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The Biology of Cephalopods from the Cooperative U.S.-Japan Squid Jigging Surveys off Oregon and Washington, 1990

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ERRATA NOTICE

THE BIOLOGY OF CEPHALOPODS FROM THE COOPERATIVE U.S.-JAPAN SQUID JIGGING SURVEYS OFF OREGON AND WASHINGTON, 1990

by

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INTRODUCTION

In 1990 the National Marine Mammal Laboratory (NMML) was requested to prepare cephalopod identification material for the Resource Assessment and Conservation Engineering (RACE) Divison of the Alaska Fisheries Science Center (AFSC). This reference material was to be used by U.S. fisheries observers to aid in the identification of cephalopods likely to be caught off the Oregon and Washington coasts during the cooperative U.S.-Japan squid jigging surveys in August-September 1990. The senior author also gave a demonstration on squid identification using preserved cephalopod specimens to the U.S. observers. A description and catch data of this U.S.-Japan squid jigging operation are reported by June and Wilkins (1991).

At the request of the NMML, whole specimens of each species were collected from jigging stations fished at intervals of 10 minutes of latitude. Another intention of the collection was to demonstrate changes in size and maturity of cephalopods by degree of latitude in the sampling area over 10-day periods. Unfortunately the sample sizes were too small to satisfactorily describe changes in size and maturity. Emphasis was also placed on the collection of specimen material that could be used by biologists examining the diet of marine mammals, fish, and birds. This report presents the biological data gathered during examination of these cephalopod specimens.

METHODS AND MATERIALS

Squid samples for the NMML were placed in plastic bags, labelled with vessel number, haul number, date, species, and then frozen aboard the vessels. Nearly 50% of the preserved specimens had their mantles sliced open in the field and although these were carefully closed before freezing, there may have been some weight loss (including parts lost in the process of handling and freezing) and damage or loss of gonads or gonad parts, (e.g., ruptured spermduct, damaged nidamental glands).

In the laboratory, the squid samples were allowed to thaw overnight. The following morning, each squid was weighed and the mantle length was measured. Statoliths were removed and stored dry in gelatin capsules. The buccal mass (containing the beaks and radula) was removed and placed in a jar of water to allow the tissue to decay. After several days of soaking the beaks and radula were easily removed from the decayed buccal mass. The beaks and radula were stored in 50% isopropyl alcohol. Methods used to measure and describe beaks follow that of Clarke (1986). The squid mantle of whole specimens were sliced open and the sex identified. In females the nidamental gland was measured and the ovaries weighed; in males the testes were weighed and the presence or absence of spermatophores in the spermduct was noted. The spermduct was weighed when spermatophores were present. Squid stomachs containing food were refrozen for later examination. To our knowledge the 200 <u>Ommastrephes</u> <u>bartrami</u> stomachs examined by Bernard (1981) is the only report available on the feeding habits of this species from the eastern North Pacific Ocean. We know of no reports on the feeding habits of <u>Onychoteuthis</u> <u>borealijaponica</u>, <u>Gonatopsis</u> <u>borealis</u>, or <u>Moroteuthis</u> <u>robusta</u> from the eastern North Pacific Ocean. The mantle was weighed to provide product recovery rate calculated as a percent of the frozen whole weight of the animal. The undamaged gladius was extracted from the mantle and a length measurement recorded. The lower rostral length of all beaks were measured and information on beak wing darkening was noted.

Judging degree of maturity of the cephalopod specimens can be a problem. Amaratunga and Durward (1979) describe the maturation of Illex illecebrosus in considerable detail and their description of maturity for other species of squids is useful.

In this study, we considered a female squid immature if the developing eggs were not obvious and the nidamental glands were small for the species. Large nidamental glands indicate approaching maturity along with increasing ovary weights. Male squids were considered immature if there were few or no spermatophores in the spermduct. The squid was considered maturing if spermatophores were present and mature if the spermduct was large and packed with spermatophores.

RESULTS

This report complements the report of June and Wilkins (1991), and provides biological information for each squid sample. Our laboratory weights of specimens are in most instances lighter than fresh weights due to normal fluid loss during storage and unavoidable loss of some material from specimens opened in the field. Data on maturity (i.e., gonad weights and nidamental gland lengths was not obtained for all specimens. Following are the numbers of squids examined:

Species	Total catch	Examined M	Examined F	Examined Total
Ommastrephes bartrami	8,395	98	112	210
Onychoteuthis borealijaponica	1,450	72	63	135
Gonatopsis borealis	117	13	11	24
Moroteuthis robusta	18	2	7	9
Loligo opalescens	6	-	-	6
Gonatus sp.	1	1	-	1

Whole Specimens

Selected specimens of each species were preserved for the cephalopod reference collections at the NMML and Resource Ecology and Fisheries Management (REFM) Division of the AFSC. A total of 26 specimens representing six species for NMML and 13 specimens representing five species for REFM were preserved. Size and maturity data, statoliths, beaks, and radulas were collected from each specimen. In addition, 8 specimens (three species) and 6 specimens (two species), respectively, were sent to the U.S. National Museum, Washington, D.C., and to the Santa Barbara Museum of Natural History, Santa Barbara, California.

Stomachs

A series of stomachs containing food from our samples were saved from these species and will be reported on in the near future by a REFM biologist.

Statoliths

Statoliths can be used to identify squids to family, genera and frequently to species. If needed, statoliths can be cleaned, using the method described by Morris and Aldrich (1985). Additional references describing statolith extraction methods and descriptive terms are found in Clarke (1978), Clarke and Maddock (1988), and Morris and Aldrich (1984, 1985). Treacy and Crawford (1981) describe methods of recovering statoliths from stomachs of marine mammals. A series of statoliths from each species examined has been placed in the NMML cephalopod reference collection.

A representative series of *O. bartrami* and *O. borealijaponica* statoliths along with relevant data were sent to Michael Seki and Keith Bigelow, Southwest Fisheries Science Center, Honolulu, Hawaii for use in squid distribution and maturity studies.

Mantle Weights

To complement June and Wilkins' (1991) study of product recovery, we also cleaned and weighed mantles. The recovery rate from processing whole squid to mantles expressed as a percentage was 52.8% for *O. bartrami*, 53% for *O. borealijaponica*, and 51.4% *G. borealis*. June and Wilkins' (1991) recovery rate of a much larger sample of *O. bartrami* was 49%.

Gladii

Size frequencies of the measured, undamaged gladii and mantle length are shown in Figures 1-3. The fitted curve of each figure combines male and female measurements. These data were compiled to demonstrate the possibility of using gladius length for mantle length, in those cases where mantle length cannot be obtained. Table 1 gives the results of regression analysis on mantle length against gladius length for *O. bartrami*, *O.*

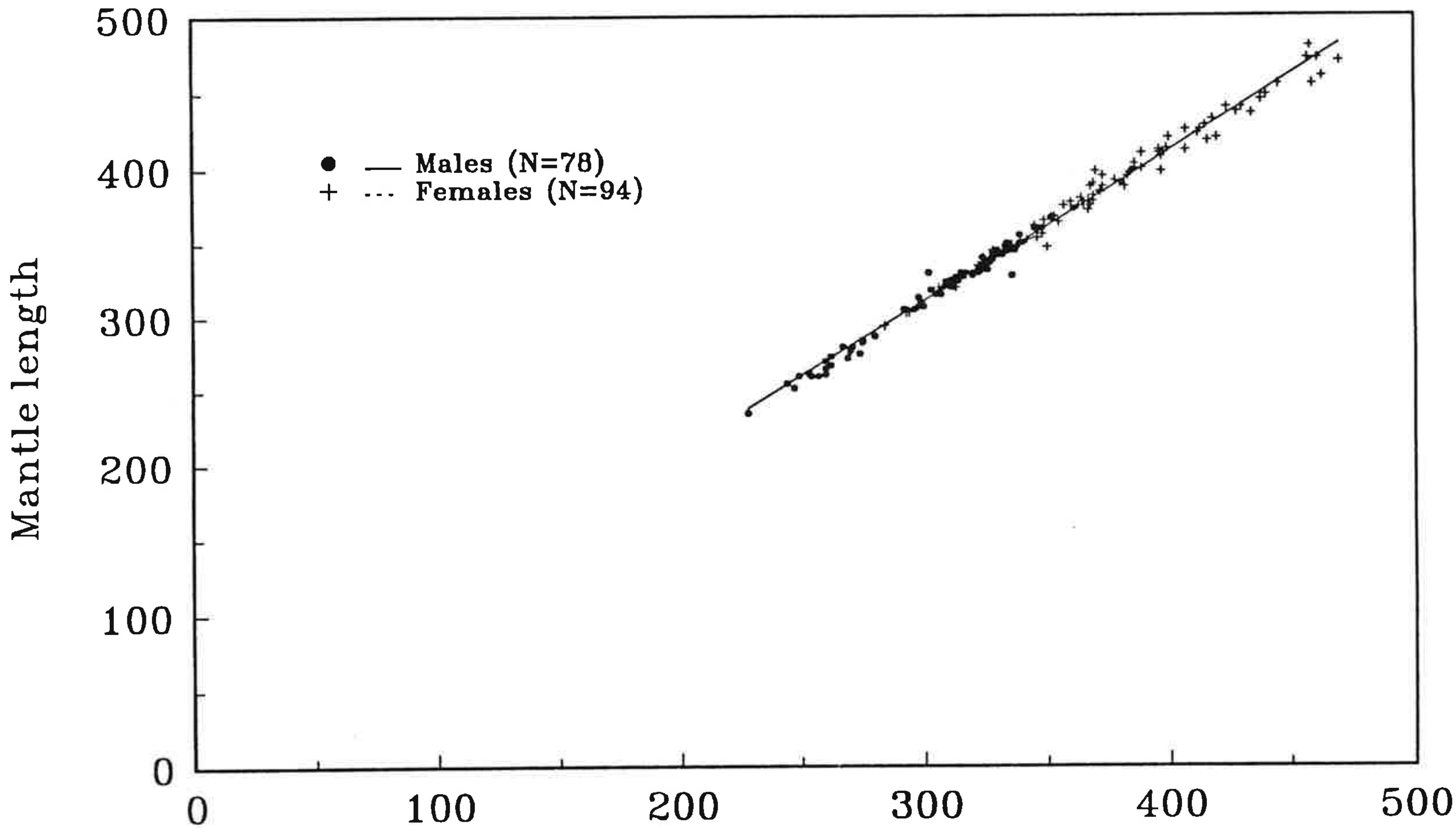

Figure 1.--Relationship of mantle length (mm) and gladius length (mm) of male and female *Ommastrephes bartrami*.

