 | 2,856 |
| 20 | 811 | | | | | | | | | | | | | | 994 | 75 | 0 | 93 | 7 | 0 | 1,069 |
| 21 | | | | | | | | | 2 | | | | | | 15 | 61 | 0 | 20 | 80 | 0 | 76 |
| 22 | | | | | | | | | | | | | | | 795 | 0 | 11 | 98 | 0 | 2 | 806 |
| 23 | 1,059 | | | | | | | | | | | | | | 1,091 | 0 | 0 | 100 | 0 | 0 | 1,091 |
| 24 | 1,131 | | | | | | | | | | | | | | 1,131 | 0 | 0 | 100 | 0 | 0 | 1,131 |
| 25 | 1,517 | | | | | | | | | | | | | | 1,993 | 93 | 0 | 96 | 4 | 0 | 2,086 |
| 26 | 1,553 | | | | | | | | | | | | | | 1,553 | 0 | 0 | 100 | 0 | 0 | 1,553 |
| 27 | 178 | | | | | | | 45 | | | | | | | 223 | 0 | 0 | 100 | 0 | 0 | 223 |
| 28 | 395 | | | | 2 | | | | | | | | | | 397 | 0 | 0 | 100 | 0 | 0 | 397 |
| 29 | | | | | | | | | | | | | | | — | 0 | 0 | 100 | 0 | 0 | — |
| 30 | | | | | | | | | | | | | | | 505 | 0 | 0 | 100 | 0 | 0 | 505 |
| 31 | 689 | | | | | | | | | | | | | | 1,328 | 162 | 0 | 89 | 11 | 0 | 1,490 |
| 32 | 387 | | | | | | | | | | | | | | 531 | 39 | 0 | 93 | 7 | 0 | 570 |
| 33 | | | | | | | | | | | | | | | 36 | 319 | 0 | 10 | 90 | 0 | 355 |
| 34 | 80 | | | | | | | | | | | | | | 362 | 445 | 0 | 45 | 55 | 0 | 807 |
| 35 | 1,090 | 375 | | | | | | | | | | | | | 1,871 | 11 | 0 | 99 | 1 | 0 | 1,882 |
| 36 | | | | | 2 | | | | | | | | | | 140 | 725 | 0 | 16 | 84 | 0 | 865 |
| 37 | | | | | | | | | | | | | | | 24 | 10 | 0 | 71 | 29 | 0 | 34 |
| 38 | 1,273 | | | | | | | | | | | | | | 1,273 | 0 | 0 | 100 | 0 | 0 | 1,273 |
| 39 | 572 | | | | | | | | | | | | | | 715 | 26 | 0 | 96 | 4 | 0 | 741 |
| 40 | 569 | | | | | | | | | | | | | | 644 | 21 | 0 | 97 | 3 | 0 | 665 |
| 41 | | | | | | | | | | | | | | | 78 | 0 | 0 | 100 | 0 | 0 | 78 |
| 42 | | | | | | | | | | | | | | | 419 | 388 | 0 | 52 | 48 | 0 | 807 |
| 43 | 114 | | | | | | | | | | | | | | 163 | 0 | 0 | 100 | 0 | 0 | 163 |
| 44 | 108 | | | | | | | | | | 487 | | | | 675 | 287 | 0 | 70 | 30 | 0 | 962 |
| 45 | 98 | | | | | | | | | | 6 | | | | 161 | 44 | 0 | 79 | 21 | 0 | 205 |
| 46 | | | | | | | | | | | | | | | 408 | 116 | 0 | 78 | 22 | 0 | 524 |
| 47 | | | | | | | | | | | | | | | 426 | 76 | 0 | 85 | 15 | 0 | 502 |
| 48 | 644 | | | | | | | | | | | | | | 678 | 0 | 0 | 100 | 0 | 0 | 678 |
| 49 | 226 | | | | | | | | | | | | | | 574 | 21 | 0 | 96 | 4 | 0 | 595 |
| 50 | 627 | | | | | | | | | | | | | | 650 | 0 | 0 | 100 | 0 | 0 | 650 |
| 51 | | | | | | | | | | | | | | | 389 | 242 | 0 | 62 | 38 | 0 | 631 |
| 52 | 768 | | | | | | | | | | | | | | 838 | 0 | 0 | 100 | 0 | 0 | 838 |
| 53 | 151 | | | | | | | | | | | | | | 151 | 73 | 0 | 77 | 23 | 0 | 224 |
| 54 | 684 | | | | | | | | | | | | | | 789 | 200 | 0 | 80 | 20 | 0 | 989 |
| 55 | 93 | | | | | | | | | | | 7 | | | 100 | 0 | 0 | 100 | 0 | 0 | 100 |
| 56 | | | 12 | | | | | | | | | | | | 12 | 0 | 0 | 100 | 0 | 0 | 12 |
| 57 | | | | | | 15 | | | | 85 | | 5 | | | 105 | 0 | 0 | 100 | 0 | 0 | 105 |
| 58 | | | | | | | | 1 | | | | | 2 | 1 | 4 | 992 | 2 | <1 | >99 | <1 | 998 |
| 59 | | 146 | | | | | | | | | | | | | 146 | 73 | 0 | 67 | 33 | 0 | 219 |
| 60 | 379 | | | | | | | | 235 | | | | | | 679 | 0 | 0 | 100 | 0 | 0 | 679 |
| 61 | | | | | | | | 164 | | | | | | | 164 | 0 | 0 | 100 | 0 | 0 | 164 |
| 62 | 446 | | | | | | | | | | | | | | 468 | 34 | 0 | 93 | 7 | 0 | 502 |
| 63 | 617 | | | | | | | | | | | | | | 628 | 0 | 0 | 100 | 0 | 0 | 628 |
| 64 | 600 | | | | | | | | | | | | | | 713 | 0 | 0 | 100 | 0 | 0 | 713 |
| 65 | | | | 26 | | | | | 209 | | | | | | 391 | 420 | 0 | 48 | 52 | 0 | 811 |

