CURRENT SKIPJACK OCEANOGRAPHY CRUISES IN EASTERN TROPICAL PACIFIC OCEAN

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A series of skipjack oceanography cruises is planned for two offshore areas in the eastern tropical Pacific Ocean. This report reviews the objectives, operational procedures, and preliminary results of the first of these cruises--by the NMFS research vessels 'David Starr Jordan' and 'Townsend Cromwell', about 1,100 to 2,500 nautical miles south of San Diego, Calif., in October-December, 1970.

The regulation of yellowfin tuna in the eastern Pacific Ocean, through an annual catch quota, has necessitated the utilization of alternative tuna resources by the U.S. tuna fleet for much of the year. One of the most important alternatives, and in the same general region, is the stock of skipjack tuna (Katsuwonus pelamis), which is unregulated and currently underexploited. At present, skipjack are only fished heavily in the inshore areas along the American coasts, but they certainly occur offshore. Indeed, U.S. purse seiners fishing north of the Equator to the west of the boundary of the IATTC* regulatory area took about 900 tons of skipjack in 1969 and 6,300 tons in 1970. However, these vessels were fishing primarily for yellowfin, and skipjack catches were largely incidental. Offshore skipjack are expected to contain a considerable proportion larger in size than those taken in the inshore fishery and hence more acceptable to the canning industry.

THE EASTROPAC expedition of 1967-68, for which the National Marine Fisheries Service (NMFS) was the lead agency, gave oceanographic results (Love, 1970 and in prep.). These indicated environmental conditions generally suitable for skipjack: surface temperature at 20°-29° C and presence of skipjack forage (food) over a large region north of 5° S from 100° to 130° W. More detailed work on EASTROPAC data (Blackburn and Laurs, in press) has shown that the skipjack forage was concentrated in several zonal (east-west) bands, and at levels of abundance equal to, or greater than, those in existing inshore skipjack fishing areas. Skipjack do occur in these offshore forage-rich zones. This was shown in October 1969, when the Honolulu-based NMFS research vessel 'Charles H. Gilbert' fished north of the Equator near 120° W, where there is normally a forage-rich zone. Many skipjack were seen and caught (Hida, 1970).

The current series of skipjack cruises is designed for detailed investigations, on a seasonal basis, of the occurrence and relative abundance of skipjack in two areas (designated 'A' and 'B' in Fig. 1) of offshore waters considered most suitable for skipjack. To understand their occurrence in such offshore areas, we need to know the ways in which ocean features and conditions determine the distribution and migrations of skipjack.

This report reviews the objectives, operational procedures, and preliminary results of the first cruise. It was a 2-vessel operation, in October-December 1970, in the eastern tropical Pacific about 1,100 to 2,300 nautical miles south of San Diego (Area 'A' Fig. 1): The NMFS research vessel Townsend Cromwell (Hawaii Area Fishery Research Center, R. Uchida, NMFS-Cruise Leader), left San Diego October 23 and arrived in Honolulu November 29; and the David Starr Jordan (Fishery-Oceanography Center, La Jolla,

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*IATTC--Inter-American Tropical Tuna Commission.