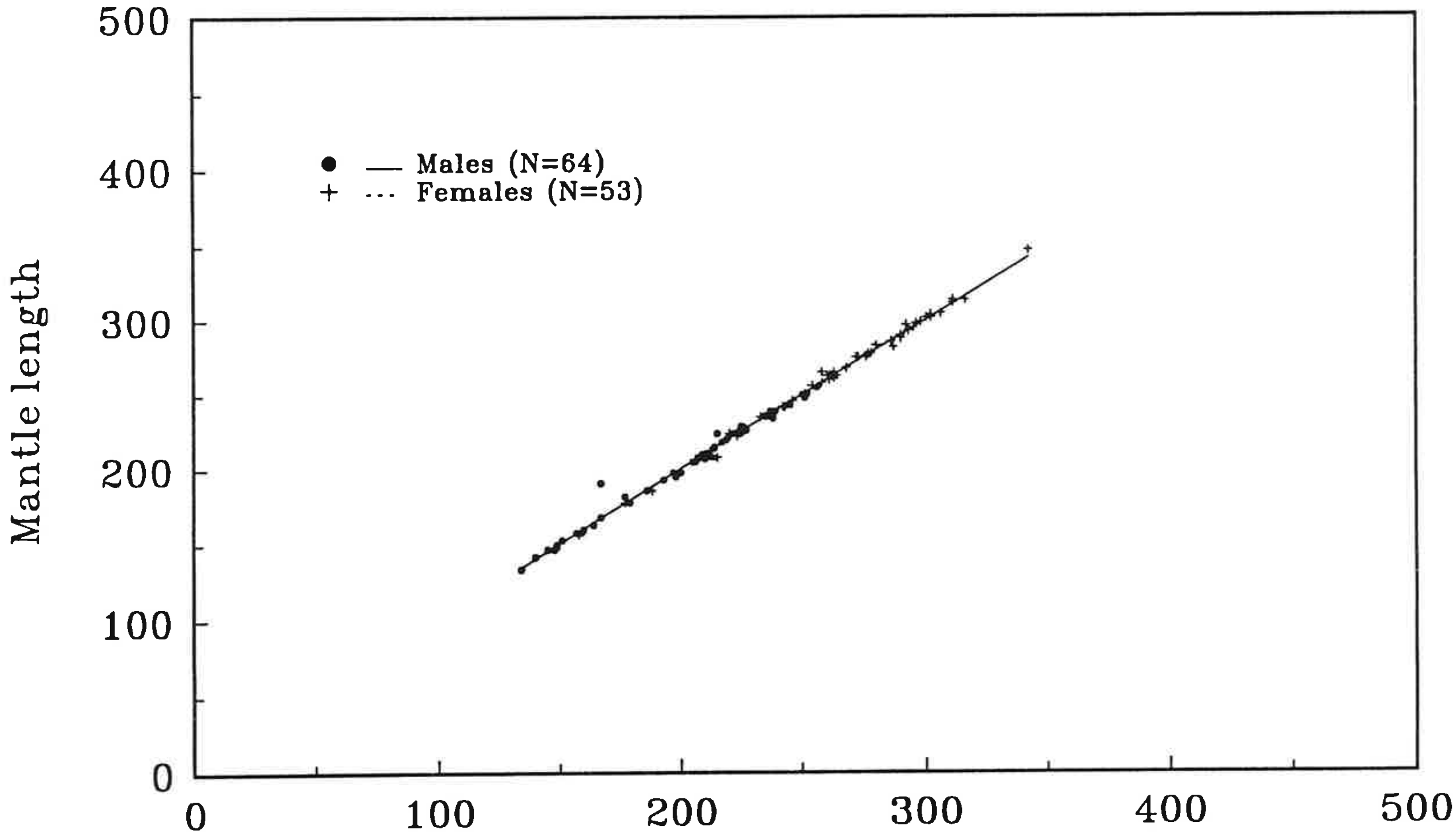

Figure 2.--Relationship of mantle length (mm) and gladius length (mm) of male and female *Onychoteuthis borealijaponica*.

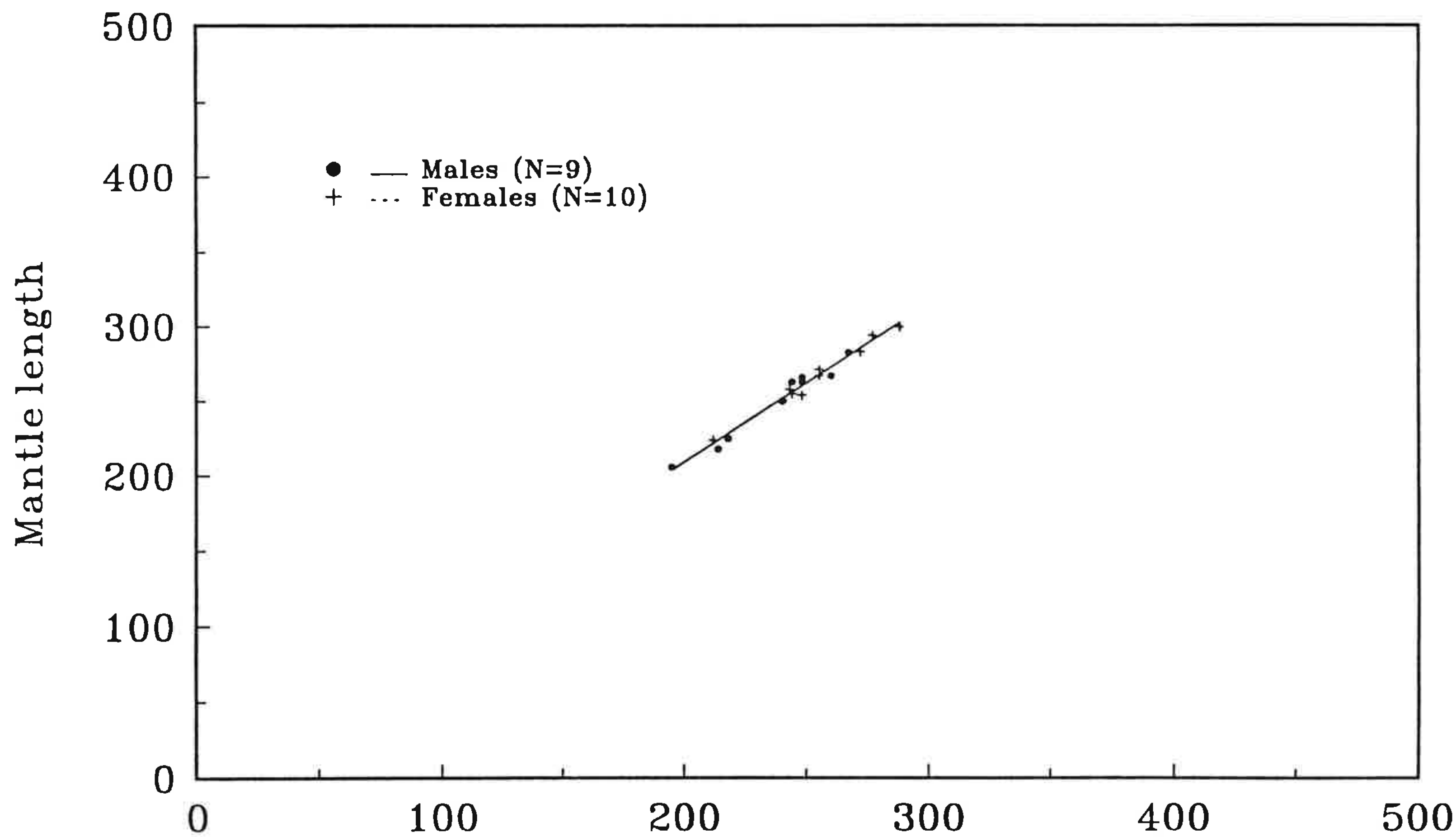

Figure 3.--Relationship of mantle length (mm) and gladius length (mm) of male and female *Gonatopsis borealis*.

Table 1.--Regression statistics for mantle length (mm) against gladius length (mm), ML = a + b GL, for O. bartrami, O. borealijaponica and G. borealis.

Species	Sample Size*	a	b	r^2
O. bartrami	172 (78, 94)	8.409	1.008	0.990
O. borealijaponica	117 (64, 53)	1.002	0.998	0.996
G. borealis	19 (9, 10)	-3.771	1.064	0.976

* Numbers in parentheses are male and female sample size, respectively

Table 2.--Regression statistics for mantle length (mm) against lower rostral length (mm), ML = a + b LRL, for O. bartrami, O. borealijaponica and G. borealis.

Species	Sample Size*	a	b	r^2
O. bartrami	183 (93, 90)	75.734	38.043	0.883
O. borealijaponica	119 (58, 61)	-70.584	61.082	0.824
G. borealis	18 (11, 7)	96.757	23.682	0.363

* Numbers in parentheses are male and female sample size, respectively

Table 3.--Regression statistics for log (weight = g) against log (lower rostral length = mm), log (w) = a + b log (LRL), for O. bartrami, O. borealijaponica and G. borealis.

Species	Sample Size*	a	b	r^2
O. bartrami	183 (93, 90)	2.034	2.577	0.914
O. borealijaponica	119 (57, 62)	-0.107	3.591	0.725
G. borealis	18 (11, 7)	3.503	1.428	0.225

* Numbers in parentheses are male and female sample size, respectively

borealijaponica, and G. borealis. The regressions were based on the combined data for males and females. The results indicate a very good fit and a near 1:1 relationship between mantle length and gladius length. It would appear that gladius length approximates mantle length in O. borealijaponica and might also be used for G. borealis size determinations. Samples of undamaged gladii from all species examined have been preserved and placed in the NMML reference collection.

Identifiable Hard Parts

Radulas are sometimes found in predator stomachs and can be used in the identification of prey.

The lower rostral length of squid beaks from predator stomachs has been used to calculate mantle length and weight of the specimen from which the beak came (Wolff 1984, Clarke 1986). We present here the lower rostral length of beaks from combined male and female samples of O. bartrami (Figs. 4 and 5), O. borealijaponica (Figs. 6 and 7), and G. borealis (Figs. 8 and 9) and their respective mantle lengths and weights for comparison with the beaks only calculations of Wolff (1984) and Clarke (1986).

The results of the regression of mantle length against lower rostral length are presented in Table 2. The sample size is small for G. borealis and the fit is rather poor. The fits for O. bartrami and O. borealijaponica are based on much larger sample sizes and give a correspondingly better fit.