[1]See Appendix Table 1.
[2]Includes *I. coindetii*, *I. illecebrosus*, and *I. oxygonius* (see Discussion).
[3]May include more than one species.
[4]Includes weights of fragments.

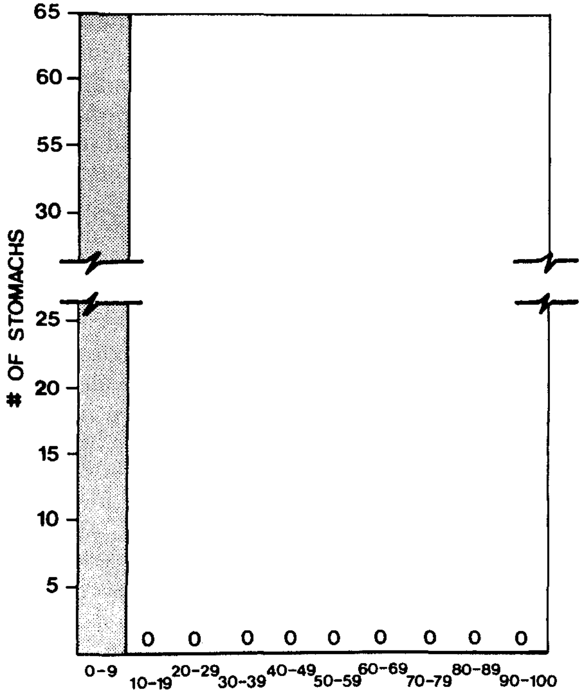


FIGURE 3.—Shrimp remains as percent of total stomach contents by weight.

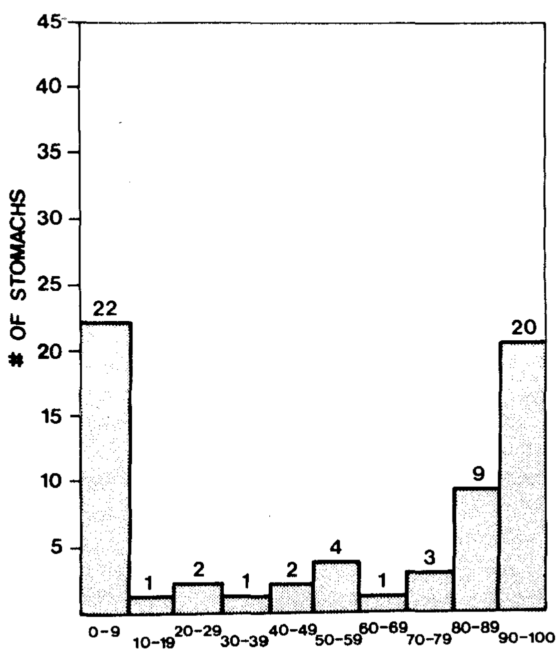


FIGURE 4.—*Illex* spp. remains as percent of total stomach contents by weight.

