

OBSERVATIONS OF THE CO-OCCURRENCE OF SQUID AND SALMONIDS
IN THE CENTRAL NORTH PACIFIC OCEAN
DURING THE SUMMER OF 1986

by

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INTRODUCTION

Since 1978, a high seas gill-net fishery for flying squid (Onnastrephes bartrami) has been developed by Japan, the Republic of Korea, and Taiwan in the North Pacific Ocean. In recent years, as many as 700 vessels have participated in this fishery, fishing a vast area eastward from Japan to about 145°W longitude, and between 35° and 46°N latitude. Because of the large size of the fishery, other important species, such as salmon, tuna, marine mammals, and seabirds, may be caught incidentally in relatively high numbers. The 1986 cruise of the research vessel Hai Kung was the first joint US/Taiwan research effort directed specifically toward the flying squid resource in the North Pacific Ocean. At the invitation of the Taiwan Fisheries Research Institute (TFRI), a U.S. scientist participated in each leg of the cruise. The following report summarizes observations from the cruise.

CRUISE PERIOD AND AREA

The cruise began on 16 July 1986, when the Hai Kung departed Keelung, Taiwan. The first 8 d of the cruise were spent transiting to the first survey area near 40°N, 150°E which is nearly 1,800 nautical miles from Taiwan (Fig. 1). Stations were occupied along N-S transects at 155°E, 157°E, 173°E, 178°E, 177°W and 172°W. Oceanographic sampling was performed at, and periodically between, gill-net stations until we reached the last sample point (38°00'N, 172°00'W) prior to running to Honolulu, Hawaii, where the vessel docked on August 25.

The Hai Kung sailed from Honolulu Harbor on the afternoon of 1 September, heading west northwest to longitude 175°W where five gill-net sets were completed from 8-15 September (Fig. 1). We then travelled west and reached the second survey area, longitude 171°E, on 19 September. Because of inclement weather, only two of five gill-net sets planned were completed. We left the second survey area on 25 September and arrived at the third survey area on 28 September, but immediately evacuated to waters east of the Kuril Islands because of typhoon Ben. After the typhoon passed, we completed a single successful gill-net

operation on 29 September. The gill net was set again, then lost in a severe storm. We abandoned the search for the lost gill net after 2 days, once again forced by a typhoon to a coastal area, this time to waters east of Hokkaido Island. After the typhoon passed, we sailed south to Taiwan, arriving 17 October.

OBJECTIVES

1. Estimate the distribution and abundance of squid and salmon by fishing gill nets at predetermined locations.
2. Observation of environmental and hydrographical conditions by sampling with Nansen bottles and recording of NOAA-APT satellite data.
3. Biological measurement on squids and salmon caught (e.g. species, sex, and length).

METHODS

The Hai Kung was launched in 1975 and is basically a low profile stern trawler. Vessel characteristics include length overall of 56.6 m, 3.25 m draft, and displacement of 710 gross tons. The fish holds have a capacity of 350 cubic meters. The research laboratory is equipped with a scientific echo sounder to make relative biomass estimates of marine resources, oceanographic wet chemistry equipment, and a satellite receiver/processor for analyzing sea-surface temperature (SST) data sent from NOAA satellites.

Gill-Net Specifications

Cruise Leg I

Five kilometers of monofilament gill net was fished each night. The net was made up of four mesh sizes (60, 80, 110, and 135 mm stretched measure) arranged in random blocks of five pieces (tans) of one size mesh (Table 1). A total of 40 blocks of 200 tans was fished during sets 1-7 in one continuous string of which the last four blocks of 110 mm mesh were suspended at 10 m depth from the surface by 0.5 m diameter white styrofoam floats. The sunken gear was removed after set 7 and two blocks of 60 mm mesh and two blocks of 80 mm mesh were added to the opposite end. No floats were attached to the upper (normally the floatline) of the sunken gear. The submerged gear was designed to sample organisms between 10 and 20 m depth. A flag buoy, flashing light buoy, and radar transponder were attached at the end of the gear with the sunken 110 mm mesh web. Two more flashing light buoys were attached to the floatline by 10 m lines at about one-third intervals along the floatline connecting all 200 tans. A 50 m line attached the 0-10 and 10-20 m depth sections of gear. A flag buoy and flashing light buoy marked the end of the net opposite the sunken section. Lighted and radar buoys used were very similar to those deployed by catcher boats in the Japanese mothership salmon fishery.