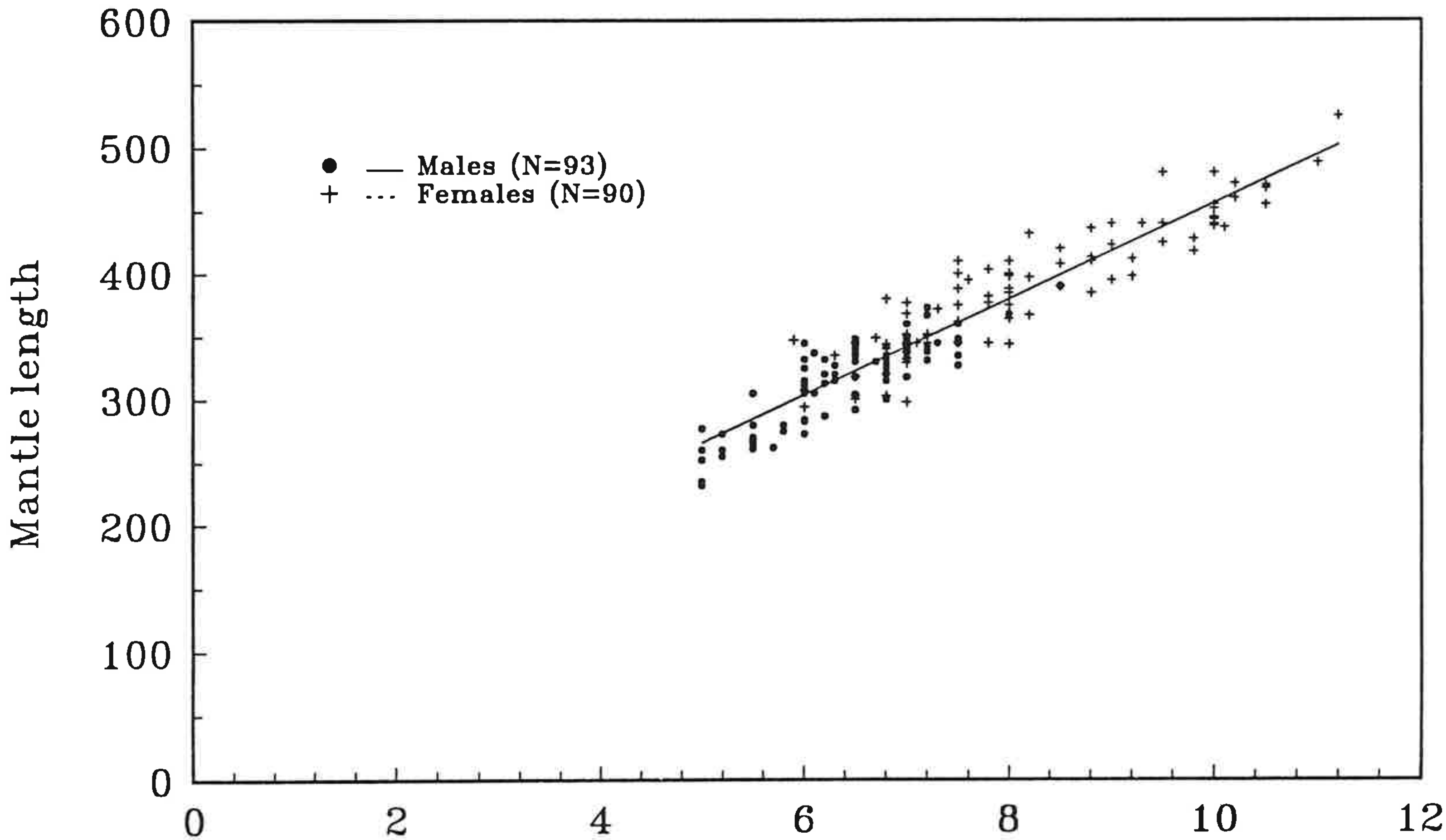

Figure 4.--Relationship of mantle length (mm) and lower rostral length (mm) of male and female *Ommastrephes bartrami*.

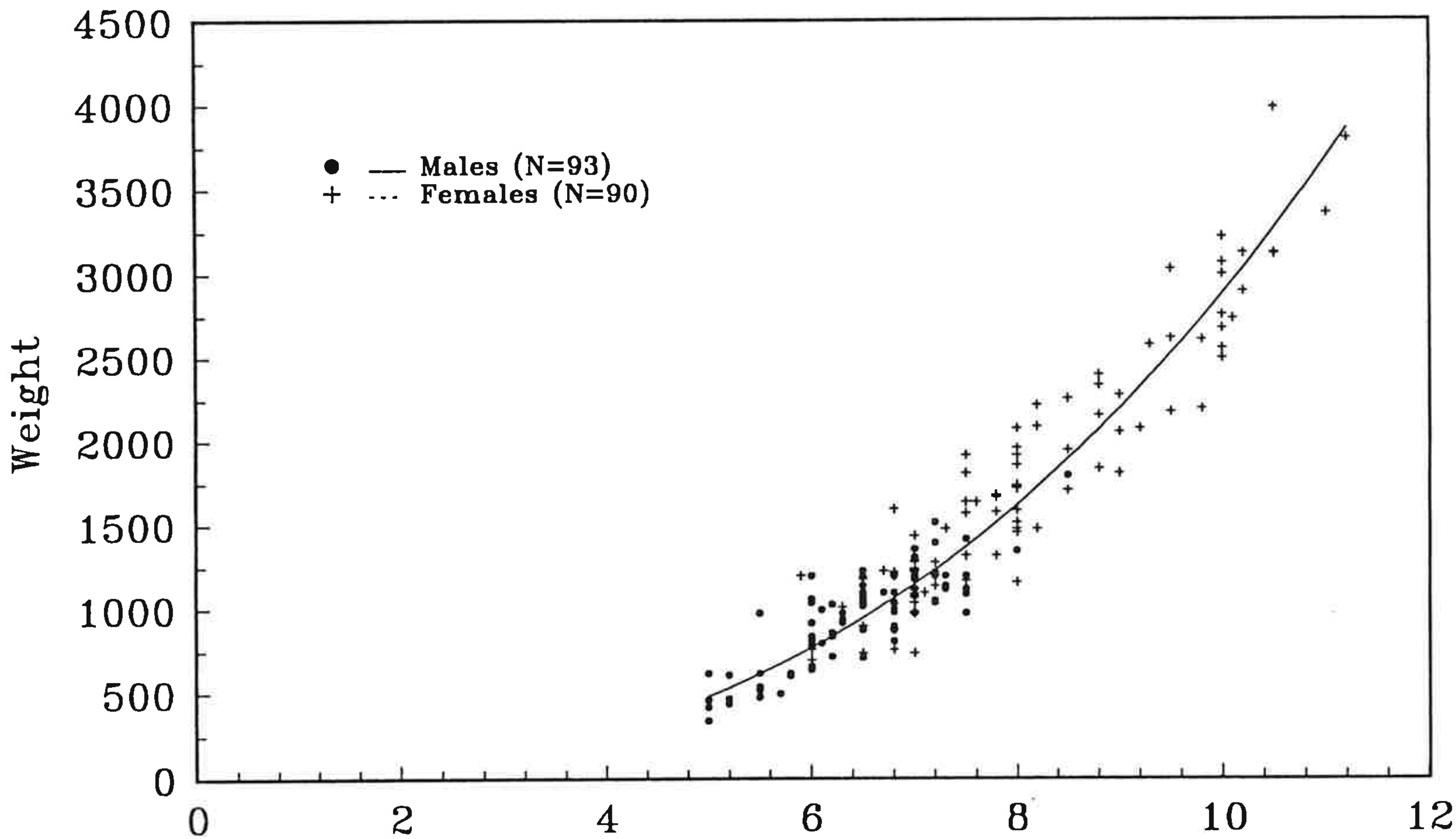

Figure 5.--Relationship of weight (g) and lower rostral length (mm) of male and female *Ommastrephes bartrami*.

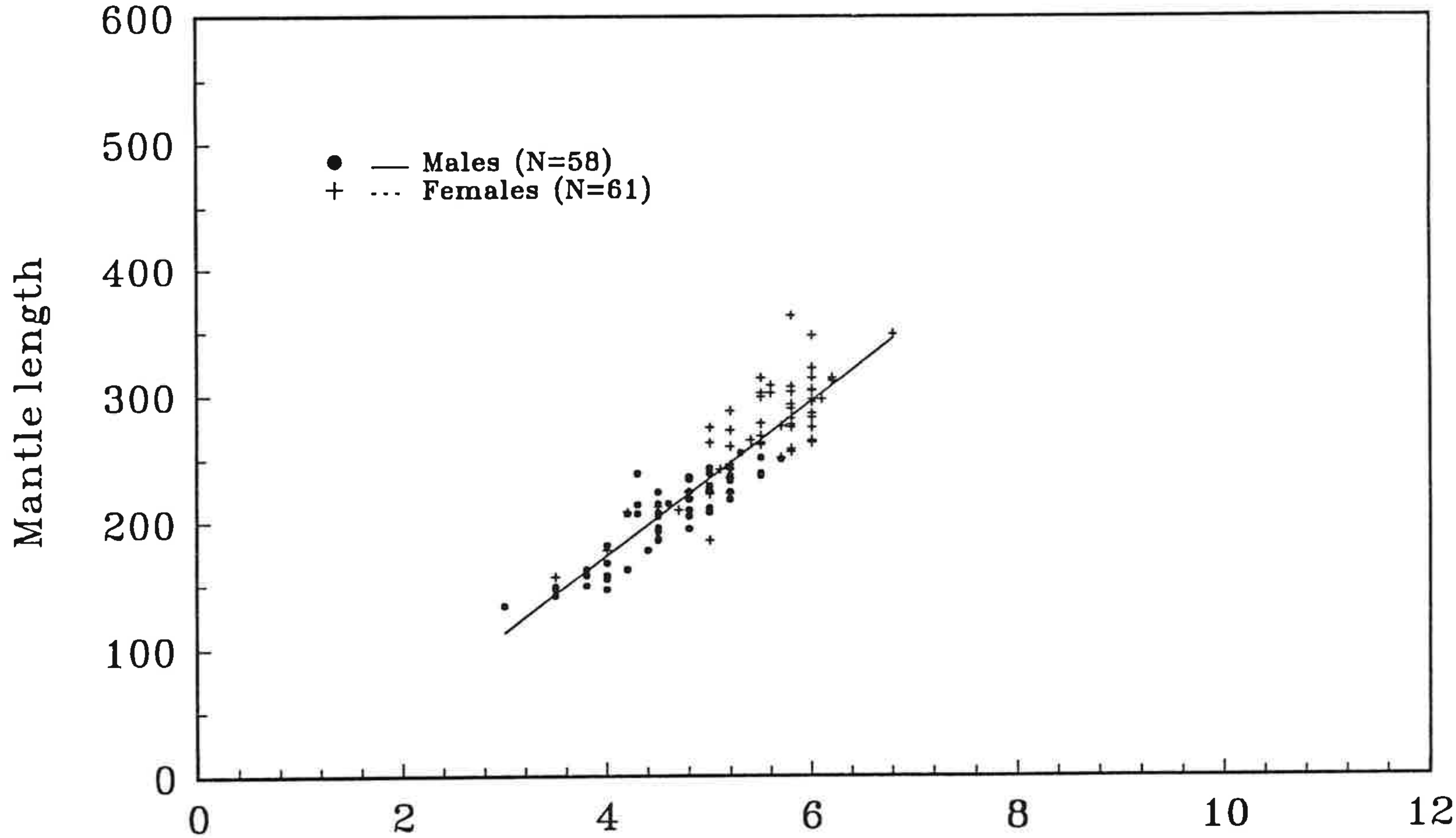

Figure 6.--Relationship of mantle length (mm) and lower rostral length (mm) of male and female Onychoteuthis borealijaponica.

