Tasmanian Tuna Survey Report of First Operational Period

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TASMANIAN TUNA SURVEY
REPORT OF FIRST OPERATIONAL PERIOD

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Summary

This report deals with the first of a two-part survey of southern bluefin tuna in Tasmanian waters. The aim of the survey was to determine the prospects of establishing a tuna fishery in Tasmanian waters, operating from Tasmanian ports. The survey was made by three vessels and one aircraft.

The various aspects of survey proposals and planning are given in detail and the results are documented.

The prospects of successful development of a tuna fishery in Tasmanian waters are discussed in terms of the occurrence of environmental conditions (temperatures) favourable for the accumulation of bluefin tuna into "rippling" schools. The relation between bluefin stocks in Tasmania and in the New South Wales and South Australian fishery grounds is examined.

A temperature atlas has been constructed of the region under survey and of western Tasmania and the coastal waters of western Victoria and south-eastern South Australia, other areas in which bluefin are known to occur. A body of cold surface water probably caused by summer upwelling was found in the Kingston–Portland area. Its effect on tuna behaviour is discussed.

Sightings of striped tuna (*Katsuwonus pelamis*) and jack mackerel (*Trachurus declivis*) are documented and estimates of minimum catches that could be made, using the appropriate fishing gear, are given for each species.

I. INTRODUCTION

It has been known for many years that southern bluefin tuna occur off the coast of Tasmania, but apart from some trolling tests in the early years of World War II no serious attempt had been made to catch these fish commercially.

On July 8, 1963, the Minister for Agriculture and Fisheries, Tasmania, wrote to the Minister for Primary Industry suggesting that a realistic test be made of the commercial possibilities of inshore tuna fishing in eastern Tasmanian waters and seeking participation of the Commonwealth Government in financing the proposed survey on a pound-for-pound basis.

Details of the proposal were discussed by officers of the Department of Primary Industry, the Tasmanian Department of Agriculture, and the CSIRO Division of Fisheries and Oceanography, and a mutually acceptable basis for survey operations was developed. In December 1964 the Minister for Primary Industry approved a Commonwealth contribution from the Fisheries Development Trust Fund of $50,000, which with the Tasmanian contribution provided $100,000 for the survey operation.

A committee was formed from representatives of the three departments concerned and responsibility for the various facets of the survey was allocated. The

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CSIRO Division of Fisheries and Oceanography was to plan the survey and to be responsible for its technical direction and administration. The Department of Primary Industry was to make officers available for consultation on matters connected with gear. The Tasmanian Department of Agriculture was to attend to the nomination of local fishermen who wished to receive instruction in fishing techniques.

It was planned to keep fishermen and other interested parties informed of recent developments by reporting briefly the results of the survey at fortnightly intervals in the CSIRO Fisheries Field Bulletins. In addition CSIRO was to prepare a report to the Committee at the end of each major operational period. This text is the report covering the first operational period from February 1 to May 31, 1965.

II. Survey Planning

(a) *Basis of Planning*

(i) *Surveying Strategy*

As a result of the fishing tests conducted by F. R. V. *Warreen*, F. V. *Weerutta*, and F. V. *Jean Nichols* in the years 1938–42, Serventy (1947, pp. 9 and 13) concluded that "trolling for tuna in Tasmania . . . is not a commercial proposition taken on its own" and that "trolling for southern bluefin on the New South Wales coast can only be regarded as a borderline industry". The tuna industry that developed in New South Wales subsequent to these tests is basically a livebait and pole fishery, trolling contributing very little to the catch. Accordingly, it was reasoned that trolling for tuna in Tasmania was still likely to be unprofitable and that if a fishery were to develop it would be either a livebait and pole fishery or a purse-seine fishery. Both types of fishery are dependent on finding fish fairly tightly schooled at or near the surface and this is usually done by "spotting" from aircraft or fishing boats.

The relative effectiveness of spotting with aircraft and with fishing boats was investigated by Hynd (1963, p. 4), who showed that aircraft are approximately 30 times more efficient than fishing boats in locating "rippling" schools* of fish. This ratio was derived using data that are approximate and have not subsequently been checked, but it is unlikely that a more rigid examination would give a result of a different order; and, since aircraft and fishing vessels cost approximately the same amount of money for a given period, it follows that the most effective use of survey funds will be attained by using aircraft as the principal survey instrument.

* Rippling schools consist of closely packed, slowly swimming fish, the uppermost of which are just below the surface. The interference waves (ripples) set up by the swimming motions of the fish cancel out the wind waves and as a result the rippler appears as a "flat" patch on the sea surface. Rippling fish are not feeding fish — in fact they invariably have empty stomachs. However, they can often be induced to take livebait chum and are then easily polable. Rippling schools provide the bulk of the catch in the New South Wales fishery and a somewhat smaller proportion in the South Australian fishery.

Feeding schools, on the other hand, contain only fish that are actively attacking feed. The individual fish appear briefly at the surface, disappearing and reappearing as the feed sounds and surfaces. Feeding schools are detected by the white splashes that the fish make as they break the surface. Feeding schools are often difficult to chum, and contribute little to the catch in the New South Wales fishery. In the South Australian fishery the proportion of the catch that comes from feeding schools is somewhat higher.

However, some fishing boats are necessary in order to identify with certainty the species and size of fish in schools found by aircraft, to determine the "fishability" of such schools, to troll for subsurface fish (in the hope that they may subsequently be chummed to the surface), to assess the availability of bait fish, to make oceanographic observations, and to act as rescue vessels if the aircraft should have to crash-land at sea. Accordingly, in planning this survey, provision was made for both aircraft and tuna pole fishing boat operations.

A further factor taken into consideration was the amount of "cover" that should be given to the survey area. The Division had had previous experience in the planning and conduct of tuna surveys (in Western Australia, Hynd and Vaux 1963, and in New South Wales and South Australia, unpublished data) and in the interpretation of their results. This experience has emphasized the difficulty of interpreting negative results when the surveying effort is very thinly spread. Hynd (1963) subsequently developed formulae for determining the amount of cover, either required or given, in a survey. With these formulae an estimate can be made of the amount of searching effort necessary for the conclusion that in the event of negative results (i.e. no fish found) the probability is high that there were no fish in the area.

(ii) *Area for Survey*

It was early agreed by all parties concerned that the survey should cover as much as possible of the Tasmanian eastern coastal waters and should extend to 50 miles offshore. The reasons for this were as follows:

(1) Records of earlier surveying by F. R. V. *Warreen* and other vessels referred to above showed that bluefin were taken at many places along the eastern coast. Moreover, sport and commercial fishermen on the eastern coast are accustomed to seeing the fish in appreciable quantities in certain places at certain times. In contrast, surveying by F.R.V. *Warreen*, F.R.V. *Stanley Fowler*, and F.R.V. *Derwent Hunter* had not revealed the presence of substantial quantities of bluefin on the northern coast, and on the western coast fishermen had reported only occasional schools. On the whole, the eastern coast looked the most promising.

(2) The weather on the western and northern coasts of Tasmania is notoriously bad and fishing is often impossible. The weather on the eastern coast is a little better and, moreover, the eastern coast frequently provides a lee in which boats can work.