Tan length was not constant over mesh sizes due to construction by various vendors. The number of floats per section of net was counted (tan) on 28 July resulting in the following:

<u>Mesh size</u>	<u>Floats per tan</u>
80 mm	31, 32, 32, 32, 31, 31, 31
110 mm	30, 30, 30

The distance between floats was estimated at about 1 m. The length of floating section of all mesh sizes together was estimated as about 5 km.

Cruise Leg II

Mesh sizes and filament types of gill net used on this cruise leg were similar to those used on the first leg except that no sunken gill net was fished, instead multifilament gill nets with mesh sizes of 120-180 mm were fished in place of the sunken nets (Table 2). The multifilament webbing of the nets used on cruise leg II was colored light gray. The monofilament gill nets fished on both cruise legs was light green.

Fishing Operations

Cruise Leg I

Squid fishing operations were conducted at 16 stations (Fig. 1; Table 3). At each station, the gill net was set at about 1830 hours each evening, taking approximately 30 minutes to deploy the net. The following morning retrieval began at approximately 0545 hours, lasting between 1.75 to 5 hours, depending upon the size of the catch. The net was retrieved starting at the sunken end which was the last end set for sets 1-8 and 13-16; sets 9-12 were retrieved in the opposite order. Data on catch composition were summarized by gear type and mesh size in a catch log. Catches were also summarized by sequential 1-minute intervals.

Cruise Leg II

Fishing operations on the second leg were similar to the first leg. Eight successful gill-net operations were completed between latitudes 42° and 46°N and on longitudes 175°W, 171°E, and 157°E (Table 4).

RESULTS

Cruise Leg I

Forty-one salmon--1 coho salmon (Oncorhynchus kisutch) and 40 chum salmon (O. keta)-- were caught on 8 August at 44°07'N, 172°56'E, the only fishing station at which salmon were caught (Table 5). The squid catch at this station was 103 boreal clubhook squid, 84 eight-armed squid and only 2 flying squid. (The remaining 36 squid dropped out at the rail.) The SST at this location was 14.1°C. Two other fishing stations encountered water temperatures lower than 15°C: 14.6°C, and 13.8°C at fishing stations 2 and 16, respectively.

Although catches of squid were most common, occurring at each fishing station, pomfret (Brama japonica) and skipjack (Katsuwonus pelamis) were most numerous in the total catch (Table 5). They were also most variable. Pomfret catches at two adjacent stations, stations 14 and 15, were 1 and 15,998 fish, respectively. Likewise, the skipjack catches were 0 and 929 for two adjacent fishing stations. Significant catches of three shark species, mackerel (Scomber japonicus) and albacore (Thunnus albacares) also occurred during cruise leg I. In all, 22 different fish species occurred in the catches.

Cruise Leg II

Salmon were caught in one set on 19 September at 46°N 171°E: 122 chum salmon (O. keta), 2 chinook salmon (O. tshawytscha), 1 steelhead trout (Salmo gairdneri), and 8 unidentified Salmonidae (dropouts) (Table 6). The SST at the time of the set was 12.8°C; 5 other stations were fished at temperatures less than or equal to 15.0°C (Table 4). Although the adipose fin of the steelhead trout was missing, no coded-wire tag was found. One hundred seventy-nine squid were caught in the same set, all boreal clubhook squid (Onychoteuthis borealijaponicus). The catch composition varied by mesh size. Eighty percent of the salmonids were caught in the 110 mm gill nets, whereas 93% of the squid in this set were caught in the 60 or 80 mm gill nets (i.e., they were small squid). Common and scientific names of species observed appear in Table 7.

DISCUSSION

Salmonids occurred coincidentally with squid in research gill net catches in July-September, 1986, near the northern boundary of the squid regulatory area of Japan. Salmon, flying squid and boreal clubhook squid were caught in gillnets fished from the TFRI vessel Hai Kung in the vicinity of 44-46°N, 171-173°E longitude. Salmon also were taken in 1986 along with flying squid in gill nets fished from the R/V Oshoro maru (Hokkaido University) along 180° longitude (T. Minoda, Pers. Comm.):

Date	Latitude °N	SST C°	Catch (No.)	
	Longitude 180°		Flying squid	Salmon
6/12 ^{a/}	37	15.3	14	0
6/12	38	14.8	76	0
6/13	39	13.8	280	1
6/14	40 ^{b/}	14.8	200	81
6/15	41	11.8	489	231
6/16	42	9.0	57	146

^{a/} Date of June 12 repeated.