## DISCUSSION

Swordfish in the Straits of Florida demonstrate a clear predilection for cephalopods as prey, specifically squids. Furthermore, the genus *Illex* constitutes the single most important component in the diet. At present, there are three nominal species of *Illex* known from the western North Atlantic: *I. illecebrosus*, *I. coindetii*, and *I. oxygonius*. A recent revision (Roper et al. 1969) attempted to stabilize the systematic positions of these taxa. However, the same authors reemphasized systematic and distributional complexities of this polytypic genus, especially in the tropical western Atlantic which includes the present study area. Numerous specimens examined in this work had the specific characters assigned to their nominal species, however, systematic problems appear to be most acute in the *I. illecebrosus*-*I. coindetii* complex. Because of the tenuous systematic and distributional aspects, as well as the poor condition of much of the material, the writers thought it best to deal with the group at the generic level rather than possibly adding to the underlying systematic and zoogeographic confusion.

Many teuthoids aggregate for feeding or reproduction (see Clarke 1966). The cephalopod prey in this study included such aggregating squid as *Illex* spp., *Ommastrephes pteropus*, *Thysanoteuthis rhombus*, *Onychoteuthis banksii*, and *Histioteuthis* sp. Additionally, *Ornithoteuthis antillarum* and *Tetronychoteuthis massyae* probably behave similarly. Heavy swordfish predation upon aggregating or schooling cephalopods is similar to reported predation on schooling fishes (Goode 1883; Tibbo et al. 1961). Tibbo et al. (1961) and Scott and Tibbo (1968) noted the use of the bill by swordfish to wound or kill prey. They suggested that swordfish slash laterally with their bills, while ascending or descending through a school of prey. The present material contained numerous decapitated squid and more frequently, oblique slash marks on mantles thus supporting the postulated foraging behavior. Furthermore, this concurs with the known horizontal orientation of the pelagic squids listed above. Ommastrephids and *Thysanoteuthis* have muscular mantles and are powerful swimmers. Swimming ability of swordfish does not appear to be a limiting factor in the selection of cephalopod prey, as indicated by the predominance of these organisms in the diet of *X. gladius*.

In the tropics, swordfish undergo daily vertical migrations, rising to feed near the surface at night and returning to deeper waters by day (Beardsley 1978). The full extent of these vertical migrations is poorly known. Cephalopods also exhibit vertical distributions and diel migrations of considerable range (Voss 1967; Clarke and Lu 1974, 1975; Lu and Clark 1975a, b; Roper and Young 1975; Herring 1977). While these works provide some data on bathymetric distribution suggesting general patterns of vertical migration, the actual distributions of most cephalopod species remain poorly known. At the familial level, all but three of the cephalopods encountered in this work may occur from the surface to depths between 500 and 1,000 m. Histioteuthids are found from near the surface to about 2,500 m. Cranchiids range, in general, from the surface to about 3,000 m, but the only species found in swordfish stomachs, *Cranchia scabra*, is confined to the upper several hundred meters of the water column (N. Voss[4]). Thore (1949) stated that adults of *Japetella diaphana* are found in 330-3,000 m of water, while younger animals are concentrated at depths of 100-330 m. Bathymetric ranges of all cephalopod species considered here encompass the upper 500 m of water. While it remains possible that swordfish forage at greater depths, it appears that most feeding is concentrated in epipelagic and upper mesopelagic waters.

This analysis of the cephalopod component of the swordfish diet supports earlier observations (Scott and Tibbo 1968), suggesting the opportunistic nature of *X. gladius* predation. Based on the data presented here, prey composition is independent of season, fish size, or sex. Rather, stomach contents appear to reflect the diversity and relative abundance of potential prey.