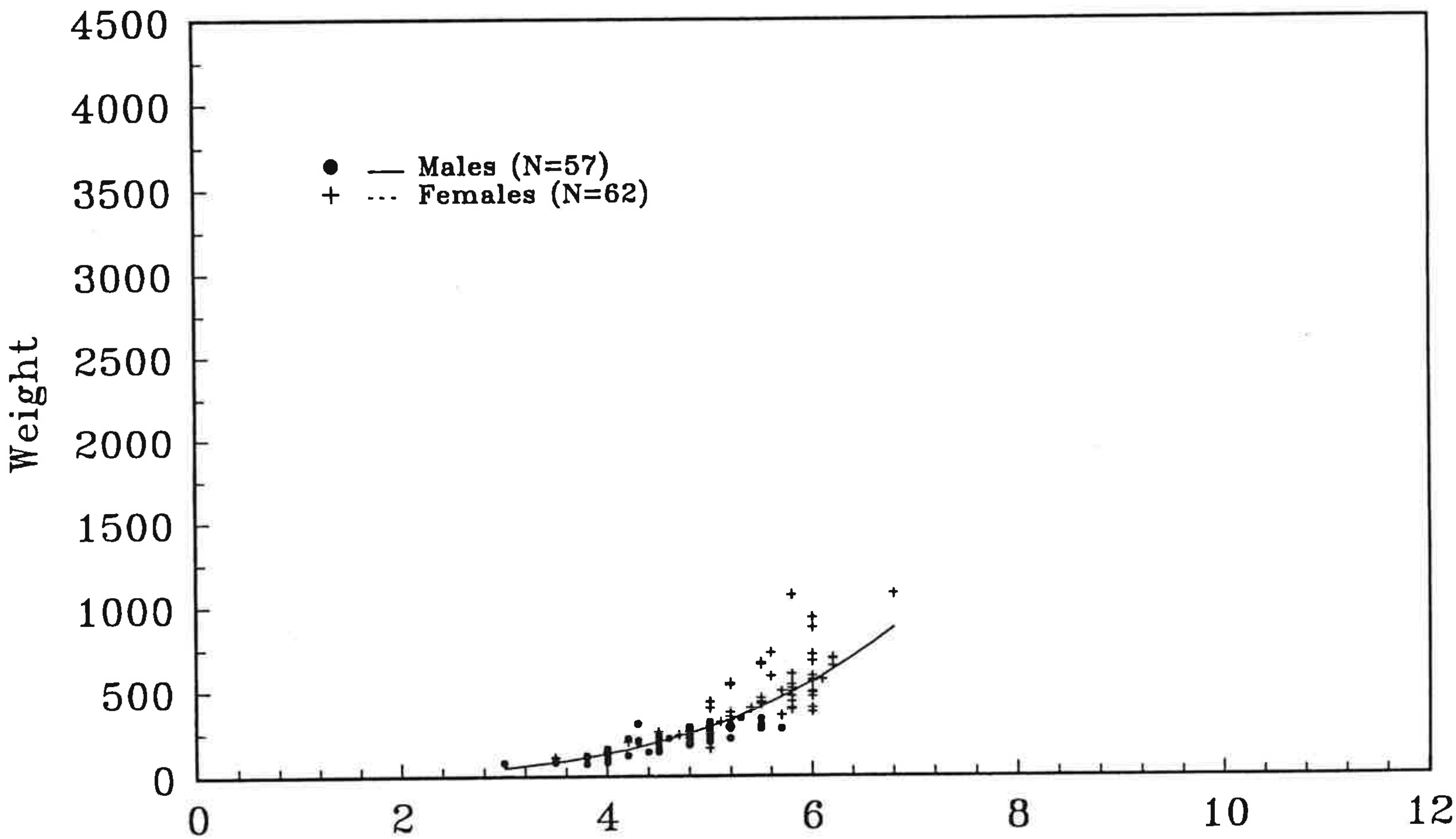

Figure 7.--Relationship of weight (g) and lower rostral length (mm) of male and female *Onychoteuthis borealijaponica*.

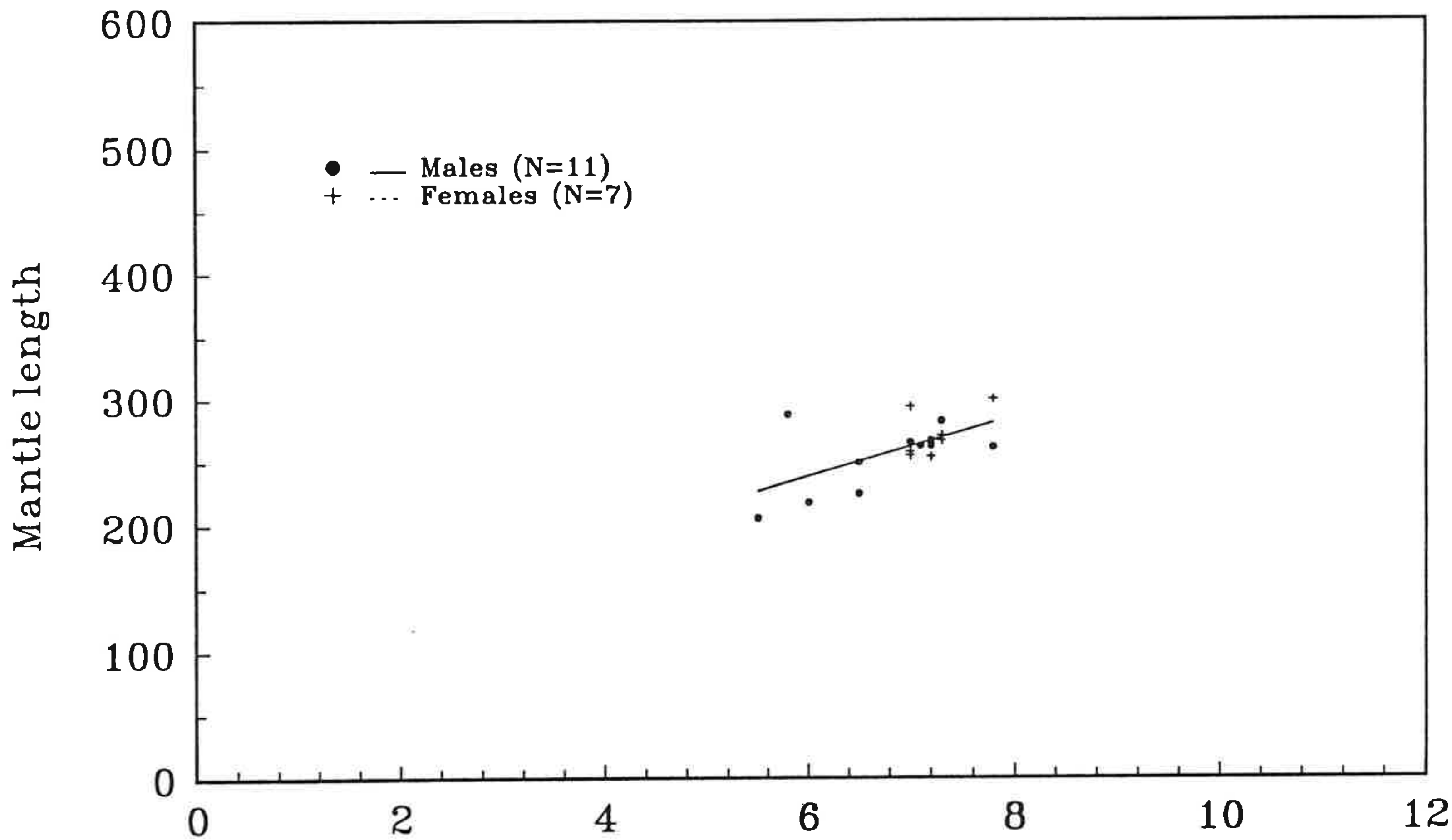

Figure 8.--Relationship of mantle length (mm) and lower rostral length (mm) of male and female <u>Gonatopsis</u> <u>borealis</u>.

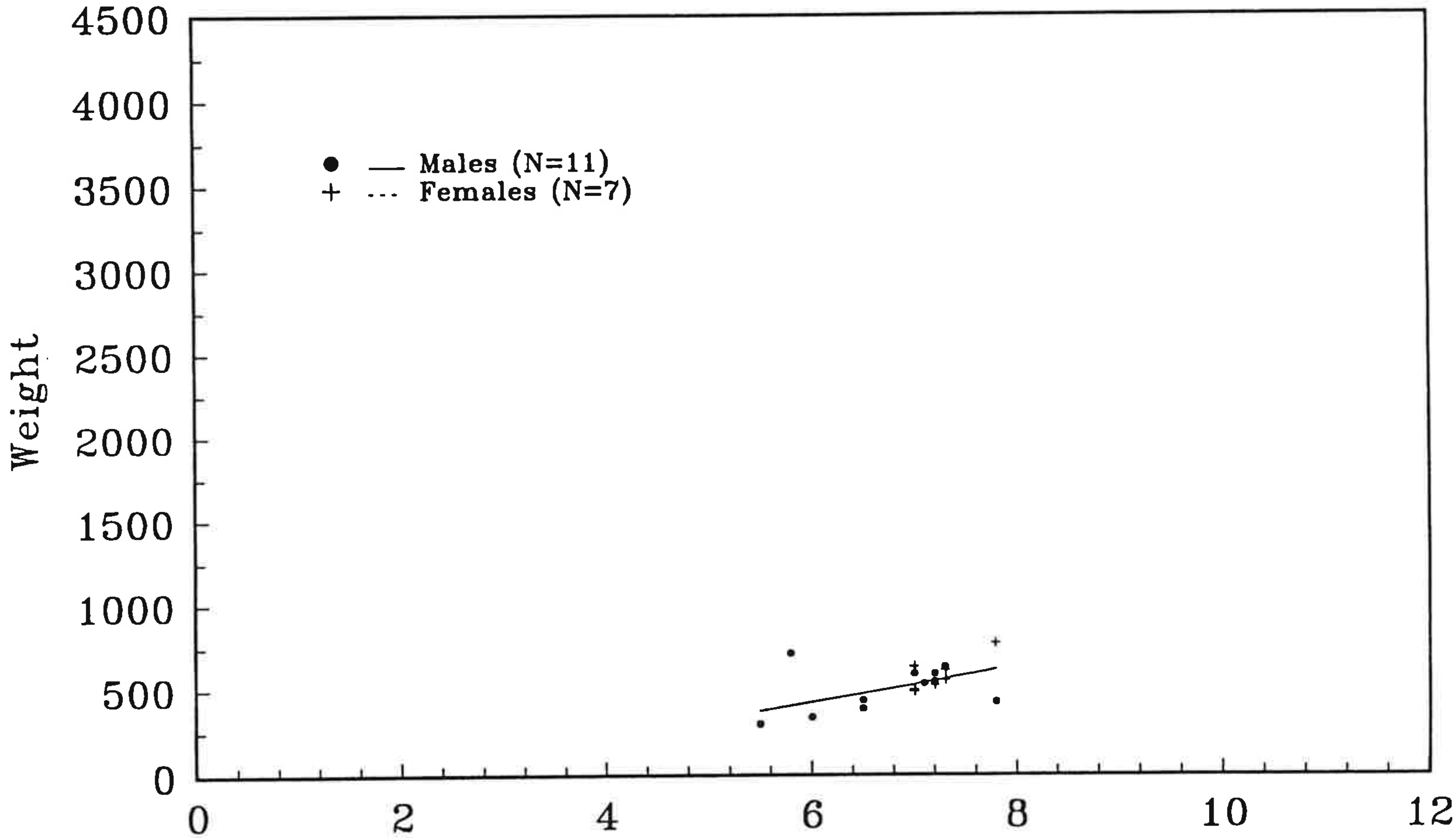

Figure 9.--Relationship of mantle weight (g) and lower rostral length (mm) of male and female Gonatopsis borealis.