^{b/} Northern boundary for June.

In general, salmon were caught along with squid in waters of 12.8-14.8°C surface temperatures within the area open to fishing by the squid fleets of Japan. No salmon were caught, but squid were taken in waters with SST equal to or greater than 14.8°C. However, both squid and salmon were most abundant at the same station at 41°N (SST = 11.8°C).

Takagi (1983) suggested that there is a distinct separation of the main distribution area of flying squid and salmonids. He found the former species was distributed in the waters where SST ranged from 12°C to 23°C, and the latter species was distributed in waters where SST ranged from 1° to 13°C and was rarely caught in waters where SST was 14°C or more. Results of our 1986 cruise survey nearly agree with Takagi with the southern boundary of the distribution of salmonids at

about 15°C. The range of distribution of SST in which flying squid are present is slightly wider (12°-24°C) than the range reported by Takagi.

Murata (1986), based on the results of a transect (175°E) gill-net survey, showed a higher abundance of flying squid in the waters between 41° and 44°N (corresponding to the transitional domain) and of salmonids in the waters north of 45°N (corresponding to the subarctic domain). In his survey, five transects (155°E, 170°E, 173°E, 177°W, 175°W) were sampled, and the results showed that the boundary was somewhat dynamic and varied from 44.5°-46°N in transect 170°E (Sep.) to 43°-44°N in transect 173°E (Aug.). No salmonids were caught to the south of 43°N (Jul.-Sep.) in transect 155°E, south of 44°N (Aug.) in transect 177°W, south of 46°N (Sep.) in transect 175°W. Flying squid were more abundant at 41°N-44°N, and larger individuals were caught farther north.

Takagi (1983) concluded the southern limit of distribution of salmonids was farther north in water colder than the 15°C isotherm. Our results agree with this conclusion, and we propose using the 15°C isotherm as a useful guide in separating the main distribution of salmonids and flying squid.

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References

1. Murata, M. 1986. Report on the flying squid fishing survey by the drift gillnetter Kanki maru No. 58 in the North Pacific in 1985. (Document submitted to the International North Pacific Fisheries Commission.) 15 p.
2. Takagi, K. 1983. Differences in area of distribution between salmon and flying squid. (Document submitted to the International North Pacific Fisheries Commission.) , 10 p.

Table 1.--Layout of gill net used in sets 1-7 during cruise leg I of the research vessel Hai Kung, 1986.

Buoy (attached by 10 m line)	Block and order set	Mesh size (mm)	Type ^{a/}
Ball marker, light red flag	1	110	Sunken
	2	110	Sunken
	3	110	Sunken
	4	110	Sunken
	5	110	Surface
	6	135	Surface
	7	110	Surface
	8	80	Surface
	9	110	Surface
	10	80	Surface
	11	80	Surface
	12	135	Surface
	13	135	Surface
	14	110	Surface
	15	80	Surface
	16	110	Surface
	17	80	Surface
	18	80	Surface
	19	80	Surface
Light buoy	20	110	Surface
	21	110	Surface
	22	80	Surface
	23	80	Surface
	24	110	Surface
	25	110	Surface
	26	80	Surface
	27	110	Surface
	28	135	Surface
	29	110	Surface
Light buoy	30	110	Surface
	31	80	Surface
	32	135	Surface
	33	110	Surface
	34	110	Surface
	35	80	Surface
	36	110	Surface
	37	135	Surface
	38	80	Surface
	39	110	Surface
Red flag radar bouy, light	40	110	Surface

^{a/}The sunken type fished 10-20 m depth; surface type fished 0-10 m.

Table 2.--Number of tans fished by set number and mesh size, for observations aboard the research vessel Hai Kung, cruise leg II, 1986.