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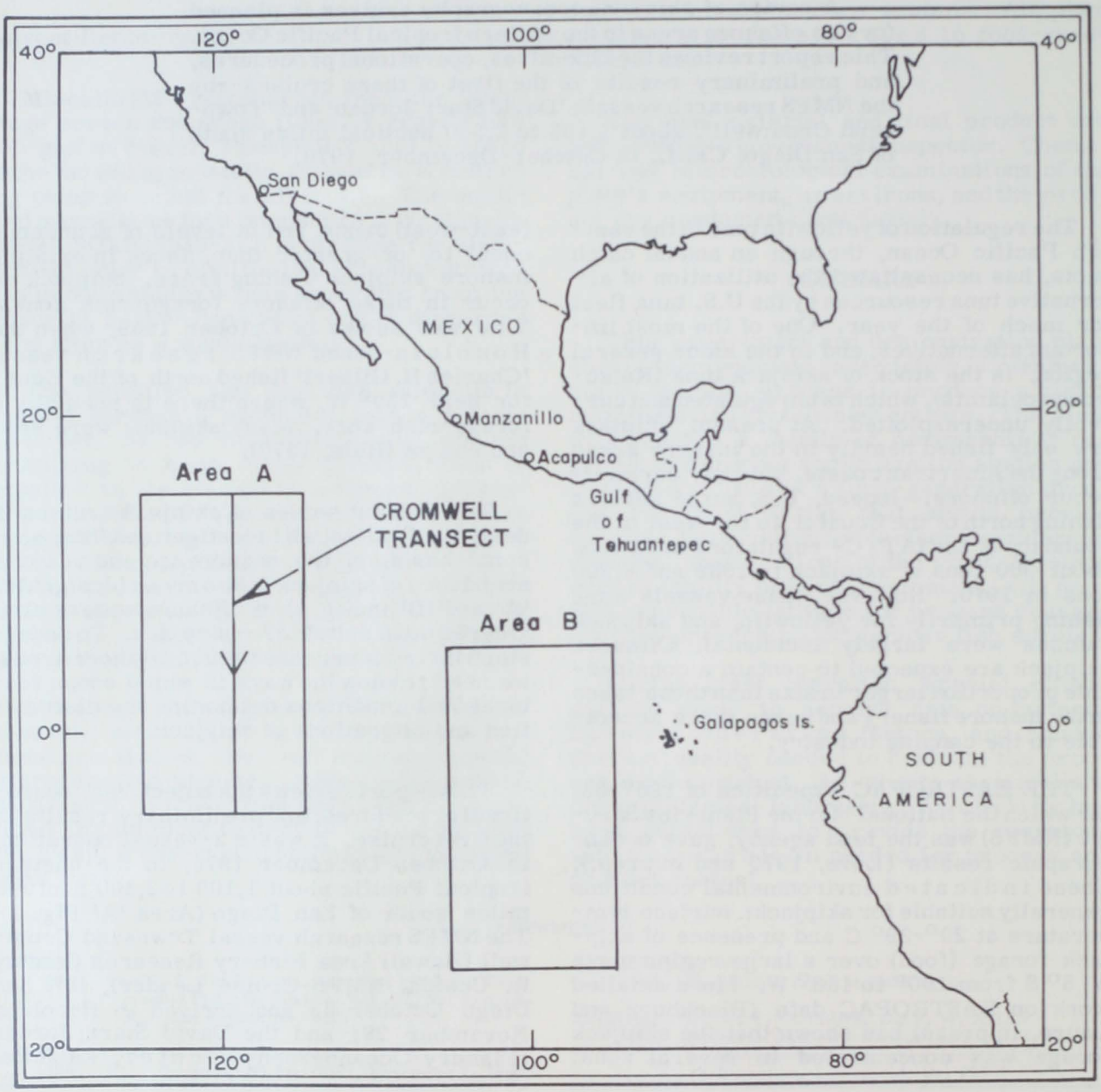

Fig. 1 - Areas of eastern tropical Pacific Ocean under investigation in current series of skipjack oceanography cruises. Also shown is location of oceanographic transect of Area 'A' completed by Cromwell in Part 1 - Operations of first cruise.