The relationship between weight and lower rostral length is assumed to be a power curve which can be linearized by taking the logarithm of each length measurement. Results of the regression of log(weight) against log(rostral length) are given in Table 3. As in Table 2, the fit based on G. borealis is poor and the fits for O. bartrami and O. borealijaponica are much better. Despite the small sample size for G. borealis, all three regressions for this species were significant ($\alpha = 0.05$), as were those for the other two species.

Damage Caused By Jigs

During the examination of squid, damage resulting from jigging action was noted to beaks as well as to arms and tentacles. The damage to beaks from jigging does not affect the saleability of the squid as only the mantle, arms and tentacles are used. However, damage to beaks does indicate that squid are aggressively attacking the jig.

Of the 210 O. bartrami examined the beaks of 34 specimens were damaged (one or both beaks) from one-half or more of the beak missing to only beak tips torn off or cracked. In one instance the entire buccal mass was missing and in two others the buccal mass was torn loose but still attached to the squid; 28 specimens had one or more arms or one or both tentacles torn off.

Of 135 O. borealijaponica examined, there were 25 occurrences of one or both beaks damaged and six instances of tentacles or arms torn off. Of the 24 G. borealis examined, 12 specimens exhibited damage to one or both beaks.

Maturity

Gonad weights and nidamental gland lengths were obtained from most of the specimens examined except those saved for the reference collections.

Ommastrephes _bartrami_ (112 females and 98 males)

Females - There were no mature females. Three females were judged as approaching maturity; however, no eggs were seen. Nidamental gland lengths for these three females were 83, 86, and 88 mm. Their mantle lengths were 443, 525, and 470 mm and the weights were 2,680, 3,800, and 3,980 g, respectively. The remaining 109 females were judged immature. Their gonad weights ranged from 1.93 to 18.27 g, nidamental gland lengths ranged from 23.5 to 75.0 mm, mantle lengths ranged from 294 to 488 mm, and weights ranged from 700 to 3,560 g.

Males - The largest male was either mature or very nearly mature. Its mantle length was 373 mm, weight was 1,520 g, gonad weight was 37.9 g, and spermduct weight was 43.73 g. Twenty-five males were judged as approaching maturity. Their mantle lengths ranged from 324 to 368 mm, weights ranged from 1,040 to 1,400 g, and gonad weights ranged between 23.3 to 33.5 g. The spermducts of the 25 specimens contained spermatophores, but none to the degree of the mature _O_. _borealijaponica_ males. Seventy-three males were judged immature; their mantle length ranged from 232 to 360 mm, weights ranged from 340 to 1,260 g, and gonad weights ranged from 1.24 to 24.6 g.

<u>Onychoteuthis</u> <u>borealijaponica</u> (63 females and 72 males)

Females - There were no mature females. Five females were judged as approaching maturity (maturing). Their gonad weights ranged from 20.62 to 38.98 g. Nidamental gland lengths of females ranged from 90 to 111 mm, mantle lengths ranged from 302 to 363 mm, and weights ranged from 590 to 1,080 g. Ovaries from two of the largest maturing females contained eggs 0.5 mm in diameter. Fifty-eight females were classed as immature; their gonad weights ranged from 0.38 to 17.50 g, nidamental gland lengths ranged from 16.00 to 86.00 mm, mantle lengths ranged from 157 to 322 mm, and weights from 110 to 880 g.

Males - Eleven mature males had gonad weights ranging from 3.74 to 8.24 g; their spermducts were packed with spermatophores (weights of three spermducts were 8.05, 8.43, and 12.30 g). The mantle lengths of these males ranged from 207 to 251 mm and weights ranged from 200 to 340 g. Testes weights of mature males were significantly less than those of maturing males. Twenty-three males considered to be approaching maturity had gonad weights ranging from 11.30 to 23.06 g. There were a few spermatophores in the spermducts of all 23 males in this group. Their mantle lengths ranged from 140 to 255 mm and weights ranged from 200 to 340 g. Thirty-eight males that were considered immature had gonad weights ranging from 0.44 to 19.54 g, and mantle lengths from 137 to 276 mm and weights from 70 to 280 g.

<u>Gonatopsis</u> <u>borealis</u> (11 females and 13 males)

Females - There were no mature females. Two females were judged as approaching maturity (maturing) their gonads weighed

11.57 and 12.56 g; one gonad contained eggs less than 0.5 mm diameter and nidamental gland lengths were 75.0 and 72.0 mm, respectively. Mantle lengths were 283 and 300 mm and weights 750 and 780 g, respectively. For the nine females considered immature, gonad weights ranged from 1.29 to 6.17 g, nidamental gland lengths varied from 30.00 to 63.0 mm, mantle lengths ranged from 224 to 294 mm, and weights from 370 to 640 g.

Males - Two males judged as being very close to maturity, had mantle lengths of 288 and 318 mm and weights 720 and 860 g, respectively. Five males judged as approaching maturity (maturing) had gonad weights ranging from 1.16 to 2.29 g. The spermducts of these five males contained some spermatophores. Their mantle lengths ranged from 263 to 283 mm and weights ranged between 540 to 640 g, respectively. Six males were judged immature; their mantle lengths ranged from 206 to 262 mm, and their weights ranged from 300 to 500 g. The gonad weight of one specimen was 1.0 g.

Moroteuthis robusta (7 females and 2 males)

Females - There were no mature females. One female judged as maturing had a mantle length of 1,080 mm, weighed 13,140 g, its nidamental gland length was 222 mm, and its gonad weighed 72.05 g. Six females were judged immature; their mantle lengths ranged from 440 to 810 mm and weights ranged from 720 to 6,080 g. Nidamental gland lengths ranged from 28.0 to 120.0 mm.

Males - There were no mature males. Two males were judged as immature: their mantle lengths were 438 and 624 mm and weighed 410 and 3,780 g, respectively. Table 4 gives catch and

Table 4.--*Moroteuthis robusta* catch and biological data for each specimen.

Vessel	Haul no.	Date	Depth: Gear m	Depth: Bottom m	Surface water temp °C	Sex	Mantle length mm	Body weight g	Maturity*	Nidamental gland mm	LRL** mm
37	25	8/24	90	2,000	17.1	F	478	1,460	1	63.0	6.8
37	25	8/24	90	2,000	17.1	F	810	6,080	1	120.0	9.0
37	25	8/24	90	2,000	17.1	F	1,080	13,140	2	222.0	11.5
37	32	8/31	90	2,000	18.8	M	624	3,780	1		8.0
37	33	9/01	90	2,000	19.0	F	378	760	1	43.0	5.8
58	17	8/17	100	3,035	15.2	F	490	720	1	59.0	6.5
63	32	9/01	100	2,851	18.8	M	438	410	1		6.5
68	12	8/12	55	3,000	18.0	F	440	1,300	1	46.0	5.2
68	30	8/30	125	2,890	19.1	F	470	1,320	1	28.0	7.0

*1= immature; 2= maturing
**Beak-lower rostral length.

biological data for this species.

Loligo opalescens (2 females, 2 males, and 2 of undetermined sex).

All *Loligo* were taken in Oregon shelf waters on jigs at 60 m depth where bottom depths ranged from 95 to 175 m.

Females - Eggs were not visible in the ovary. Their mantle lengths were 96 and 123 mm and weights 40 and 140 g, respectively.

Males - Both males were considered to be nearly mature as spermatophores were found in spermducts of each (spermatophores were found in the penis of one). Mantle lengths for these two animals were 108 and 127 mm and weights were 50 and 60 g, respectively.

Gonatus sp. (1 male)

One male specimen in poor condition (mantle length 123 mm, weight 33 g) was among the samples collected.

DISCUSSION

We do not consider our samples to be representative of the entire catch as reported by June and Wilkins (1991) since we had requested specific numbers of each species by sex from selected locations. See Figure 1 in June and Wilkins (1991) for all stations completed during the 1990 squid survey. Stations from which we received samples are indicated in Figures 10-13.

Additional information on cephalopods off Washington and Oregon from NMML files and from published reports is presented in Appendix A. In Appendix B, we discuss the impact of El Niño