Voss (1953) examined stomach contents of 241 sailfish, *Istiophorus americanus* (= *I. platypterus*), from Florida waters. Of 461 identified prey, 83% were fish, including members of at least 20 families. A total of 78 cephalopods, including 27 octopods, were found. Voss identified the octopod specimens as *Argonauta argo*, *Argonauta* sp., and *Grimpoteuthis*?. Of the 49 teuthoids recovered, all were considered *Sthenoteuthis bartrami* (= *Ommastrephes bartrami*), but probably were *O. pteropus*. Maksimov (1971) examined stomachs of sailfish from the tropical Atlantic. Teuthoids and octopods predominated as food. Over 61% of sailfish stomachs from Brazil contained squid and 50% contained octopods. Sailfish taken off Barbados contained squid, but no octopods. Jolley (1977) examined 778 sailfish from off southeast Florida and found scombrid fish to be the most important prey followed by cephalopods. Jolley found 27% of all stomachs examined to be empty.

Krumholz and de Sylva (1958) reported on the stomach contents of white marlin, *Tetrapterus albidus*, taken near Bimini, Bahamas. Nine stomachs contained cephalopods, arthropods, and fish. Squid and octopods were the most abundant items, accounting for 41% and 18%, respectively, by frequency of occurrence. An additional 41 stomachs were empty. De Sylva and Davis (1963) examined stomachs of 55 white marlin from the Middle Atlantic Bight. Round herring, *Etrumeus teres*, and *Loligo pealei* were the chief components of the diet. Ovchinnikov (1970) investigated diets of white marlin in the tropical Atlantic, noting *Loligo pealei* as the most important prey.

Krumholz and de Sylva (1958) also reported on 14 blue marlin stomachs of which 10 contained food. Fish were more important than cephalopods by frequency of occurrence. Cephalopod remains consisted of the pelagic octopods *Argonauta argo* and *Ocythoe tuberculata*, which together constituted 17% of the total number of prey. Voss and Erdman (1959) reported finding a large specimen of the squid *Thysanoteuthis rhombus* in the stomach of a blue marlin caught off San Juan, Puerto Rico. Ovchinnikov (1970) investigated stomachs of blue marlin. These fish contained teuthoids and less frequently sepioids. Fish were more important than cephalopods in the diet of blue marlin.

Two observations are apparent from comparisons of diets of istiophorids and swordfish. First, fish appear to be more important in diets of istiophorids, with cephalopods of secondary importance. The opposite is true for swordfish. Second, octopods may be a more important component of the cephalopod prey of istiophorids than of swordfish.

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on most swordfish specimens. Mitchell Roffer aided in the acquisition of pertinent literature. Lastly, thanks go to Gilbert L. Voss and Edward D. Houde for reviewing the manuscript.

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APPENDIX TABLE 1.—Swordfish collection data.