(3) The harbours in the northern half of the eastern coast are not suitable for boats over about 60 ft length overall (L.O.A.). This fact, taken in conjunction with prevailing weather, limits the effective offshore range of boats operating out of these ports to about 50 miles.

(4) It was estimated from previous survey experience that the proposed sum to be spent on this survey would not permit of extension of operations beyond 50 miles without reducing the cover to an unacceptable level. This is further discussed below.

However, it was resolved that if sightings of good quantities of tuna in areas other than the survey area were reported by fishermen during the period of the survey, the aircraft would be diverted to the area concerned in an attempt to assess the quantities of fish involved.

(iii) *Duration of Survey*

The earlier surveys by F.R.V. *Warreen* had been conducted through all seasons except winter (presumably because of the usually poor winter weather). From the records of these surveys a list was prepared of location and corresponding dates on which fish were captured. This list showed that bluefin could be expected to be found practically anywhere along the eastern coast at any time (except that there was no evidence for the winter season). The centre of best catches shifted in a fairly well-defined pattern, being situated in the north in January, moving southward until May, then returning northward in June and July. From this evidence it was concluded that there would be a reasonably good prospect of successful fishing from January to June (in July the weather is often bad), and it was resolved that the survey should be conducted during this period. Further, since any one year could be abnormal in weather, oceanographic conditions, or fish behaviour, it was resolved to conduct the survey from January to June in two successive years.

(iv) *Allocation of Funds*

Hynd (1963) investigated the problem of assessment of cover, required or given, in tuna spotting operations. He gives (1963, p. 3) a formula for the number of aircraft required to detect all surface appearances of all schools within a given area. The formula is

$$n = \frac{A}{200(20-v)},$$

where n is the number of aircraft, A is the area for survey (in sq nautical miles), and v is the average expected or experienced wind velocity (in knots). The denominator of the right-hand side of the equation represents the area "swept" by an aircraft flying for 2 hr at 100 knots, $(20-v)$ being the effective swept path width. (The spotting range of an aircraft is reduced to zero at wind speeds of 20 knots or greater.) Hence n is in fact the ratio of total area to area swept in 2 hr by one aircraft. The period 2 hr has been introduced because it is believed that rippling schools of bluefin, once they appear at the surface, remain on the average for 4–5 hr and hence inspection of an area every 2 hr should miss very few such appearances.

Calculation of a value of n in any given set of circumstances is unrealistic, since neither surveying nor commercial fishing operations are likely to have enough planes to "saturate" an area. Moreover, planes do not operate in winds stronger than 20 knots (Beaufort scale force 5) and therefore any calculation should be made with respect to time when the wind is force 5 or less.

A more realistic approach is the calculation of the proportion of an area covered by one aircraft when it flies a given number of hours in a given period. This proportion p is given by

$$p = \frac{200(20-v)}{A} \times \frac{t}{T},$$

where A is as before, v is the average expected wind velocity when the expected wind is force 5 or less, t is the number of hours flown by the aircraft, and T is the number of daylight hours in the period under consideration. The value of p so obtained is also the probability that a single appearance of a single school in daylight hours during the given period will be detected.

In the present instance A was 12,000 sq nautical miles and v, calculated from the data in Table 1, was 10 knots. Under these conditions, if an aircraft flew 40 hr per month and there were 12 hr of daylight per day, the proportion of the area covered would be

$$\frac{200\times 10}{12{,}000}\times\frac{40}{30\times 12}=0\cdot 019,$$

i.e. on the average 0·019 of the total area would be under effectively continuous observation during daylight hours, and hence the probability of a school appearing on one occasion at random within the area and being detected would be 0·019.

TABLE 1

MONTHLY AVERAGE WIND FORCE COMPOSITION FOR EASTERN TASMANIAN WATERS

Source: "Sea Areas around Australia. Oceanographic and Meteorological Data." Royal Netherlands Meteorological Institute, Publ. No. 124, 1949

Month	NE. Tasmania (St. Helens) Wind Force Composition (%)					SE. Tasmania (Hobart) Wind Force Composition (%)				
	0	1–3	4–5	6–7	8–12	0	1–3	4–5	6–7	8–12
January	2	37	48	11	2	4	26	35	26	9
February	8	27	36	29	0	2	31	38	19	10
March	6	26	32	28	8	2	30	39	20	9
April	2	35	37	21	5	8	35	30	16	11
May	2	33	32	22	11	4	25	37	26	8
June	6	29	34	17	14	2	17	40	26	15
Average	4	31	37	21	7	4	27	37	22	10
July	0	21	26	19	34	2	19	46	21	12

The probability of an individual school being detected at some time during a fishing season or a survey is considerably higher than this, since there is evidence that individual schools reappear at the surface at least 10 times a season.

Fish spotters have observed that once bluefin schools appear in a given area they are likely to be found in the same area on each of the next 3 or 4 days. Understandably, fishermen have assumed that they are seeing the same fish each day. This cannot yet be confirmed by recaptures of tagged fish, since there have been no recaptures on successive days in a given area of fish released at the one time in the same area. There have, however, been many occasions on which recaptures have been made on successive days in one area of fish released on the one day in a different area. Further, one fish was recovered on the same day 3 hr after liberation approximately 6 miles from the point of release. There is therefore a strong presumption that the fishermen are correct.

The appearances of fish schools at the surface during a season are believed by many fishermen to be regulated to some extent by moon phase and to be more likely to occur on the new and full moons than at other times. Certainly there are times when, despite intensive searching in good weather, fishermen fail to locate schools of fish. If the fishermen's views regarding relation of fish appearance with moon phase are correct, fish should appear at the surface in the order of nine times in 4 months. Whether there is in fact an underlying relation between surface appearance (and therefore catch) and moon phase cannot be demonstrated with the evidence available from commercial catches, which are usually made in an irregularly spaced series of time periods that do not fit moon phase closely. However, the fact remains that there are successive appearances of fish throughout a season and tagging information suggests that these could be successive reappearances of the same fish.

This information consists of a number of sets of recaptures, in a succession of areas and times, of fish released early in a season on the one day in one area. Of these sets the longest contains 15 recaptures made during a period of 98 days, the time interval between pairs of recaptures ranging from 1 to 28 days. Pooling recaptures separated by 4 days or less results in a grouping of the data into eight time periods with intervals of 8, 28, 9, 8, 11, 10, 10, and 12 days between means. This grouping is obviously not consistent with the fishermen's hypothesis of fortnightly appearances of fish. It suggests a much shorter cycle. However, it is consistent with the hypothesis that schools of fish are likely to appear at the surface in the order of 10 periods per season (of 4 months) and on successive days in each of these periods. On this evidence it seems that an estimate of 10 surface appearances per season of individual schools is conservative.

If this estimate is accepted as realistic and it is assumed that the fish will behave in Tasmanian waters in the same way as they behave in New South Wales waters,* the probability that an individual school would be detected at some time during a 4 month survey in which an aircraft flew 40 hr per month is at least 10 times greater than the 0·019 calculated above, i.e. 40 hr flying per month for 4 months when the wind is force 5 or less can be expected to detect of the order of one-fifth of all schools. This is an acceptable proportion for survey purposes.