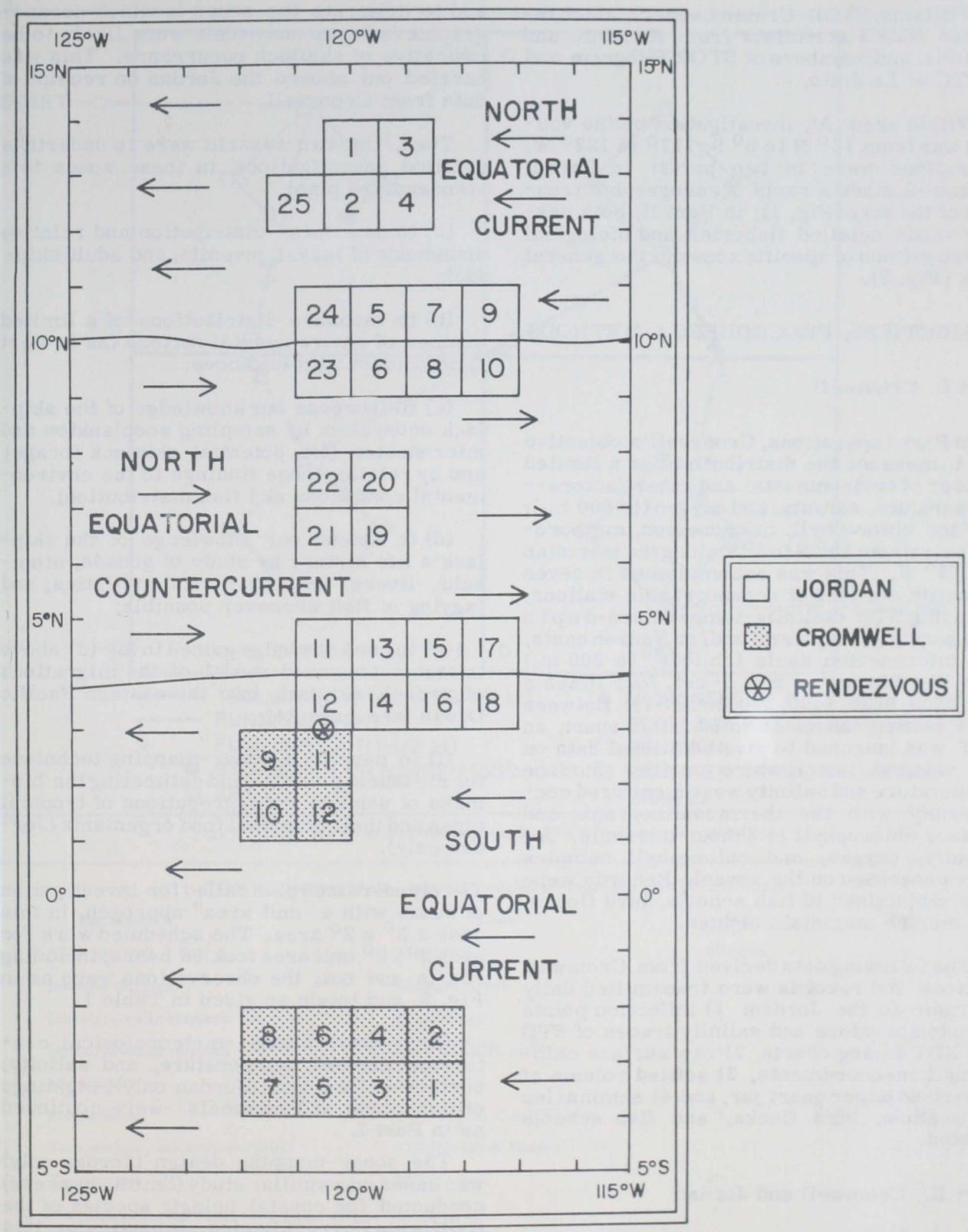

Fig. 2 - Unit areas investigated by Jordan and Cromwell in Part II Operations (first cruise) and relation to surface current systems. Numbers in quadrants of unit areas denote order of occupation by vessels.

F. Williams, STOR-Cruise Leader), which included NMFS scientists from Honolulu and La Jolla, and members of STOR Program and IATTC at La Jolla.

Within area 'A', investigation by the vessels was from 15° N to 5° S, 117° to 122° W. Operations were in two parts: in Part I, Cromwell made a rapid oceanographic transect of the area (Fig. 1); in Part II, both vessels made detailed fisheries and biological investigations of specific zones in the general area (Fig. 2).

OBJECTIVES, PROCEDURES & METHODS

Part I: Cromwell

In Part I operations, Cromwell's objective was to measure the distributions of a limited number of environmental and other factors--temperature, salinity, and oxygen (to 500 m.); surface chlorophyll, micronekton, meteorological--from 15° N to 5° S along the meridian of 119° W. This was accomplished in seven days with a series of oceanographic stations, including STD (salinity-temperature-depth data acquisition system) and/or Nansen casts, and micronekton hauls (oblique, to 200 m.) with the Blackburn 5' x 5' net, four times a day (0200, 0800, 1400, 2000 hr. PST). Between each station, about 45 to 50 miles apart, an XBT was launched to give additional data on the vertical temperature profile. Surface temperature and salinity were monitored continuously with the thermosalinograph, and surface chlorophyll at 3-hour intervals. All salinity, oxygen, and chlorophyll samples were processed on the vessel. Records were also maintained of fish schools, bird flocks, and marine mammals sighted.

The following data derived from Cromwell stations and records were transmitted daily by radio to the Jordan: 1) inflection points from temperature and salinity traces of STD and XBT analog charts, 2) raw surface chlorophyll measurements, 3) settled volume of micronekton per quart jar, and 4) summaries of weather, bird flocks, and fish schools sighted.

Part II: Cromwell and Jordan

In Part II, the first task was to compare results from Part I with historical data for the area, particularly that of EASTROPAC, and to delineate the zones in which oceanographic features and events were likely to be indicative of skipjack occurrence. This was carried out aboard the Jordan on receipt of data from Cromwell.

Then, the two vessels were to undertake detailed investigations in these zones to a standardized plan:

(a) to determine distribution and relative abundance of larval, juvenile, and adult skipjack;

(b) to measure distributions of a limited number of environmental factors (as in Part I) coincident with (a) above;

(c) to increase our knowledge of the skipjack ecosystem by sampling zooplankton and micronekton (for potential skipjack forage) and by relating these findings to the environmental conditions and fish distribution;

(d) to extend our knowledge of the skipjack's life history by study of gonads, stomachs, livers, and other vital statistics; and tagging of fish whenever possible;

(e) to use knowledge gained in (a)-(d) above to test a proposed model of the migrations of recruit skipjack into the eastern Pacific Ocean (see page 34);

(f) to develop a sonar-mapping technique for measuring the size and estimating the biomass of schools and aggregations of tropical tunas and their principal food organisms (Jordan only).