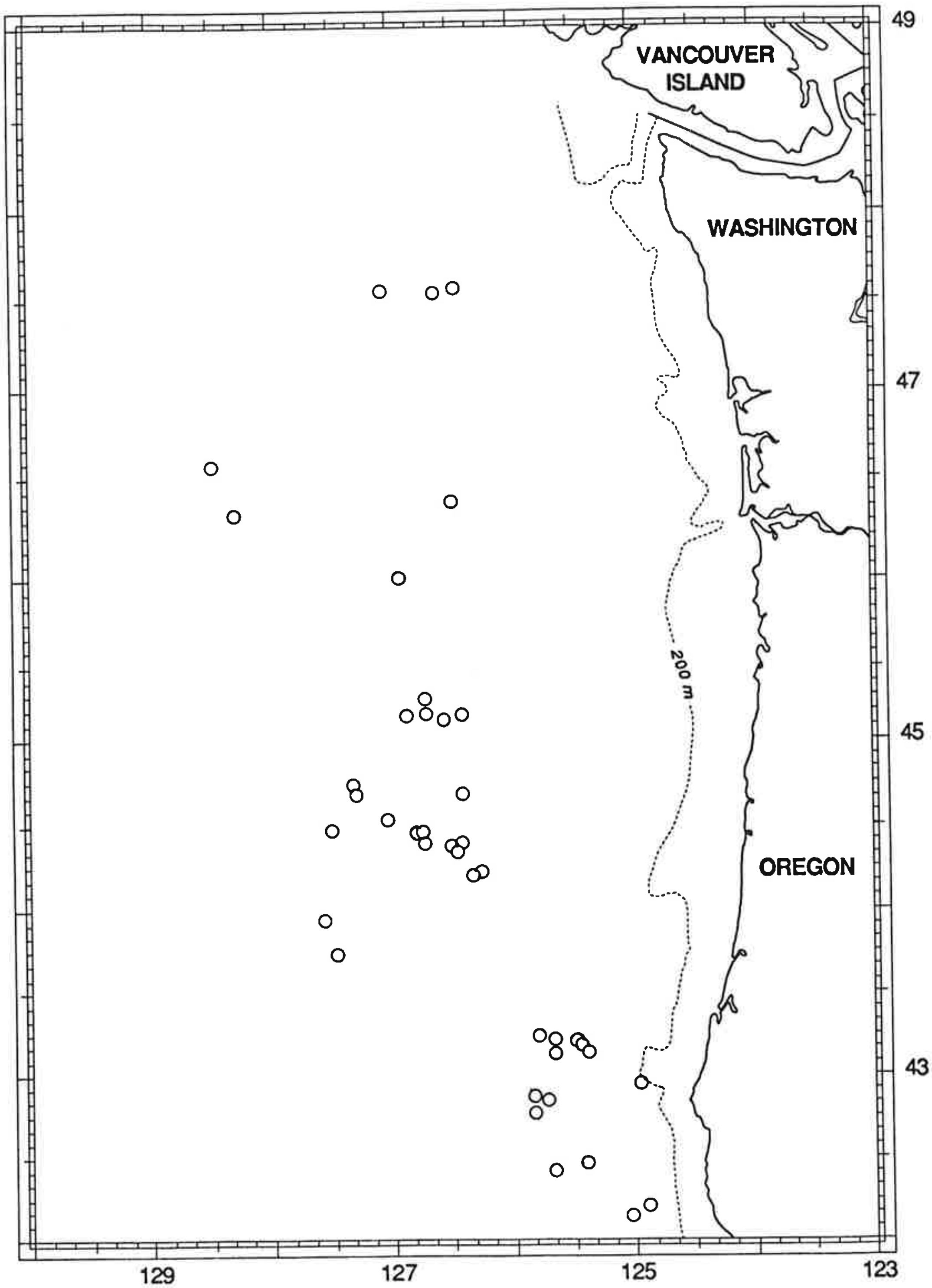

Figure 10.--Locations of Ommastrephes bartrami samples examined, taken off Oregon and Washington, 1 August - 4 September 1990.

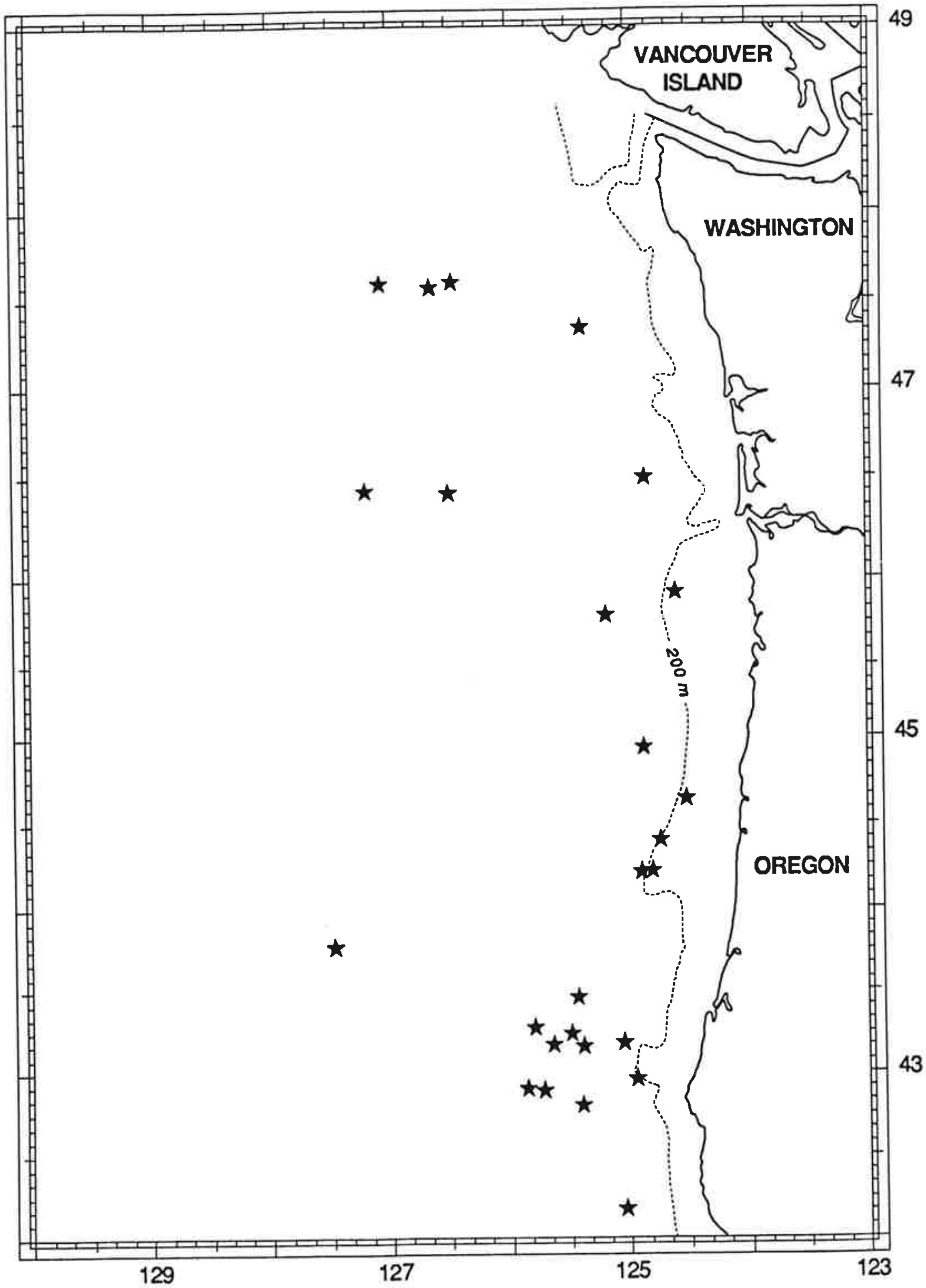

Figure 11.--Locations of Onychoteuthis borealijaponica samples examined, taken off Oregon and Washington, 1 August - 4 September 1990.

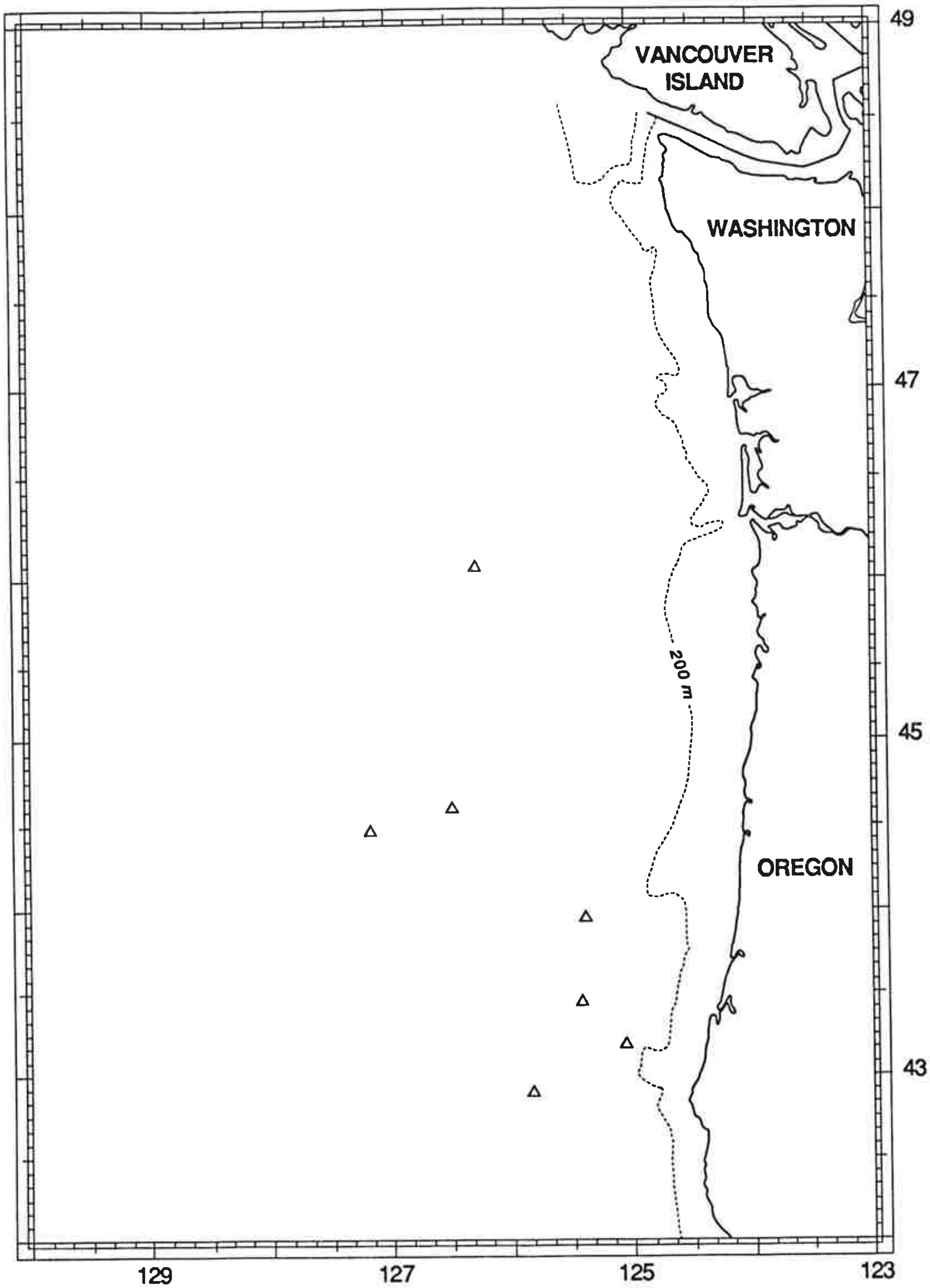

Figure 12.--Locations of Gonatopsis borealis samples examined, taken off Oregon and Washington, 1 August - 4 September 1990.