The budget provisionally allocated for the survey was $80,000, to be spread over two 6-month periods in successive years. Thus approximately $6000 was available each month for charter of both aircraft and fishing boats, the remainder being for miscellaneous expenses. Because of the distance to sea that the aircraft was required to fly, it was necessary (in accordance with Department of Civil Aviation (D.C.A.) regulations) to employ a light twin-engined aircraft. The cost of 40 hr flying with such an aircraft is about $2000. Tuna fishing vessels around 60 ft L.O.A. can be chartered for about $1000 per week. Therefore the provisional budget allowed for 40 hr flying per month by one aircraft and the supporting operations of one fishing boat.

While this level of aircraft cover is acceptable, the fishing boat operations are inadequate. Without considering the investigation of fish school sightings, one boat is inadequate for rescue facilities or oceanographical observations in the area covered

* See p. 40 for further discussion of this assumption.

by the spotting plane. Experience obtained during a survey in New South Wales waters in 1963 indicated that three surface craft would be needed to give adequate support to the aircraft operation.

This difficulty was resolved by increasing the budget to $100,000, by reducing the survey months in each year to four, and by providing the services of F.R.V. *Marelda* in lieu of one fishing boat. These measures made it possible to plan for 14 hr flying per week by the aircraft and to provide for the charter of two fishing boats. The flying hours would give a cover of 0·028 and this was made an aim of the operations. The months of January and June were excluded from the survey period, January because the behaviour of the bluefin in Bass Strait and north-eastern Tasmanian waters during this month is moderately well documented (by the operations of the New South Wales tuna fleet and Tasmanian cray and salmon boats), and June because the prospect of bad weather on the south-eastern coast was greatest for this month (see Table 1).

(*b*) *Details of Planning*

(i) *Surveying Tactics*

In commercial searching operations for bluefin tuna, whether by aircraft or fishing boats, as much use as possible is made of indicators of "preferred bluefin conditions". Such indicators are water temperature, water colour, presence of "fronts", presence of current lines, presence of "feed", presence of sea birds, etc. These indicators have been used by fishermen in their searching for bluefin for many years and have proved to be reliable to varying degrees, e.g. the presence of sea birds in an area is probably connected with the presence of feed (krill, small fish, etc.) in the area. This feed may or may not also be attractive to tuna. Fishermen have found, however, that on the average tuna are more likely to be found where there are birds and feed, other things being equal.

A far more reliable criterion of preferred bluefin conditions, at least in the New South Wales and South Australian fisheries, is water temperature. It is the experience of professional fishermen that most of their poled catches are made from schools appearing in waters whose surface temperatures lie between 62 and 68°F (16·7 and 20·0°C). This is largely borne out by the data presented in Table 2, which shows the association between sea surface temperature and commercial catch during the 1963 fishing season in New South Wales. Detailed records (in fishermen's bridge logs) were available for 75·8% of the total catch. Of the remaining 24·2%, approximately 1% were fish caught by trolling early in the season and approximately 23% were undocumented pole-caught fish. There is no reason to believe that the behaviour of this 23% of pole-caught fish was in any way different from that of the fully documented 75·8%, since the fishing vessels that failed to keep detailed logs worked in the same areas as those that kept detailed logs. Of the fully documented catch, 4·2 short tons (0·2%) was taken from waters with surface temperatures less than 62°F and 716·8 short tons (32·9%) from waters with surface temperatures greater than 68°F. Thus the data presented in Table 2 support the statement of the professional fishermen, except that an appreciable proportion of the catch was taken from waters with surface temperatures greater than 68°F. Many of the fishermen have remarked in conversation

TABLE 2

ASSOCIATION BETWEEN SEA SURFACE TEMPERATURE AND COMMERCIAL CATCH OF SOUTHERN BLUEFIN TUNA IN NEW SOUTH WALES FROM AUGUST 1963 TO FEBRUARY 1964

Dashes indicate no catch

Month	Total Catch (short tons)	Poled Catch with Temperature Documentation* (short tons)	Documented Catch† (short tons) from Water with Surface Temperature of: < 62	62–68	> 68	62–69	> 69°F
Aug.	0·9	—					
Sept.	32·7	3·0‡ (9·2)	3·0 (100)	—	—	—	—
Oct.	59·9	53·5 (89·3)	1·2 (2·2)	52·3 (97·8)	—	52·3 (97·8)	—
Nov.	684·8	486·0 (71·0)	—	428·3 (88·1)	57·7 (11·9)	484·5 (99·7)	1·5 (0·3)
Dec.	1191·4	948·8 (79·6)	—	567·1 (59·8)	381·7 (40·2)	928·2 (97·8)	20·6 (2·2)
Jan.	881·1	689·5 (78·3)	—	412·1 (59·8)	277·4 (40·2)	650·5 (94·3)	39·0 (5·7)
Feb.	26·4	—					
Total	2877·2	2180·8 (75·8)	4·2 (0·2)	1459·8 (66·9)	716·8 (32·9)	2115·5 (97·0)	61·1 (2·8)

* Values in parentheses give the percent of the total catch.
† Values in parentheses give the percent of the documented catch.
‡ The balance (29·7 tons) was nearly all troll-caught fish.

that the 1963 season was unusual in this respect. Further, inspection of the far right column of Table 2 shows that only 61·1 short tons (2·8%) was taken from waters with surface temperatures greater than 69°F, so that in fact 97·0% of the fully documented catch was taken from waters whose surface temperatures lay in the range 62–69°F. This is approximately the proportion that fishermen expect to take each year in waters with surface temperatures in the range 62–68°F, so we may accept 1963 as a somewhat unusual season in which the upper temperature limit for the appearance of rippling schools was 1°F higher than normal. However, as a general rule it is a good tactic when searching for rippling schools to locate areas of water with surface temperatures in the range 62–68°F.

Another useful indicator is the presence or absence of fronts. These to fishermen are phenomena that are visible at the surface either as a line of slick or debris, or as a change in water colour, or both, and that usually show on their thermographs as a sharp drop or rise in temperature, sometimes of as much as 5°F (2·8°C). If these fronts are found where water temperatures are right for rippling behaviour, fishermen have found that rippling bluefin appear more often near the fronts than away from them.

If full advantage is to be taken of these indicators, aircraft and vessels cannot adhere to a rigid plan of movements. This is reflected in the instructions given to both aircraft and fishing boats in the present survey.

The basic strategy of the operation consisted in

(1) the use of an aircraft to cover the whole of the survey area at regular intervals according to a more or less fixed flight plan;

(2) the use of three surface craft to investigate the aircraft's findings or to investigate areas with promising surface indications;

(3) the routine collection of oceanographic data by the surface craft to help explain the presence or absence of fish and, if present, to help explain their behaviour.

Both aircraft and surface craft, however, were instructed to diverge from such fixed courses as they were given to investigate promising indications of the presence of tuna, the aircraft to follow major current lines and the surface craft to follow fronts.