The standardized plan called for investigation of zones with a "unit area" approach, in this case a 2° x 2° area. The scheduled work for each 2° x 2° unit area took 96 hours, including run in and out; the observations were as in Fig. 3, and totals as given in Table 1.

Other observations--meteorological, continuous surface temperature, and salinity; surface chlorophyll (Jordan only); sightings of fish, birds, and mammals--were continued as in Part I.

The sonar-mapping design (Jordan only) was based on a similar study (Smith, in press) conducted for coastal pelagic species of the California Current Region. In particular, this entails determining the range and school size dependence on numbers of sonar targets per unit area.

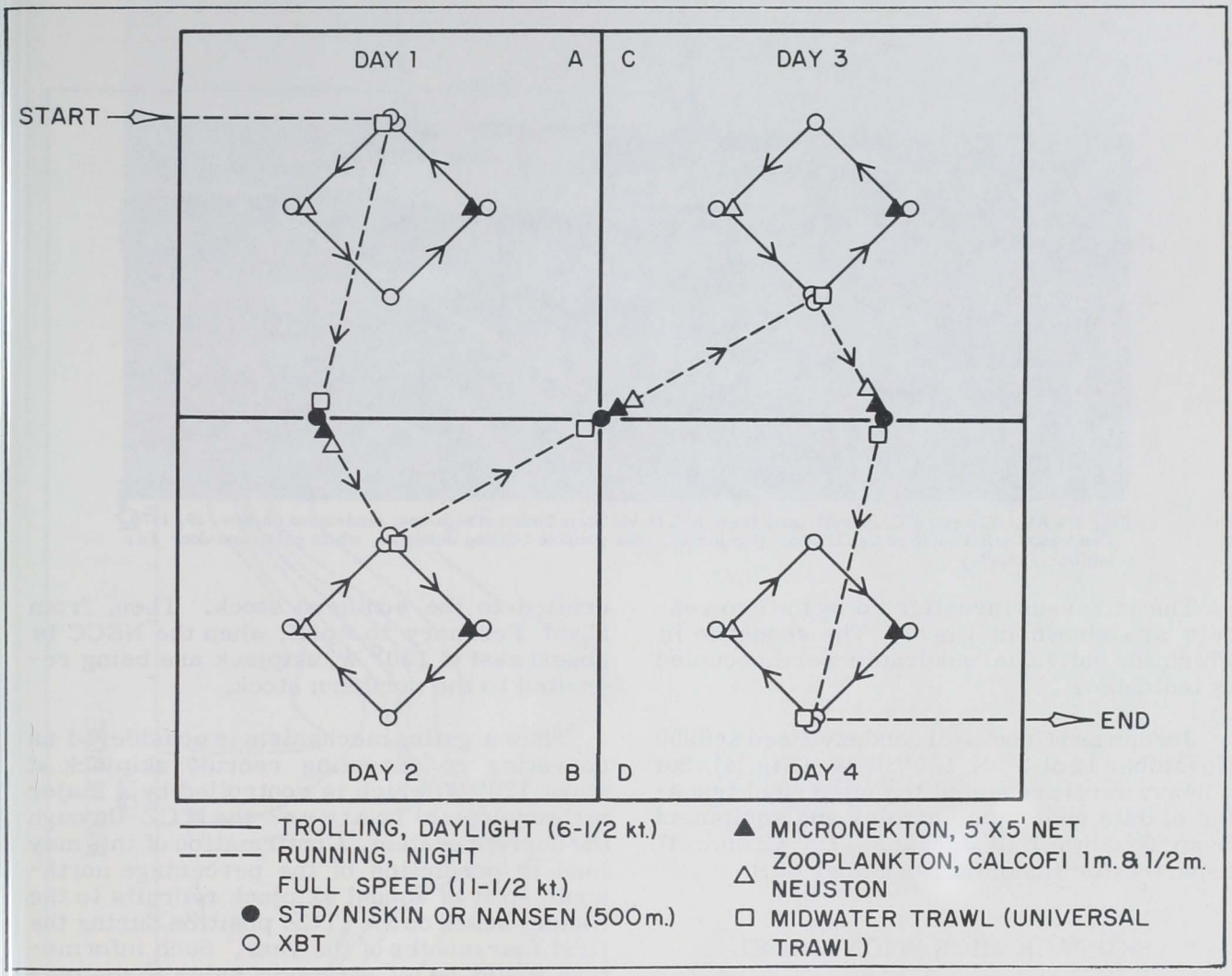

Fig. 3 - Track and scheduled observations for 2° x 2° unit area investigations.