Mesh size (mm)	Filament type	Set number							
		1	2	3	4	5	6	7	8
120	mono	5	5	5	5	5	5	5	5
120	multi	6	6	4	4	4	4	4	4
140	mono	5	5	5	5	5	5	5	4
140	multi	5	5	5	4	4	4	4	4
160	mono	5	5	3	4	4	4	4	3
160	multi	5	5	5	5	5	5	5	5
180	mono	5	5	5	5	5	5	5	3
180	multi	5	5	5	5	5	5	5	3
60	mono	10	10	10	10	10	10	0	0
80	mono	65	65	45	60	60	60	45	45
110	mono	135	135	113	120	120	120	35	79
135	mono	12	12	9	8	8	8	2	2
Total		258	258	214 ^{a/}	235	235	235	119 ^{b/}	157

^{a/}Number of tans fished does not include 42 tans that were retrieved tangled.

^{b/}Number of tans fished does not include 116 tans that were retrieved tangled.

Table 4.--Dates, fishing locations, and sea-surface temperatures (SST) for fishing operations of the research vessel Hai Kung, cruise leg II, 1986.

Set	Latitude	Longitude	Date		SST (°C)	
			Set	Retrieved	Set	Retrieve
1	42°N	175°W	8 Sept	9 Sept	16.8	16.2
2	43°N	175°W	9 Sept	10 Sept	15.0	15.0
3	44°N	175°W	10 Sept	13 Sept ^{a/}	13.8	13.4
4	45°N	175°W	13 Sept	14 Sept	13.0	12.8
5	46°N	175°W	14 Sept	15 Sept	13.2	13.0
6	46°N	171°E	19 Sept	20 Sept	12.9	12.8
7	44.5°N	171°E	20 Sept	25 Sept ^{b/}	14.4	13.3
8	43°N	157°E	28 Sept	29 Sept	18.0	17.2
9	44°N	155°E	2 Oct	lost	16.8	n.a.

^{a/}Forty-four tans retrieved on 12 September.

^{b/}Two tans retrieved on 24 September.

Table 3.--Station location and sea-surface temperatures (SST) for fishing operations on cruise leg I of the research vessel Hai Kung, 1986.

Set	Latitude	Longitude	Date	SST (°C)	
				Set	Retrieval
1	41°07'N	152°57'E	July 25	17.2	16.8
2	40°56'N	154°59'E	26	15.0	14.6
3	39°29'N	155°04'E	27	16.4	16.0
4	39°40'N	157°06'E	28	17.6	17.6
5	41°00'N	157°05'E	29	16.8	16.8
6	37°54'N	173°11'E	Aug. 02	22.7	22.8
7	39°33'N	172°56'E	03	22.7	22.0
8	41°06'N	173°10'E	04	20.8	20.1
9	42°28'N	173°01'E	05	16.0	15.8
10	44°07'N	172°53'E	06	14.4	14.1
11	38°03'N	177°02'W	09	23.2	23.1
12	39°30'N	176°53'W	10	22.0	21.8
13	40°00'N	176°57'W	11	20.7	20.2
14	40°56'N	176°58'W	12	18.7	19.0
15	42°27'N	176°55'W	13	15.6	15.9
16	43°58'N	176°58'W	14	13.4	13.8

Table 5. Summary of estimated catch of gillnets fished in the North Pacific Ocean on cruise leg 1 of the Taiwan Fisheries Research Institute vessel HAI KUNG, 1986.

Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Net Hauled																	
(Month/Day)	7/25	7/26	7/27	7/28	7/29	8/2	8/3	8/4	8/5	8/6	8/9	8/10	8/11	8/12	8/13	8/14	
Latitude N	41°07'	40°56'	39°29'	39°40'	41°00'	37°54'	39°33'	41°06'	42°28'	44°07'	38°03'	39°30'	40°00'	40°56'	42°27'	43°58'	
Longitude E/W	152°57'E	154°59'E	155°04'E	157°06'E	157°05'E	173°11'E	172°56'E	173°10'E	173°01'E	172°53'E	177°02'W	176°53'W	176°57'W	176°58'W	176°55'W	176°58'W	
Sea Surface																	
Temperature °C	16.8	14.6	16.0	17.6	16.8	22.8	22.0	22.1	15.8	14.1	23.1	21.8	20.2	19.0	15.9	13.8	
Squids ¹	27	12	42	44	14	1	72	103	5	225	27	26	180	711	53	52	1,594
Sharks ²	612	3	2	3	438	2	3	1	2	2	1	-	1	5	28	1	1,104
Salmon																	
Chum	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-	40
Coho	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Sardine	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	-	18
Saury	4	-	-	-	-	-	-	-	-	-	-	-	73	-	2	-	79
Flying Fish	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2
Albacore	2	-	68	3	41	-	-	3	1	-	-	-	-	13	-	3	134
Skipjack	-	-	-	377	-	13	74	-	-	-	15	-	929	319	-	-	1,727
Mackerel	1	195	-	-	2	1	-	1	-	-	-	-	-	-	-	-	200
Striped Marlin	-	-	1	-	-	-	-	-	-	-	1	2	3	-	-	-	7
Mahi Mahi	-	-	-	-	-	2	-	1	-	-	-	-	1	-	-	-	4
Pomfret	23	201	16	6	227	1	3	111	737	285	-	-	-	1	15,998	9	17,618
Yellowtail	-	-	-	-	-	-	-	-	-	-	-	6	5	-	-	-	11
Pilotfish	-	-	1	-	-	1	-	-	-	-	1	6	-	-	-	-	9
Lancetfish	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	2
Psenes	-	-	-	-	-	-	-	3	-	-	7	-	-	-	-	-	10
Squaretail	-	-	-	-	1	-	-	-	2	-	-	-	-	-	45	1	49
Ocean Sunfish	-	-	2	-	2	-	-	-	-	-	-	1	1	8	9	1	24
Ragfish	-	-	-	-	2	-	-	-	3	1	-	-	-	-	-	-	6
Fulmar	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	2
Black-footed																	
Albatross	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	2
Common Dolphin	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Turtle	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1

¹Squids - include: Ommastrephes bartramii; Gonatopsis borealis; Onychoteuthis borealijaponicus; and Moroteuthis lönnergi.

²Sharks - include: Prionace glauca; Lamna ditropis; and Squalis acanthus.

Table 6.--Estimated gill-net catch by set number and species, for observations aboard the research vessel Hai Kung, cruise leg II, 1986.

Species	Set number								Total
	1	2	3	4	5	6	7	8	
Flying squid	555	574	240	25	37	0	10	419	1,860
Boreal clubhook squid	0	0	0	0	3	179	4	0	186
Shark	22	10	2	1	1	2	8	4	50
Chum salmon	0	0	0	0	0	122	0	0	122
Chinook salmon	0	0	0	0	0	2	0	0	2
Steelhead trout	0	0	0	0	0	1	0	0	1
Salmonidae	0	0	0	0	0	8	0	0	8
Skipjack	367	0	0	0	0	0	0	267	634
Yellowtail	7	2	0	0	0	0	0	0	9
Albacore	2	8	2	0	0	0	0	62	74
Swordfish	1	1	0	0	0	0	0	0	2
Pomfret	13	511	50	4	48	228	64	0	918
Smalleye squaretail	17	0	0	0	0	0	0	0	17
Pilotfish	7	0	0	0	0	0	0	0	7
Ocean sunfish	1	8	0	0	0	0	0	0	9
Sardine	0	0	0	0	0	0	52	0	52
Mackerel	0	0	0	0	0	0	1	0	1
Saury	0	0	0	0	0	0	1	0	1

Table 7.--List of common and scientific names of animals caught in gill nets fished on cruise leg I of the research vessel Hai Kung, 1986.

Common name	Scientific name
Steelhead trout	<u>Salmo gairdneri</u>
Salmon	
Chinook	<u>Oncorhynchus tshawytscha</u>
Chum	<u>Oncorhynchus keta</u>
Coho	<u>Oncorhynchus kisutch</u>
Sardine	<u>Sardinops melanostictus</u>
Saury	<u>Cololabis saira</u>
Flying fish	<u>Cypselurus sp.</u>
Albacore	<u>Thunnus albacares</u>
Skipjack	<u>Katsuwonus pelamis</u>
Mackerel	<u>Scomber japonicus</u>
Marlin	<u>Tetrapturus audax</u>
Swordfish	<u>Xiphias gladius</u>
Mahi Mahi	<u>Coryphaena hippurus</u>
Pomfret	<u>Brama japonica</u>
Yellowtail	<u>Seriola lalandi</u>
Pilotfish	<u>Naucrates ductor</u>
Lancetfish	<u>Alepisaurus ferox</u>
<u>Psenes</u>	<u>Psenes pellucidus</u>
Smalleye squaretail	<u>Tetraodon curvieri</u>
Ocean sunfish	<u>Mola mola</u>
<u>Desmodema</u>	<u>Desmodema polystictum</u>
Ragfish	<u>Desmodema polystictum</u>