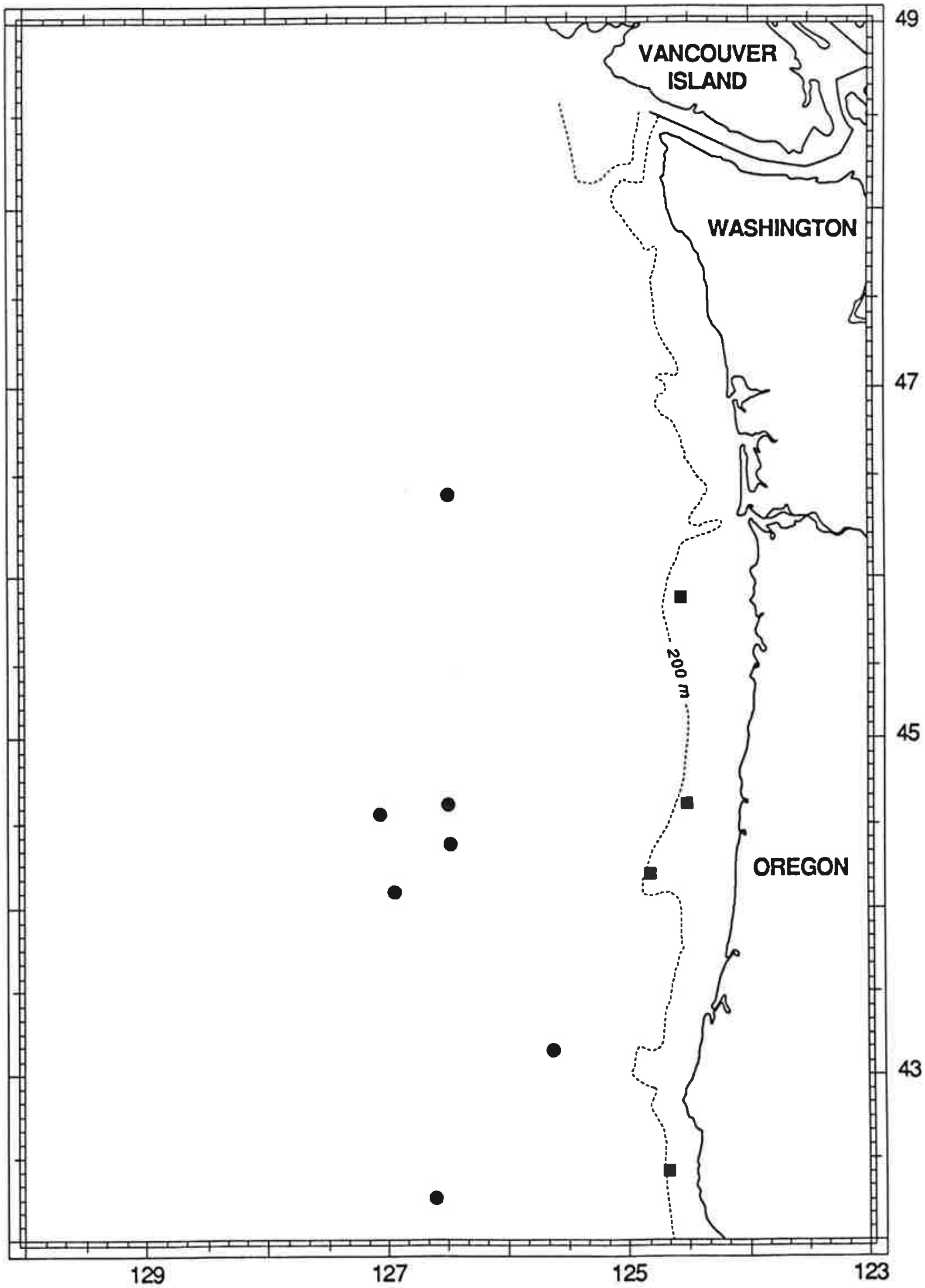

Figure 13.--Locations of Moroteuthis robusta (●) and Loligo opalescens (■) samples examined, taken off Oregon and Washington, 1 August - 4 September 1990.

events on the distribution patterns of _O. bartrami_ and _L. opalescens_.

The gladius is frequently encountered in marine mammal stomachs and can be used for squid identification to family and in some instances to genus. A useful reference for the gladius of squids is Toll (1982). The gladius approximates mantle length in some species so it can be substituted for mantle length where mantle length cannot be measured.

Cephalopod beaks and chitinous sucker rings and hooks persist in predator stomachs long after soft body parts are digested and are often distinctive of a particular species. Beaks and radulas are an important tool in the identification of prey from stomachs and scats (Clarke 1986).

Sex of the squid cannot be determined from beaks alone, although size of beak (lower rostral length) and degree of wing darkening may in some instances be indicative of a possibility of its coming from a male or female. Our relatively large sample size of these three species might be useful to complement Wolff's (1984) and Clarke's (1985) estimates of the length and weight of these species from lower rostral length measurements.

In all instances, using the formulae of Wolff and Clarke to calculate length and weight of squids from our lower rostral length measurements resulted in underestimating the actual size. These differences might be attributed to the sample size and size of specimens that Wolff and Clarke used to arrive at their formulae. Wolff measured 20 beaks each of _O. bartrami_ and _O. banksii_ to arrive at his formulae. Clarke cites Wolff for

O. bartrami and uses Wolff's O. banksii formulae for O. borealijaponica. Clarke measured 15 G. borealis to arrive at his formulae for this species. The specimens Wolff measured and weighed (Figs. 43 and 52, O. bartrami; and Figs. 41 and 50, O. banksii) are much smaller than our specimens, and as plots indicate, so were Clarke's G. borealis. Growth rates in younger squids may be quite different than those of maturing squids. There is also a possibility that their samples came from different subpopulations with different growth rates than the Oregon and Washington samples we examined.

Ommastrephes bartrami

The specimens we examined were taken off the Oregon and Washington coasts from 1 August through 4 September 1990. June and Wilkins (1991) report that during this survey, O. bartrami were taken when surface water tempertures were greater than 12° C. Catch records for O. bartrami in the waters off Oregon northward indicate that most catches were made in waters beyond the continental shelf with surface temperatures ranging from 12.3° to 24.2° C.

The following surface temperature ranges were obtained from Bernard (1980 and 1981), Robinson and Jamieson (1984), Sloan (1984), Jamieson and Heritage (1987 and 1988), Mercer and Bucy (1983), June and Wilkins (1991), and Shaw and Jamieson (1990):

Oregon (lat. 42°-46°N.)	Surface water temperature
June	12.3° to 15.0° C.
July	14.1° to 14.8° C.
August	13.2° to 24.2° C.

Washington (lat. 46°-48°N.)

June	12.4° to 14.6° C.
July	12.9° to 15.8° C.
August	14.2° to 18.9° C.
September	14.2° to 15.9° C.

Vancouver Island, B.C. (lat. 48°-51°N.)

July	12.8° to 15.7° C.
August	13.8° to 16.4° C.
September	13.2° to 16.9° C.
October	15.2° to 16.5° C.

Vancouver Is. to Queen Charlotte Is. (Lat. 51°-54°N)

August	14.4° to 16.6° C.
September	14.4° to 16.8° C.

Sinclair (1991) provides a excellent review of O. bartrami including the distribution as related to sea surface temperatures elsewhere in the North Pacific Ocean.

The effect of warm surface waters during El Niño years most certainly contributes to the northerly distribution of this species. Our literature search failed to locate any records of catches of larval forms of O. bartrami off Oregon and northward into British Columbia waters where this species is caught in summer and autumn as maturing squid.

Murata (1990) discusses the seasonal distribution pattern of this species in the northwest Pacific. There is a northward movement in the spring of larval and young squid, and a southward movement in autumn and winter of maturing squid. Bernard (1981, Fig.1) suggests that the eastern North Pacific population exhibits a northward offshelf movement of young rapidly growing squid into autumn, then an offshore and southerly movement of the maturing squids in late autumn and early winter. The discovery of paralarvae in Hawaiian waters in winter and spring supports this migratory pattern (Young and Hirota 1990). Bigelow and Landgraf (1991) estimated a hatch date in January 1991 from a paralarvae sample collected in March-April along the Hawaiian Archipelago.

Murata (1990) provides an excellent summary of the seasonal movements of O. bartrami and its growth rates. He mentions four different size groups in the North Pacific population and cited several papers indicating a life span of 1 year for two of the groups and possibly 1.5 years for two of the groups.

Nakamura (1988) reports the size of mature O. bartrami caught during the spawning season in April-May off the Izu-Ogasawara Islands (western Pacific). He indicates that the mantle lengths of mature males ranged from 29 to 39 cm and that females mantle lengths varied from 40 to 46 cm.

In the survey of June and Wilkins (1991), 2,539 O. bartrami were measured with a mean overall mantle length of 40.4 cm and an average weight of 2.21 kg. They observed a bimodal length frequency distribution for both sexes, with the males peaking at 270 and 350 mm and the females at 380 and 460 mm mantle lengths.

Kubodera et al. (1983) also observed two size groups of O. bartrami in their study; one group of males and females restricted to subtropical waters and one group of large females that migrate northward. They state that most females and all males mature at about 1 year of age and spawn in winter and spring in southern subtropical waters.

Our samples were mostly immature specimens. We judged three females to be maturing; they were within the size limits for mature females as reported by Nakamura (1988) for a western Pacific Ocean population. Among the males, 1 was very close to maturity and 25 others were approaching maturity; these specimens all were within the size limits for mature males as reported by Nakamura (1988).

The population sampled off Oregon and Washington in August may, however, represent a population of larger-sized animals than that sampled by Nakamura (1988) in the western Pacific. If the population off Oregon and Washington in August is the same as that sampled off Hawaii in winter and spring, then our samples were still about 3 months from spawning stage. Stations from which we received samples are shown in Figure 2.

June and Wilkins (1991, p. 99) illustrate length-weight relationships of the specimens measured and weighed in the field.

Onychoteuthis borealijaponica

Jefferts (1983) as well as Okutani and Murata (1983), provide an excellent review of the range and the biological information on this species. Bernard (1980) reports the capture of a few large individuals at the weather ship (Station P; lat. 50·N., long. 145·W.) 500 miles west of Vancouver Island in winter of 1979. Bernard also provides information on *O. borealijaponica* in British Columbia waters, and reports on small numbers being taken by jigging gear in September and October 1979. Sloan (1984) reported poor catches of *O. borealijaponica* by jigging at four stations off Vancouver Island in July 1983. Kubodera et al. (1983) reported small catches of O. borealijaponica from surface gillnets in the Gulf of Alaska in July 1981 in surface water temperatures of 12·-13· C. Kubodera et al. (1983) also reported on O. borealijaponica from the northwestern Pacific indicating that sexes were found in nearly equal numbers in the July and August catches. Most females measured 19-32 cm dorsal mantle length (DML) and males measured 18-25 cm DML. The largest female measured 35.5 cm and the largest male measured 34.5 cm DML. Kubodera et al. (1983) also reported a decrease of testis weight in larger males as spermatophores are stored in the spermduct as we found in the 11 mature male O. borealijaponica sample.

Mercer and Bucy (1983) report catching two or more size (age) groups during their May to September sampling period off Washington in 1981. They report a gradual increase in body size (about 2 cm per month) into September, with spermatophores beginning to develop in late July. Their largest female taken 13 September measured 294 mm DML with a nidamental gland length of 103 mm. We listed our five largest females as maturing; they measured 302 and 363 mm DML with nidamental gland lengths of 90-111 mm. June and Wilkins (1991) present length-weight relationships of specimens measured in the field.

Mercer and Bucy (1983) suggest a spawning period from early to midwinter for their July-August samples which agrees with Bernards (1980) winter records of large specimens from Ocean Station P.