Table 1 - Number of observations scheduled for each unit area (2° x 2° area)

Parameter	Gear	Day	Night
Adult skipjack	Trolling	40 hours	-
Juvenile skipjack	Midwater trawl	-	7[a]
Larval/juvenile skipjack	Neuston net	4	3
Larval/juvenile skipjack	1 m. CalCOFI net[b]	4	3
Micronekton	5' x 5' net	4	3
Zooplankton	1 m. & $\frac{1}{2}$ m. CalCOFI nets	4	3
Temperature, salinity, oxygen[c]	STD/Niskin or Nansen	-	3
Temperature	XBT	20	-

[a] 4 hauls occupied equal time either side of marine dawn.
[b] Same hauls as for zooplankton.
[c] No salinity or oxygen samples were obtained during Part II on Cromwell due to elimination of Nansen casts.

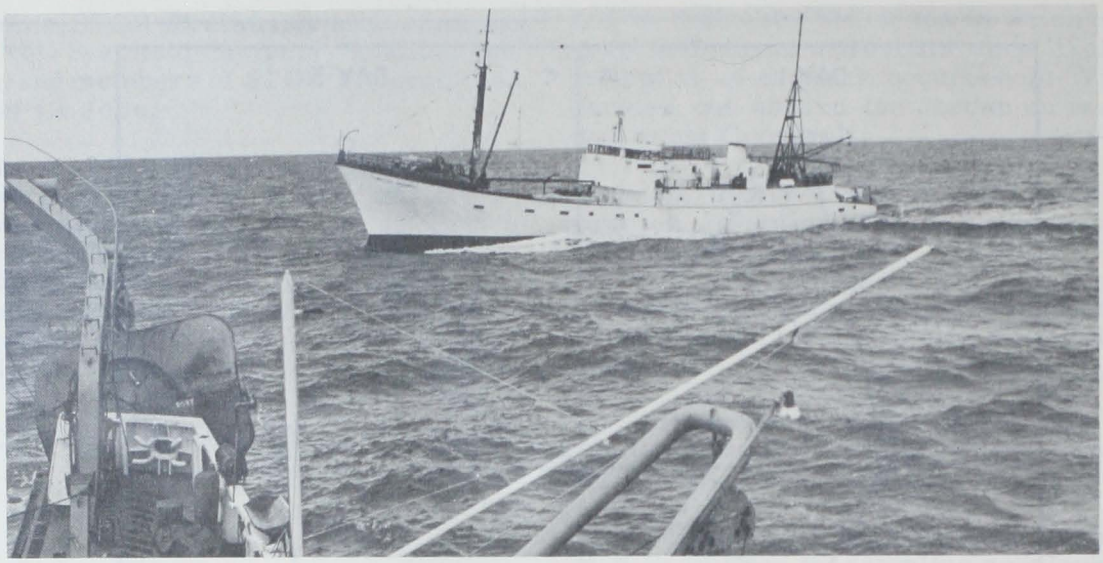

Fig. 4 - RV. Townsend Cromwell seen from RV. David Starr Jordan at high-seas rendezvous on Nov. 19, 1970, about 1800 miles south of San Diego. (On Jordan, note portside trolling outrigger, white pole, and door for midwater trawl.)

The unit areas investigated by the two vessels are shown in Fig. 2. The sequence in which the individual quadrants were occupied is indicated.

Jordan and Cromwell rendezvoused at 0900 November 19 at 3° N, 120°30' W. (Fig. 4), but a heavy swell prevented the envisaged transfer of data and some samples and equipment from Cromwell to Jordan. (The Cromwell departed for Honolulu November 20.)

SKIPJACK MIGRATION MODEL

The adolescent (sexually immature) fish, which form the bulk of the skipjack catch in the eastern Pacific, are considered to have a central Pacific origin (Rothschild, 1965). Any model of the migration of the juvenile skipjack (<35 cm) eastwards must account for the separation into the northern stock (Acapulco to California) and the southern stock (eastern Gulf of Tehuantepec to northern Chile).

The proposed migration model of Williams (in preparation) indicates that changes in flow of surface North Equatorial Countercurrent (NECC), due to seasonal changes in position of Inter-tropical Convergence Zone (ITCZ)--the meteorological equator--are responsible for north-south split of incoming recruit skipjack. When NECC eastward flow is continuous to Central America coast from May/June to December/January, skipjack are being recruited to the southern stock. Then, from about February to April, when the NECC is absent east of 120° W, skipjack are being recruited to the northern stock.

Thus a gating mechanism is considered as operating on incoming recruit skipjack at about 120° W, which is controlled by a major meteorological feature--the ITCZ-through the current system. Confirmation of this may lead to prediction of the percentage north-south split of annual skipjack recruits to the fishery based on the ITCZ position during the first four months of the year. Such information would be of strategic value to the tuna industry and to those studying skipjack population dynamics.

Testing this migration model is necessary if the oceanographic monitoring and forecasting system (presently for U.S. west coast albacore fishery) of NMFS Fishery-Oceanography Center, La Jolla, now being extended to tropical tunas, is to have predictive value for skipjack.