(ii) *Aircraft Search Plans*

The aircraft chartered was a Piper Apache (VH-RLB) with a maximum endurance of some 6½ hr. Allowing for the mandatory D.C.A. reserves of 45 min plus 15% of planned flight time, the maximum planned flight time was of the order of 4 hr. Accordingly two standard flight plans, each of approximately 3½ hr flight time, were drawn up. In plan 1 the aircraft was to depart from Hobart and land at St. Helens; in plan 2 the aircraft was to depart from and land at St. Helens. The aircraft was to fly according to plans 1 and 2 in that order on one day, and plans 2 and 1 in that order on the following day, thus arriving back in Hobart. If the weather was unfavourable for spotting on the second day the aircraft was to remain at St. Helens until conditions improved. This routine was to be followed once a week, giving a total of approximately 14 hr flying per week. The proposed flight plans are shown in Figure 1. Apart from interference by bad weather, these plans proved to be practicable in that navigational problems in them were minimal and reduction of spotting range by glare (sunlight reflected from the sea surface) could not have been improved by replanning of flight paths.

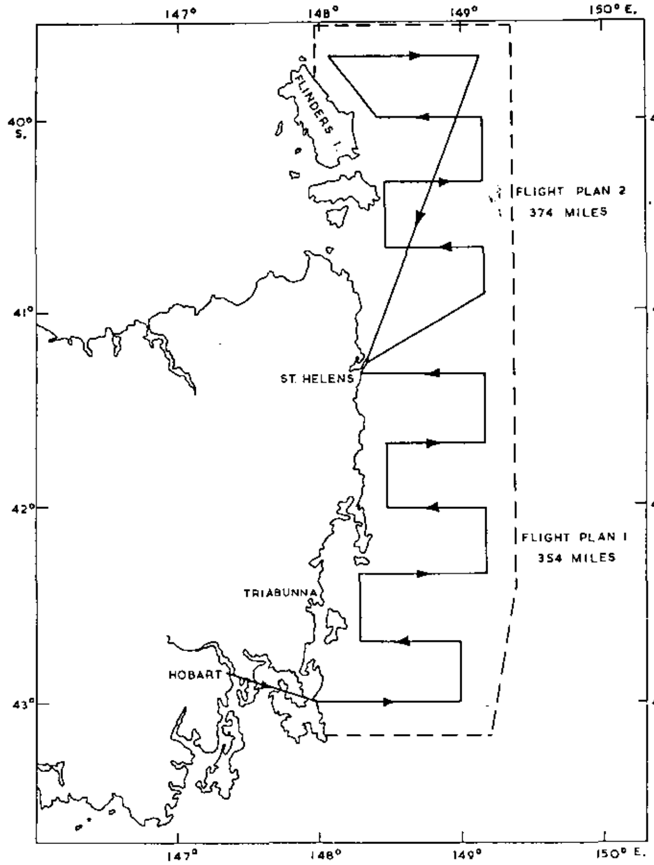


Fig. 1.—Aircraft flight plans for Tasmanian tuna survey. The area enclosed by the broken line and the coast is 11,300 sq miles.

The aircraft carried a fish spotter, a professional fisherman with considerable experience in aerial and surface vessel spotting of tuna and salmon. His instructions were as follows.

Construct track chart of each flight flown on grid charts provided. Have pilot check position by radio compass at seaward end of east–west legs where possible.*

In addition to flight paths, record the following information on the charts:

(1) Location and direction of current lines. Mark prominent current lines as solid lines with triangles on the side on which the water is rougher. Mark weak current lines as thin wavy lines.

* CSIRO research workers use a grid system for recording positions in Australian coastal waters and blank foolscap-sized sectional charts are available for field use. Part of the system of grid references is shown in Figures 8(*a*)–8(*c*).

(2) *Water colour, e.g. dirty green, green, blue, etc.*

(3) *Location of survey vessels if sighted or if given by radio (any appropriate symbol).*

(4) *Location of Japanese longline vessels sighted (any appropriate symbol).*

(5) *Wind speed and direction.*

(6) *Fish and bird occurrences.*

Record fish, bird, whale occurrences, etc. as follows:

(i) Southern bluefin	*B (in blue pencil)*
(ii) Striped tuna	*S (in red pencil)*
(iii) Albacore	*A (in green pencil)*
(iv) Other fish	
Salmon	*Sa (in black pencil)*
Jack mackerel	*J (in black pencil)*
Feed	*F (in black pencil)*
(v) Mutton Birds	*M (in black pencil)*
(vi) Whales	*W (in black pencil)*
(vii) Porpoises	*P (in black pencil)*

(iii) *Fishing Boat Search Plans*

Two tuna fishing boats from Eden, *Two Freddies* and *Rosebud,* were selected from a number of applicants. *Two Freddies* is an "ice boat", 56 ft L.O.A., with a normal crew of five including the skipper. *Rosebud* is also an ice boat, 60 ft L.O.A., with a normal crew of five. Although ice boats are gradually disappearing from the Australian tuna fleet, the lack of refrigeration was not considered a handicap on the survey, since there was no intention to catch and store large quantities of tuna. Both vessels carried echo-sounders and thermographs.

Instructions to the skippers of these boats for the conduct of operations were far less explicit than corresponding instructions to the aircraft pilot and spotter. It was explained to them that in general they were expected to carry out normal tuna searching procedures and that their areas and bases of operation would be dictated by the results of the aircraft's observations and of their own observations of water conditions. Specific instructions, however, were issued to ensure that both vessels would not be searching close together even if they used the same port or anchorage overnight. Also radio schedules (see below) were arranged so that vessel movements could be directed from Cronulla, if necessary. Further, the contracts with the boats' owners provided for two rates of pay, one for hours when the boat was not under way, the other (double the first) for hours when the boat was under way. In this way an incentive to keep working was introduced into the contracts.

The boats were fitted with bathythermographs (B.T.). A set of monthly traverses to supplement F.R.V. *Marelda*'s traverses was planned (see below) and, in addition, instructions were issued to make other B.T. observations where appropriate at 10 mile intervals.

In the event that a boat located polable fish, the skipper was instructed to work the school until its fishability and the species and size of fish were proved, then to concentrate on catching for tagging (which requires more care in catching and handling of fish than normal fishing operations).

On each boat one of the normal crew was replaced by a Technical Assistant from Cronulla, whose duty it was to keep appropriate records of the vessel's activities, to carry out the hydrological work, and (with the assistance of the crew) to tag and measure fish.