| Fish no. | Date landed | Sex[1] | Lower jaw fork length (cm) | Weight (kg) | Method of capture[2] | Hookup time (e.s.t) | Fish no. | Date landed | Sex[1] | Lower jaw fork length (cm) | Weight (kg) | Method of capture[2] | Hookup time (e.s.t) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17 June 1978 | M | 138 | 30 | R | — | 34 | 20 July 1978 | M | 170 | 72 | R | 0400 |
| 2 | 17 June 1978 | M | 142 | 35 | R | — | 35 | 20 July 1978 | M | 178 | 77 | R | 2238 |
| 3 | 21 June 1978 | M | 142 | 29 | R | 0006 | 36 | 21 July 1978 | M | 134 | 30 | R | 0320 |
| 4 | 21 June 1978 | M | 155 | 45 | R | 0152 | 37 | 21 July 1978 | M | 156 | 47 | R | 0220 |
| 5 | 21 June 1978 | M | 167 | 62 | R | 0300 | 38 | 21 July 1978 | M | 169 | 59 | R | 2200 |
| 6 | 21 June 1978 | M | 176 | 69 | R | 0045 | 39 | 21 July 1978 | M | 170 | 65 | R | 2230 |
| 7 | 21 June 1978 | M | 196 | 102 | R | 0500 | 40 | 21 July 1978 | M | 174 | 74 | R | 0147 |
| 8 | 21 June 1978 | F | 205 | 120 | R | 2300 | 41 | 21 July 1978 | F | 211 | 136 | R | 0255 |
| 9 | 21 June 1978 | M | 206 | 101 | R | 0050 | 42 | 27 July 1978 | M | 153 | [3]45 | LL | — |
| 10 | 22 June 1978 | M | 134 | 29 | R | 0315 | 43 | 27 July 1978 | M | 199 | [3]101 | LL | — |
| 11 | 22 June 1978 | M | 142 | 35 | R | 2230 | 44 | 13 Sept. 1978 | M | 138 | [3]33 | LL | — |
| 12 | 22 June 1978 | M | 151 | 41 | R | 0400 | 45 | 29 Sept. 1978 | M | 101 | [3]13 | LL | — |
| 13 | 23 June 1978 | M | 189 | 80 | R | 0246 | 46 | 29 Sept. 1978 | M | 165 | [3]57 | LL | — |
| 14 | 23 June 1978 | F | 214 | 126 | R | 0435 | 47 | 29 Sept. 1978 | M | 235? | [4]166 | LL | — |
| 15 | 24 June 1978 | M | 147 | 41 | R | 0530 | 48 | 30 Sept. 1978 | F | 106 | [3]12 | LL | — |
| 16 | 24 June 1978 | M | 193 | 92 | R | 2400 | 49 | 30 Sept. 1978 | M | 169 | [3]61 | LL | — |
| 17 | 24 June 1978 | M | 206 | 112 | R | 0430 | 50 | 5 Oct. 1978 | F | 102 | [3]11 | LL | — |
| 18 | 24 June 1978 | F | 207 | 105 | R | — | 51 | 5 Oct. 1978 | M | 143 | [3]37 | LL | — |
| 19 | 24 June 1978 | F | 209 | 118 | R | — | 52 | 5 Oct. 1978 | M | 150 | [3]42 | LL | — |
| 20 | 17 July 1978 | M | 141 | 36 | R | 0150 | 53 | 6 Feb. 1979 | F | 121 | [3]19 | LL | — |
| 21 | 17 July 1978 | M | 160 | 52 | R | 0243 | 54 | 7 Mar. 1979 | F | 241 | [4]203 | LL | — |
| 22 | 17 July 1978 | M | 175 | 64 | R | 2312 | 55 | 10 Apr. 1979 | M | 126 | [3]25 | LL | — |
| 23 | 17 July 1978 | M | 181 | 77 | R | 2345 | 56 | 10 Apr. 1979 | F | 131 | [3]25 | LL | — |
| 24 | 17 July 1978 | M | 186 | 72 | R | 2304 | 57 | 10 Apr. 1979 | F | 132 | [3]26 | LL | — |
| 25 | 17 July 1978 | F | 213 | 143 | R | 2207 | 58 | 10 Apr. 1979 | M | 157 | [3]49 | LL | — |
| 26 | 18 July 1978 | — | 118 | 20 | R | 0345 | 59 | 10 Apr. 1979 | M | 163 | [3]55 | LL | — |
| 27 | 18 July 1978 | M | 158 | 50 | R | 2251 | 60 | 11 Apr. 1979 | M | 165 | [3]57 | LL | — |
| 28 | 18 July 1978 | M | 200 | 110 | R | — | 61 | 6 June 1979 | M | 155 | [3]47 | LL | — |
| 29 | 18 July 1978 | M | 209 | 115 | R | 2400 | 62 | 29 Sept. 1979 | F | 106 | [3]12 | LL | — |
| 30 | 18 July 1978 | M | 214 | 125 | R | 0315 | 63 | 29 Sept. 1979 | M | 174 | [3]67 | LL | — |
| 31 | 18 July 1978 | M | 218 | 114 | R | 2300 | 64 | 5 Oct. 1979 | M | 124 | [3]24 | LL | — |
| 32 | 20 July 1978 | M | 132 | 27 | R | 0112 | 65 | — | — | — | — | — | — |
| 33 | 20 July 1978 | M | 140 | 39 | R | 0410 | | | | | | | |

[1]M = Male, F = Female.
[2]R = Rod and reel, LL = Longline.
[3]Weight computed from weight/length formulas according to sex (Southeast Fisheries Center text footnote 3).
[4]Weight computed from dressed weight/whole weight formula (South Atlantic Fishery Management Council. 1980. Draft Swordfish Management Plan. Unpubl. manuscr.)