PRELIMINARY RESULTS

Part I: Oceanographic Transect

Preliminary analyses show the distribution of temperature (Fig. 5) and salinity was generally similar to that observed at the same meridian, 119° W, in late October, 1967, during EASTROPAC. The lowest surface

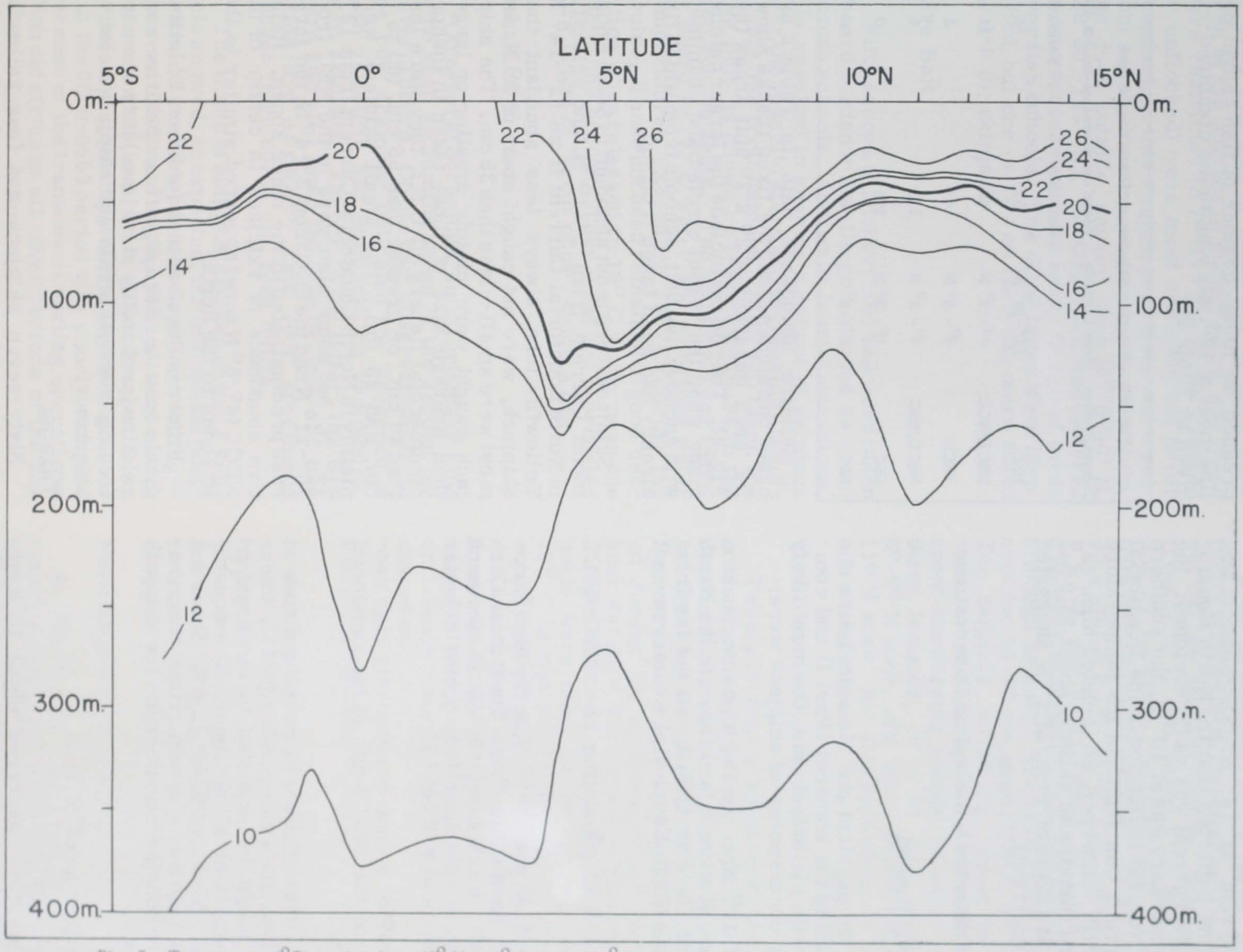

Fig. 5 - Temperature (°C) section from 15° N to 5° S along 119° W, Nov. 1-7, 1970 (Cromwell, Part I Operations--first cruise).

temperature, 20° C, was observed in the South Equatorial Current at 1° S, and the lowest surface salinity, 32.9‰, in the North Equatorial Current at 13° N. The slope of the thermocline indicated that the North Equatorial Countercurrent was well developed: the northern boundary was at 10° N, the southern at 4° N. No clear indication of the Equatorial Undercurrent was found in the temperature distribution. However, an isolated high-salinity core (maximum salinity about 35.2‰, centered at a depth of 50 m. at 1° S, suggested the Undercurrent).