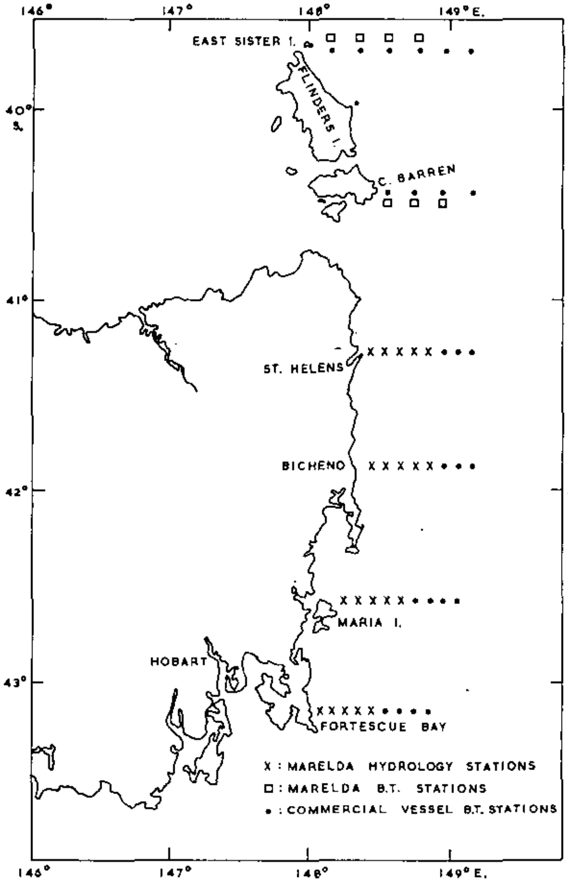


Fig. 2.—F.R.V. *Marelda* and commercial vessel hydrology and bathythermograph (B.T.) stations.

(iv) *F.R.V.* Marelda *Cruise Plans*

Cruise plans for F.R.V. *Marelda* (36 ft L.O.A.) allocated first priority to hydrological work. Six traverses, each consisting of three to five stations and extending eastward from the coast up to 25 miles, were planned. Stations of the two most northerly traverses (off East Sister Island and Cape Barren) were to be occupied once in February. Stations of the other four (off St. Helens, Bicheno, Maria Island, and Fortesque Bay) were to be occupied once a month in March, April, and May. This work was to be supplemented by observations from one or other of the fishing boats, which were to occupy stations of the East Sister Island and Cape Barren traverses in March, April, and May and to extend the other four traverses to seaward in the same months by a further three or four stations. All *Marelda* and fishing boat stations together with the type of observations to be carried out are shown in Figure 2.

Second and subsequent priorities in *Marelda* cruise plans were (1) inshore searching for tuna between Triabunna and St. Helens, (2) B.T. traverse along a line from grid reference A285 to B485, thence to B982, (3) inshore searching for tuna between Fortesque Bay and Maria Island. All southern bluefin tuna that were viable after capture were to be tagged and released.

(v) *Radio Communications*

Both fishing boats and *Marelda* carried h.f. radio and maintained contact with each other on 4095 kc/s. The aircraft maintained contact with the fishing boats on 4620 kc/s. In addition the Cronulla base station VL2CO maintained contact with the fishing boats on three daily schedules on 4620 kc/s, either direct or by relay through VH2BK in Eden or F.V. *Marauder* fishing in the vicinity of Eden.

In this way the whole operation was properly coordinated and changes of plans were readily communicated to the fishing boats or to *Marelda*.

III. Survey Results

The results achieved on the survey have been briefly reported in CSIRO Fisheries Field Bulletins Nos. 21–28 inclusive. They are given here in greater detail.

(*a*) *Areas Searched*

(i) *Aircraft Searching*

Figures 3(*a*)–3(*i*) have been prepared from the completed grid charts returned by the spotter. The outer boundary of the area searched has been determined by drawing a line 10 miles outside the outer limits of the flight path. The flight path itself is not reproduced since in general it followed the planned path. Sightings of fish occurrences, current lines, fishing boats, etc. are as recorded by the spotter.

(ii) *Boat Searching*

Figures 4(*a*)–4(*m*) show the tracks of F.R.V. *Marelda*, F.V. *Two Freddies*, and F.V. *Rosebud* during the eight half-monthly periods of the survey. They are reproduced practically unchanged from the Fisheries Field Bulletins.

(*b*) *Searching Effort*

(i) *Aircraft Searching*

As stated above it was planned to fly 14 hr per week during the period of the survey. The actual time flown was 204 hr 43 min, which represents an average of 12 hr per week. Some of this flying was on the west coast and some of the remainder represents "dead" time, since it was over land. The "effective" flying time spent on the east coast was 161 hr 17 min. This is tabulated by half-monthly periods in Table 3.

(ii) *Boat Searching*

When costing the projected survey it was estimated that the average hours the two fishing vessels would steam per week, having regard to the expected weather conditions, was 50. Hours actually steamed by *Rosebud* were 838 hr 15 min and by *Two Freddies* 710 hr 5 min. These represent average weekly rates of 48·9 and 41·4 respectively. The low average of *Two Freddies* was partly due to 6 days lost through engine trouble. If these 6 days are excluded, her average weekly rate was 43·6.

TABLE 3

EFFECTIVE FLYING TIME AND COVER GIVEN TO THE EAST COAST SURVEY AREA BY HALF-MONTHLY PERIODS FROM FEBRUARY 1 TO MAY 31, 1965

Period	Date	Effective Flying Time		Cover Given
1	Feb. 1–14, 1965	24 hr	35 min	0·038
2	Feb. 15–28, 1965	16	13	0·021
3	Mar. 1–15, 1965	14	10	0·017
4	Mar. 16–31, 1965	41	35	0·063
5	Apr. 1–15, 1965	21	25	0·029
6	Apr. 16–30, 1965	13	30	0·022
7	May 1–15, 1965	27	22	0·043
8	May 16–31, 1965	2	7	0·004
	Total	161	17	

(*c*) *Fish Catches and Sightings*

Sightings of fish and other occurrences by the aircraft are recorded in Figures 3(*a*)–3(*i*). Tuna catches and sightings of other fish, whales, etc. by the fishing boats are recorded in Figures 5(*a*)–5(*i*). The numbers of fish of each tuna species caught and the numbers of bluefin sightings are tabulated by monthly periods in Table 4. Aircraft sightings of striped tuna are listed in Table 5, jack mackerel in Table 6.

(*d*) *Oceanographical Results*

Surface isotherms or average temperatures for each half-monthly period are given in Figures 5(*a*)–5(*i*). These figures have been constructed from the information contained in the thermograms recorded by the vessels when following the tracks shown in Figures 4(*a*)–4(*m*) inclusive. The thermographs were all Negretti and Zambra Model T353, range 0–30°C, readable to 0·2°C. They were checked every 3 hr against the temperature of a surface sample taken by bucket. The temperature of this sample was read from a constant immersion thermometer accurate to 0·1°F. Discrepancies between thermograph temperatures and temperatures of samples taken by bucket rarely exceeded 0·2°C.

The numbers of oceanographical observations made each month are tabulated in Table 7.