During the 1 August-4 September sampling period only four samples of O. borealijaponica were taken over shelf waters off Oregon and none off Washington. Off Oregon, we received samples from 20 stations fishing depths that ranged from 50-130 m over bottom depths of 95-3,200 m and where surface water temperatures ranged from 10.2° to 18.9° C. Off Washington at 7 stations, fishing depth ranged from 60 to 110 m over bottom depths of 310-2,673 m where surface water temperatures ranged from 16.0° to 18.2° C.

The locations where our samples of O. borealijaponica were caught are shown in Figure 11. Mercer and Bucy (1983) discussing their jigging catches reported monthly surface water temperatures as follows: May, 8.9°-10.0° C; June, 13.6°-15.5° C; July, 14.8°-16.8° C; August, 13.5°-15.7° C; and September, 14.3° C.

Gonatopsis borealis

Jefferts (1985) summarizes the range of this species in North Pacific waters. Okutani et al. (1988) provide additional information on its seasonal distribution, abundance, and maturity. Kubodera et al. (1983) report on the catch of this species in surface gillnets, mostly west of long. 175° W. from 1977 to 1981 and include data on six Gulf of Alaska sets in 1980 and nine sets in 1981. G. borealis was taken in four of the six sets in 1980 and six of the nine sets in 1981, with surface water temperatures of 11°-12° C. in 1980 and 12°-13° C. in 1981. They state that catches were relatively low in the Gulf of Alaska compared to those of western subarctic Pacific waters. There were no G. borealis listed as caught during Canadian experimental gillnet fisheries between 1979 and 1987 off the coasts of Oregon, Washington, or British Columbia (Bernard 1980, 1981; Robinson and Jamison 1984; Sloan 1984; Jamison and Heritage 1987, 1988).

During the present study, we examined 11 female and 13 male G. borealis. June and Wilkins (1991) report a total catch of 117 of this species, of which 57 were sexed; males comprised 53% and females 47% of the sample. The authors also provide length-weight relationships of specimens measured in the field.

Our samples were all taken from 8 sets in off-shelf Oregon waters (Fig. 12). Gear depth ranged from 50 to 130 m over bottom depths of 2,000-3,000 m and surface water temperatures of 15.4°-19.0° C.

Kubodera et al. (1983) mention an observed vertical stratification of O. bartrami, O. borealijaponica, and G. borealis related to water temperatures. O. bartrami was taken in surface water gillnets, O. borealijaponica by jigging at 50 m, and G. borealis by jigging below 50 m. Unfortunately none of our samples of G. borealis were taken by the vessel that was able to record the temperature at the depths jigs were fished.

Kubodera et al. (1983) report two distinct size (age) groups in summer from the northwestern Pacific. The range of the small size groups was 11-18 cm DML peaking at about 15 cm in females and 14 cm in males. The large group which appeared mainly in July ranged from 20 to 27 cm in females and from 20 to 25 cm in males. Of our samples taken in August, females and males ranged in size from 224 to 300 mm for females and 206 to 283 mm for males, somewhat larger than their Kubodera et al's. size group from the western Pacific which were taken in July. Our sample is too small to determine if two size groups were present in the catch.

Moroteuthis robusta

Jefferts (1983) describes the range of this species. She examined 35 specimens taken in demersal hauls which ranged in mantle length from 327 to 1,360 mm. Her specimens were all taken from shelf waters at depths of 200-500 m. Pattie (1968) describes five trawl-caught specimens taken off Washington-British Columbia which measured from 860 to 1,290 mm mantle length. Kubodera et al. (1983) report 17 squids taken in surface gillnets in offshelf waters, all from the western Pacific except 1 from the Gulf of Alaska. Six of the 17 examined specimens were immature females with mantle lengths of 90-120 cm. Okutani (1983) describes a new species Moroteuthis pacifica (which is now considered a juvenile stage of M. robusta). His four specimens that were taken from offshelf surface waters measured for males 159.9 mm and 89.7 mm, for females 106.4 mm, and for unsexed 90.3 mm. Our specimens were all taken on jigs fished at 55-125 m depth from offshelf waters. Mantle lengths of males ranged from 438 to 624 mm; females ranged from 440 to 1,080 mm in mantle length, weights of males ranged from 410 to 3,780 g and females ranged from 720 to 13,140 g. See also length-weight relationship figures (p 101) in June and Wilkins (1991). The locations where our samples of M. robusta were caught are shown in Figure 13.

It would appear that as this species approaches maturity (i.e., adulthood), it becomes a bottom or near-bottom dwelling species in shelf and slope waters. This is corroborated by stomach content records of deep diving cetaceans and from bottom trawl records.

Loligo opalescens

Maupin (1989)reports the spawning peak for this species off Oregon as spring and early summer, off northern Washington in mid- to late summer, and in Puget Sound, Washington, from December through February. Bernard (1980) reports two major spawning periods off British Columbia. A winter spawning in the Strait of Georgia and Queen Charlotte Strait and summer spawning near Victoria and off the west coast of Vancouver Island. Maupin (1989) reports spawning in Southeastern Alaskan waters from March to May. See Wing and Mercer (1990) for additional information on British Columbia and Southeastern Alaskan spawning records.

Wing and Mercer (1990) report new Alaskan records and a range extension northward in southeastern Alaska to Yakobi Island (lat. 58° N.) with egg capsules collected in Rowan Bay (lat. 56° N.). For information on the range and life history of this species in the northeastern Pacific see Maupin (1989), Jefferts (1983), Bernard (1980), and Wolotira et al. (1990).

The locations where L. opalescens were caught off Oregon and Washington are shown in Figure 13.

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Appendix A

Supplementary information on squid species reported from Oregon and Washington.

This section summarizes squid occurrence information that may be useful to biologists or fishermen regarding presence of squids of possible commercial importance off Oregon and Washington during other months of the year in Appendix Tables A-1 and A-2.

Table A-1.--Cephalopods reported from stomachs of marine mammals and other sources off Oregon.

Month	*Ommastrephes bartrami*	*Onychoteuthis borealijaponica*	*Gonatopsis borealis*	*Berryteuthis magister*	*Gonatus* spp.	*Loligo opalescens*
January		1				1
April		1		1	1	1
June	2,3					
July	2					

1 Kajimura (1984); 2 Jamieson and Heritage (1987); 3 Jamieson and Heritage (1988).

Table A-2.--Cephalopods reported from stomachs of marine mammals and other sources off Washington.

Month	Ommastrephes bartrami	Onychoteuthis borealijaponicus	Gonatopsis borealis	Berryteuthis magister	Gonatus spp.	Loligo opalescens
January		1,2		1	1,2	1
February		1,2		1	1,2	1,2
March		1,	1	1	1	1
April		1,2	1	1	1,2	1
May		1,6	1	1	1	1
June		1,6	1			1
July	3,4,5	6				
August	3,4	6				
December					1	1

1 Kajimura (1984); 2 Kajimura et al. (1980); 3 Bernard (1981); 4 Robinson and Jamieson (1984); 5 Jamieson and Heritage (1987); 6 Mercer and Bucy (1986).

Appendix B

El Niños and squids

The occurrence of El Niños along the coast of western North America is the subject of numerous papers and books. Reports on the effect of El Niños on cephalopods, particularly from Oregon waters northward, are scant.

In this section, we attempt to gather scattered references relating to cephalopods and El Niños that might be useful to fishermen and biologists. Certainly much remains to be done and other references relevant to this subject may be available but not read by us.

It would appear that the northward range of two species (*Ommastrephes bartrami* and *Loligo opalescens*) taken during the August 1990 study off Oregon and Washington is extended north during El Niño events.

Major El Niño events occurred off the west coast of North America in 1940-41, 1957-58, and 1982-83 (Cannon et al. 1985). During the 1958-59 El Niño, warm water reduced the zooplankton level off California but in the Gulf of Alaska, warmer water produced a high level of zooplankton (Bailey and Incze 1985). During the 1982-83 El Niño event, Pearcy et al. (1985) reported the resulting warm ocean currents and reduced upwelling of nutrient-rich cool water from this event affected production and availability of prey in coastal waters off California, Oregon, and Washington.

Ommastrephes bartrami. Robinson and Jamieson (1984) state that during warm water (El Niño) years, *O. bartrami* are present north to the Queen Charlotte Islands based on 19 July to 29 August gill net catches. Karinen et al. (1985) reported anomalously warm surface waters offshore and in inside waters of Southeastern Alaska in 1983 and the first records of O. bartrami caught off Forrester Island (lat. 54° 45' N.) by jigging.

Loligo opalescens. Pearcy et al. (1985), in discussing the effects of the 1983 El Niño on coastal nekton off Oregon and Washington waters, reported that L. opalescens ranked first in abundance in June purse seine catches off Oregon in 1979-1982 but dropped to sixth in 1983 and fifth in 1984.

Figure 1 in Schoener and Fluharty (1985) shows that L. opalescens increased in abundance off Washington during El Niño years. In regard to L. opalescens, they reported that "catches are large during or shortly following El Niños while in other years the fishery is small or non-existent." They found among the several fauna studied that only squid (Loligo) showed an apparent relationship to El Niños.

Karinen et al. (1985) report records of fish and invertebrates in the eastern Gulf of Alaska during the 1983 El Niño and describe the formation of the Sitka Eddy, which moves in a northwesterly direction across the Gulf of Alaska. Wing and Mercer (1990) have summarized records of occurrence of L. opalescens in Alaskan waters.

During the course of Fur Seal Investigations by the United States and Canada, scientists have identified L. opalescens from the stomachs of northern fur seals (Callorhinus ursinus) that were caught in the Gulf of Alaska in April 1958 by the United States and during June 1962 by Canada (Appendix Table B-1).

Table B-1.--Loligo opalescens identified from stomachs of northern fur seals (Callorhinus ursinus) taken in the Gulf of Alaska.

Seal no.	Date collected	Location latitude	Location longitude	No. in stomach	Stomach volume cc
739	04-23-58	58°07'N.	139°43'W	6	396
742	04-24-58	57°21'N.	139°40'W.	59	1080
2281*	11-06-62	57°51'N.	143°15'W.	-	1185
2287*	11-06-62	58°00'N.	144°05'W.	-	685
2292*	11-06-62	58°02'N.	144°30'W.	-	35
2300*	11-06-62	58°04'N.	144°55'W.	-	12

*Canadian data from the late Dr. Michael Bigg, Pacific Biological Station, Nanaimo, B.C., Canada.

These seals were all taken in offshelf waters. At least four of the six had fed recently, based on stomach volume. In seal nos. 739 and 742, L. opalescens comprised 90 and 50 % of the stomach content volume, respectively. These Loligo could have been transported northward and offshore by the aforementioned Sitka Eddy; however, it is possible that the seals fed over shelf waters before moving into deep water. Bigg and Fawcett (1985) suggest that most Loligo will be digested by fur seals within about 5 hours, in which case those seals with appreciable stomach volumes of Loligo would have recently fed near their capture locations or have made rapid trips from shelf waters where Loligo are normaly found.