Part II: Fisheries & Biological Observations

Zones Investigated

From the physical and biological data obtained during the transect (Part I) and comparison with historical data, the most likely zones for occurrences of skipjack were:

1) 12°-14° N, a zone of high micronekton catches and shallow mixed layer in the North Equatorial Current (NEC), but not far from the surface North Equatorial Countercurrent (NECC);

2) 9°-11° N, straddling the NEC-NECC boundary;

3) 3°-5° N and 1°-3° N in the high "productivity" band of the South Equatorial Current (SEC), between the NECC southern boundary and cold upwelled equatorial water (at approximately 0°30' N);

4) 2°-4° S, a zone of relatively high productivity in the SEC south of the equatorial upwelling.

It was decided also to examine a zone at 6°-8° N near the center of the NECC, where skipjack might be expected to be absent or present only in small numbers. The equatorial zone from about 0°30' N to 2° S was not examined because near-surface temperatures were considered rather low for skipjack occurrence.

Relative Abundance of Tuna

Trolling time averaged about 10 hours per day at 6½ knots; the effort in each zone was 4-8 days. Skipjack and yellowfin tuna were the principal species caught (boarded, tagged, or lost but identified). Relative abundance of tuna in 2° latitude zones--expressed as mean-number of fish caught per line-hour x 10^3, all longitudes combined--is given in Table 2.

Table 2 - Relative abundance of troll caught tuna

Current System	Zone Latitude	Mean catch per line-hour x 10^3	
		Skipjack	Yellowfin
NEC	12°-14° N	52	34
NEC/NECC	9°-11° N	39	11
NECC	6°- 8° N	43	2
NECC/SEC	3°- 5° N	115	8
SEC	1°- 3° N	196	0
SEC	2°- 4° S	82	0

Relative abundance data in Table 2 are based on catches along the fixed tracks shown for each quadrant of 2° x 2° unit areas (see Fig. 2). They do not include the larger catches made when the vessel circled and chummed, with anchovy live bait, schools from which fish already had been taken trolling.

Skipjack were most abundant in South Equatorial Current from 1°-3° N, and yellowfin in North Equatorial Current from 12°-14° N. Yellowfin tuna, always less abundant than skipjack, were not caught south of 3° N, and most were small--less than 35 cm. The skipjack caught were mainly smaller or larger than average size of those taken in inshore commercial fishery off U.S.: they were less than 40 cm., or greater than 55 cm. (up to 71 cm. and 20 lb.). The small skipjack were mainly in North Equatorial Current from 12°-14° N, but some also were in the NEC from 10°-11° N and the SEC from 3°-4° N; the large ones predominated in the other zones. Relative abundance of skipjack in center of the NECC (6°-8° N zone) appeared similar to that in zones to the north.

First results show that for 2° or 1° latitudinal zones there is a significant positive correlation (probability at 5% level) between surface chlorophyll levels and skipjack relative abundance.

Tagging

Sixty-seven skipjack and four yellowfin were tagged from the two vessels during the cruise.

Fish Schools, Bird Flocks, Marine Mammals

Very few tuna or other fish schools were seen at the surface in survey area, and these were restricted to 7°-11° N. Birds (flocked or unflocked) were most common, but never abundant, in this region; porpoises were seldom seen. However, on passage to Honolulu, and just outside survey area (6°-8°40' N, 128°30'-133° W), the Cromwell encountered on two successive days many flocks of birds over fish schools. Few of the latter were identified, but one or two on each day were noted as 4-8 lb. skipjack.

Live Bait

Fifty scoops of anchovy live bait were taken aboard Jordan in San Diego and used as chum on tuna schools. And, on at least 3 occasions, this resulted in keeping a school of skipjack near the vessel's stern and increasing considerably the troll catches. Fish had taken the live bait as shown by fresh anchovies in the stomach contents. The anchovy were taken on board in 17° C water and withstood water temperatures exceeding 29° C during the cruise. Those not used remained in good condition when released in 19° C water near the end of the cruise. They were fed a proprietary brand of "trout chow" twice a day.

Behavior of Tuna

On several occasions, small groups of tuna were seen swimming ahead of the Jordan for several hours. On one day, observations from the bow chamber indicated the presence of both yellowfin and skipjack; on two others, only skipjack. On one of the latter, the fish were sampled from the bow by hook and line using live anchovy bait; four specimens ranged from 60-64 cm. fork length.

The times of skipjack catches on the 2 vessels showed, as expected, the immediate postdawn and predusk periods best for trolling--between 0600 and 0759, 19% of total catch; between 1700 and 1759, 30%. The postdawn percentage probably would have been greater but the 0600-0659 period was poorly sampled because of the transdawn trawling operations. Fish did strike at all other periods of the day but to a lesser extent.