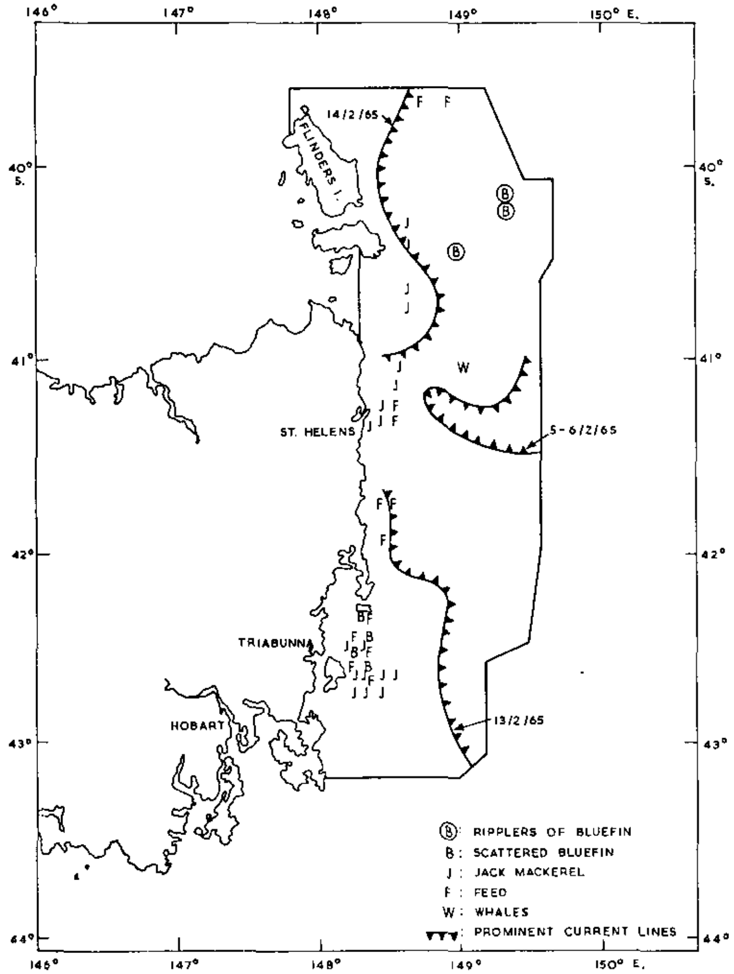


Fig. 3(*a*)

Figs. 3(*a*)–3(*i*).—Aircraft coverage and sightings on (*a*) February 5, 6, 13, and 14; (*b*) February 18, 24, 25, and 26; (*c*) March 5, 10, and 11; (*d*) March 15, 16, 17, 19, 20, 23, 24, 25, and 26; (*e*) April 2, 9, 13, 14, and 15; (*f*) April 24, 27, 28, and 29; (*g*) May 1, 2, 6, and 7, and May 14 and 15 in part; (*h*) May 3 and 4, and May 14 and 15 in part; and (*i*) May 25; 1965.

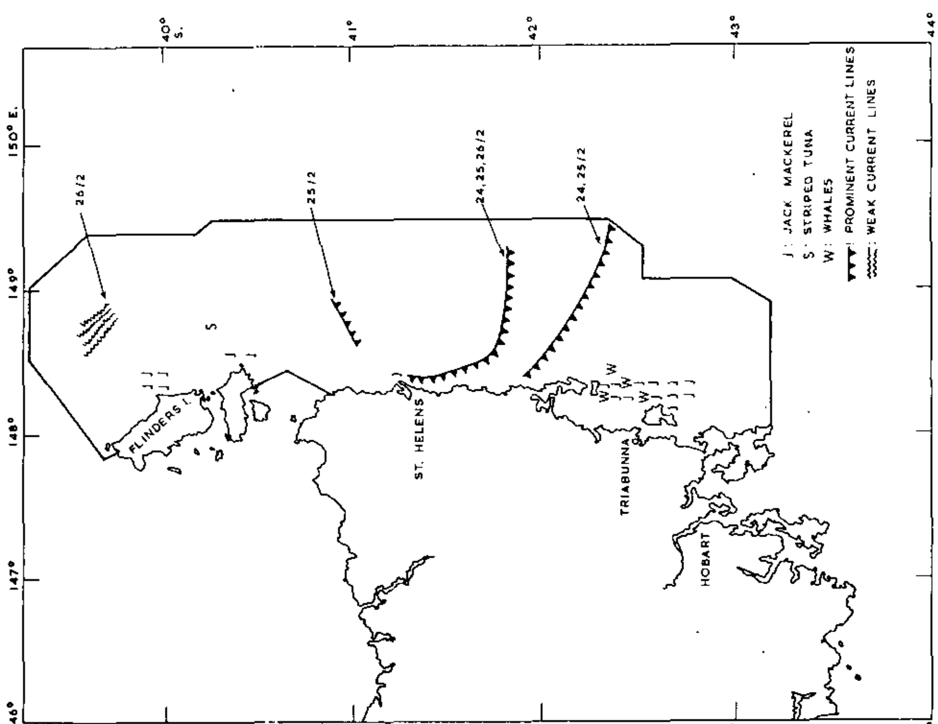

26/2
25/2
24, 25, 26/2
24, 25/2
FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
J: JACK MACKEREL
S: STRIPED TUNA
W: WHALES
: PROMINENT CURRENT LINES
: WEAK CURRENT LINES

Fig. 3(*b*)

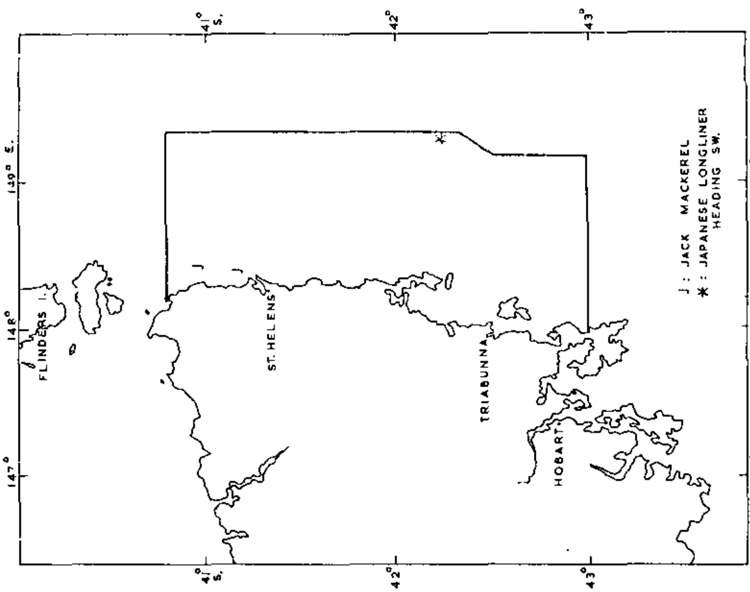

FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
J: JACK MACKEREL
✱: JAPANESE LONGLINER HEADING SW.