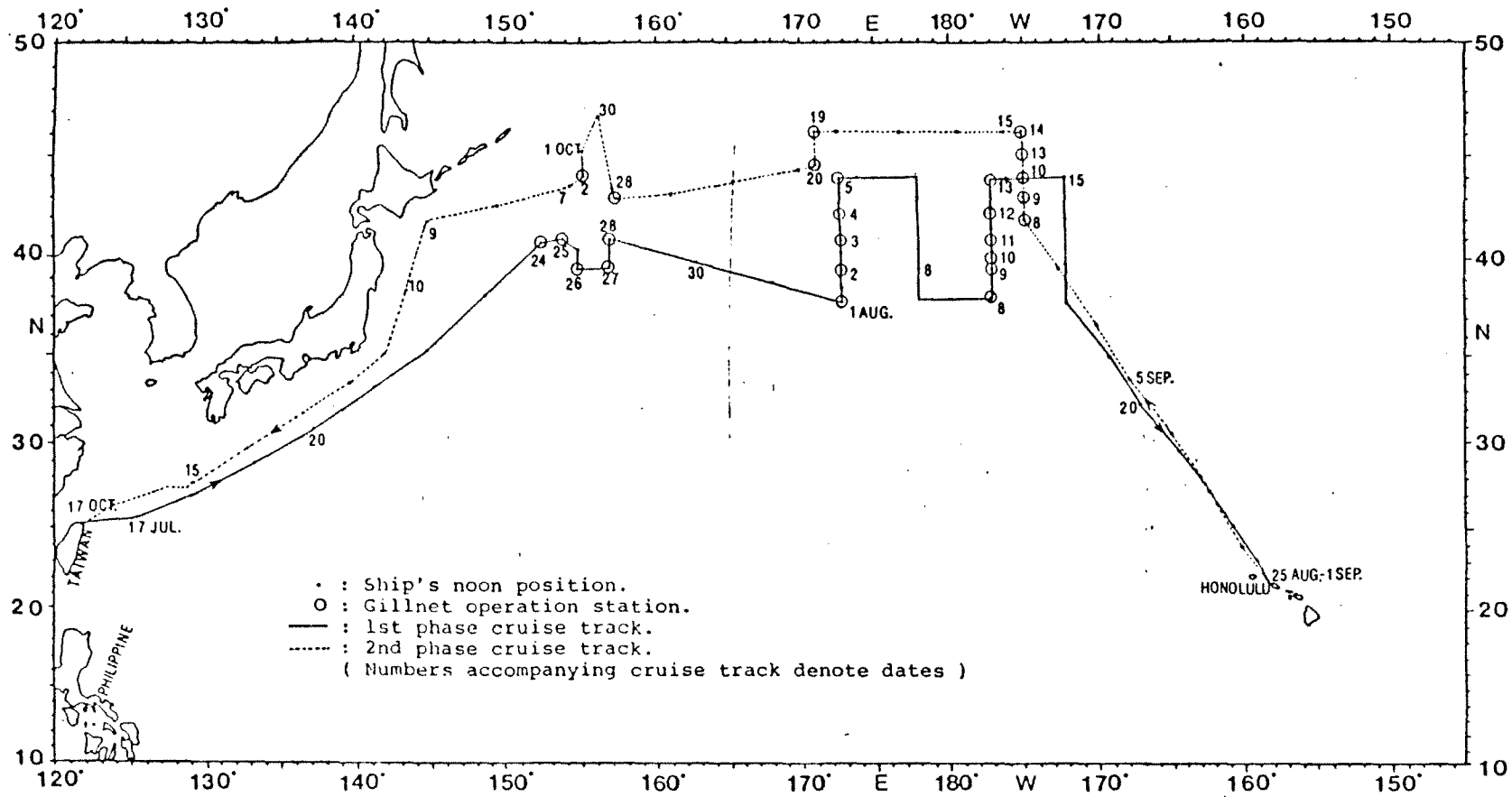


Figure 1.--The cruise track of North Pacific flying squid resources investigation of the research vessel Hai Hung, 17 July-17 October 1986. Diagram courtesy of the chief officer of the Hai Kung.