Biology

Fork lengths (cm.) were taken, gonad maturity states noted, and stomach contents preserved for all fish landed. Skipjack ranged from 32 to 71 cm. (about 1-20 lb.) on Jordan, and 37 to 64 cm. on Cromwell. The Jordan data fall into 3 size groups: 32-40 cm. (mean 35.3 cm., n = 17), 45-50 cm. (mean 47.5 cm., n = 11), and 53.71 (mean 59.7.cm., n = 92). Cromwell data tend to indicate similar groups, although numbers are very much fewer, except for 54-60 cm. group (mean 57.3, n = 14). Ten skipjack, 53-68 cm., taken in 3°-5° N zone, were females with recently spent or spent-recovering gonads; of latter category, three females, 46 to 61 cm., were taken in 6°-7° N zone, and four, 59-64 cm., in 10°-11° N zone. All skipjack taken on Cromwell were immature.

Tuna Larvae and Juveniles

Twenty 15-minute neuston hauls were made from Cromwell, and 40 from Jordan. The Jordan samples were sorted on board ship, but these appeared to contain no tuna or billfish larvae or juveniles. On Cromwell 8, and on Jordan 10, midwater-trawl hauls of $1\frac{1}{2}$-hour duration were made around midnight to a depth of 30 m.; and, respectively, 11 and 9 hauls were made to 100 meters, or depth of 20° C isotherm if less than 100 m., spaced equally either side of marine dawn. On Jordan, trawl depth was monitored by telemetry from trawl warp transducers. Her trawl samples were roughly sorted on board; a 17 cm. Auxis (frigate mackerel) was only tuna observed.

Potential Skipjack Forage

Jordan made 42 tows with 5' x 5' net, Cromwell 44, to determine total micronekton and skipjack forage in Part I and II operations. The zooplankton samples from the 1-m. and $\frac{1}{2}$-m. CalCOFI nets, 38 on Jordan and 20 on Cromwell, and all midwater-trawl samples also will be examined in this respect.

Environmental Conditions

In addition to the Part I oceanographic transect, oceanographic conditions will be described for unit areas of Part II. In all,

for Parts I and II, Jordan made 122 XBT drops and 17 STD/Niskin casts; Cromwell made 58 XBT drops and 8 STD/Nansen casts for vertical profiles of temperature, salinity, and oxygen. Nansen casts also were made for STD calibrations.

Acoustic Data

On Jordan, acoustic data were collected on incidence of schools of large-fish targets, single large-fish targets, schools of small fish, and scattering layers. For most of cruise, thermal stratification was so shallow and abrupt that near-surface targets were not detectable with surface-mounted sonars. Single-fish targets were detectable to 150 m. lateral range (30 kHz, 10 m-sec pulse); in November, the incidence ranged from a rate of 180 per day (Nov. 15) down to 6 per day (Nov. 18). Many schools of small fish were detected on the sounder at depths of 260-400 m. On occasion, these schools also were detectable with long-range sonar due to downwelling sound-propagation conditions. The range in these instances was about 2000 m. (11 kHz, 30 m-sec pulse). Major layers were present near thermocline, and at a depth of 350 m. Maximum rates of migration were on the order of 16 cm./sec. vertical motion, with average rates of 6.5 cm./sec. 6 hours before and after local apparent noon. One school of Vinciguerria sp., an important forage species for skipjack, was detected near surface with the 11 kHz sonar at 900 m. range; later, the school was sampled by midwater trawl (15 x 15 m. trawl with 3 mm. bar mesh). No schools of large fish were detected.

Communications

In a two-vessel operation of this type, good radio communications are essential to coordinate efforts. Throughout cruise, Jordan was in contact with Cromwell and NMFS shore station WWD to transfer scientific data, weather, and general messages (CW, voice, teletype). In November alone, Jordan handled 718 messages. Jordan received daily facsimile (FAX) charts of eastern Pacific weather from Fleet Weather Central-Alameda, which included position of the Inter-tropical Convergence Zone. In addition, experiments continued with transmission by FAX of special weather and other charts and data from Fishery-Oceanography Center, La Jolla.

PRELIMINARY RESULTS AND SKIPJACK MIGRATION MODEL

At the time of this first cruise, the NECC was well developed in the area investigated. Recruit size skipjack mainly were caught in the NEC at 12°-14° N and, to a lesser extent, in NEC and SEC immediately adjacent to the NECC. They were not found in the NECC or in the SEC south of the equator. These findings are consistent with the model for this time of year.

FUTURE CRUISES

A second cruise to Area "A" using the Jordan is taking place from March 1 to April 12, 1971. The first cruise to Area "B" is planned for August 16 to October 8, 1971.

ACKNOWLEDGMENTS

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