Fig. 3(*c*)

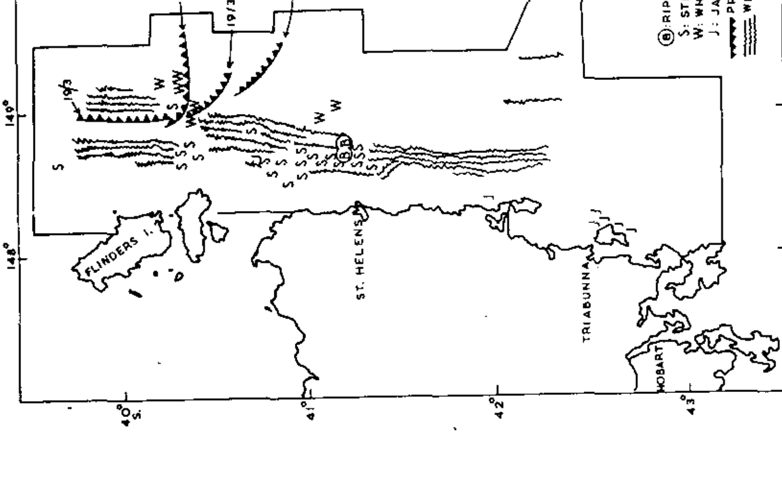

FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
19/3
16/3
25/3
B: RIPPLERS OF BLUEFIN
S: STRIPED TUNA
W: WHALES
J: JACK MACKEREL
PROMINENT CURRENT LINES
WEAK CURRENT LINES

Fig. 3(d)

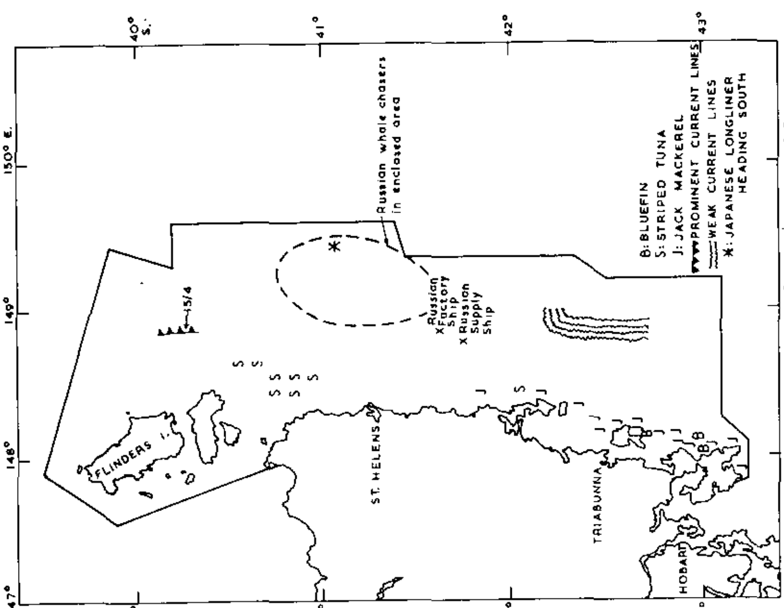

FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
15/4
Russian whale chasers in enclosed area
Russian Factory Ship
Russian Supply Ship
B: BLUEFIN
S: STRIPED TUNA
J: JACK MACKEREL
PROMINENT CURRENT LINES
WEAK CURRENT LINES
*: JAPANESE LONGLINER HEADING SOUTH

Fig. 3(e)

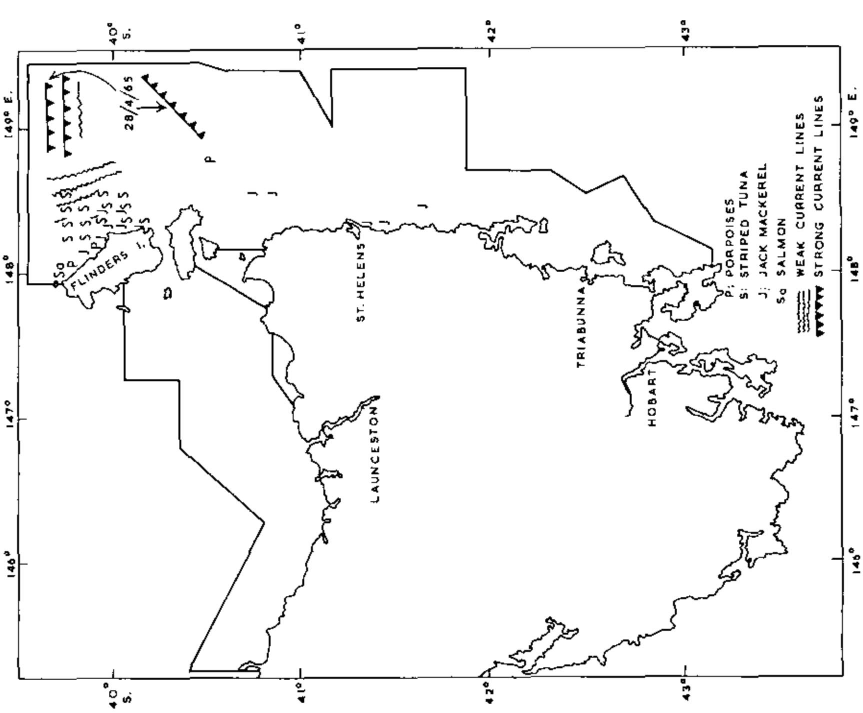

28/4/65
FLINDERS I.
ST. HELENS
LAUNCESTON
TRIABUNNA
HOBART
P: PORPOISES
S: STRIPED TUNA
J: JACK MACKEREL
Sa SALMON
WEAK CURRENT LINES
STRONG CURRENT LINES

Fig. 3(f)

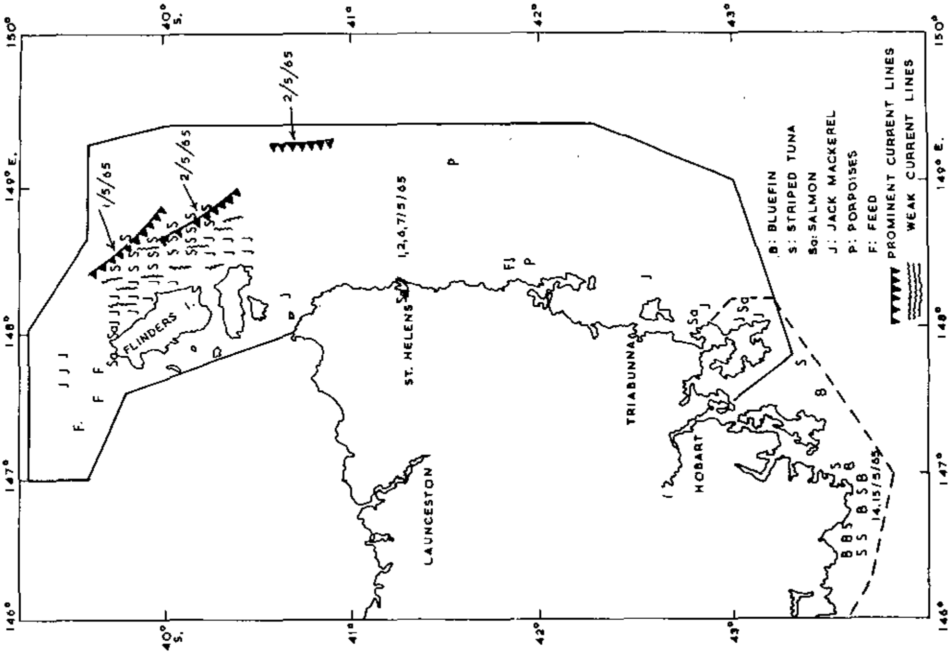

1/5/65
2/5/65
2/5/65
1,2,6,7/5/65
14,15/5/65
FLINDERS I.
ST. HELENS
LAUNCESTON
TRIABUNNA
HOBART
B: BLUEFIN
S: STRIPED TUNA
Sa: SALMON
J: JACK MACKEREL
P: PORPOISES
F: FEED
PROMINENT CURRENT LINES
WEAK CURRENT LINES

Fig. 3(g)

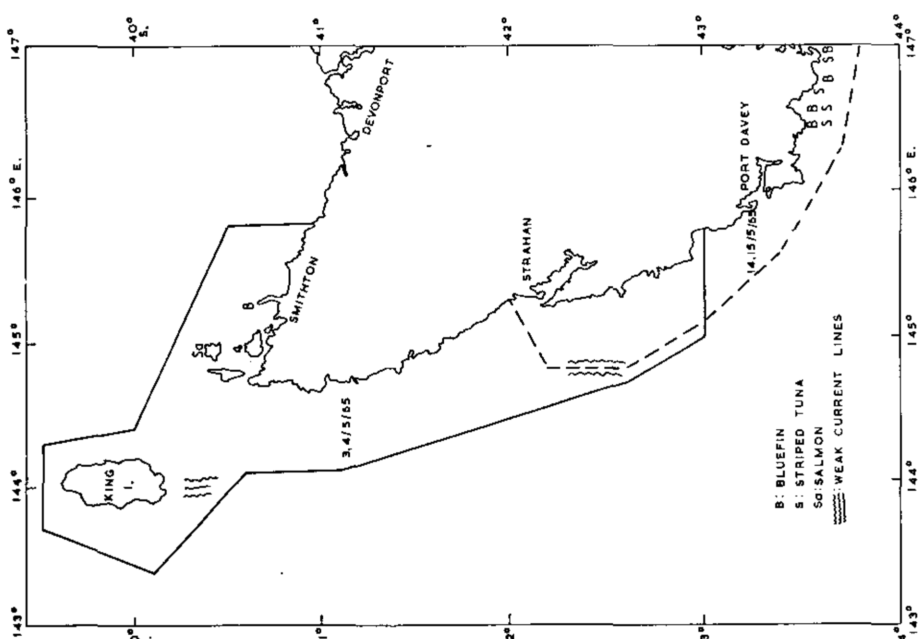

143°
144°
145°
146° E.
147°
40° S.
41°
42°
43°
44°
KING I.
SMITHTON
DEVONPORT
STRAHAN
PORT DAVEY
3,4/5/55
14,15/5/55
B: BLUEFIN
S: STRIPED TUNA
Sa: SALMON
: WEAK CURRENT LINES

Fig. 3(h)

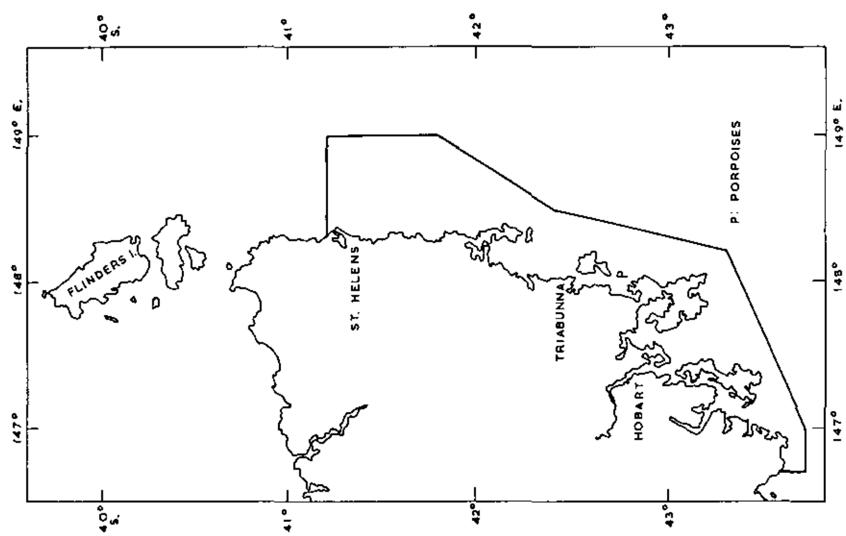

147°
148°
149° E.
40° S.
41°
42°
43°
FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
P: PORPOISES

Fig. 3(i)

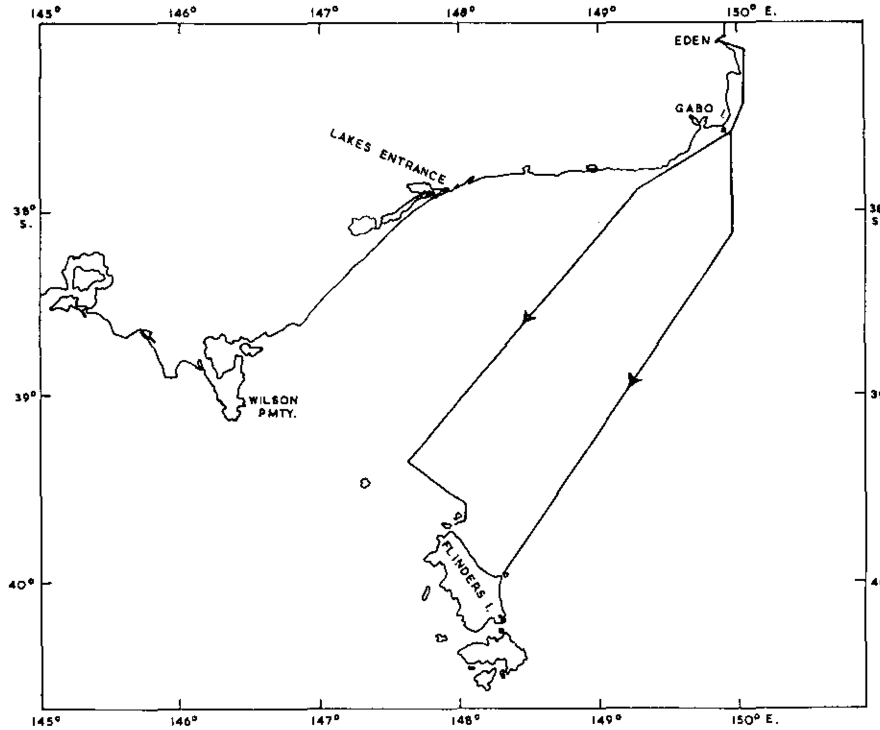


Fig. 4(a)

Figs. 4(*a*)–4(*m*).—Track charts of survey vessels on (*a*) February 1–3, (*b*) February 3–12, (*c*) February 16–28, (*d*) March 1–15 in part, (*e*) March 1–15 in part, (*f*) March 16–25 in part, (*g*) March 16–25 in part, (*h*) April 1–15, (*i*) April 16–30 in part, (*j*) April 16–30 in part, (*k*) May 1–15 in part, (*l*) May 1–15 in part, and (*m*) May 16–31; 1965.

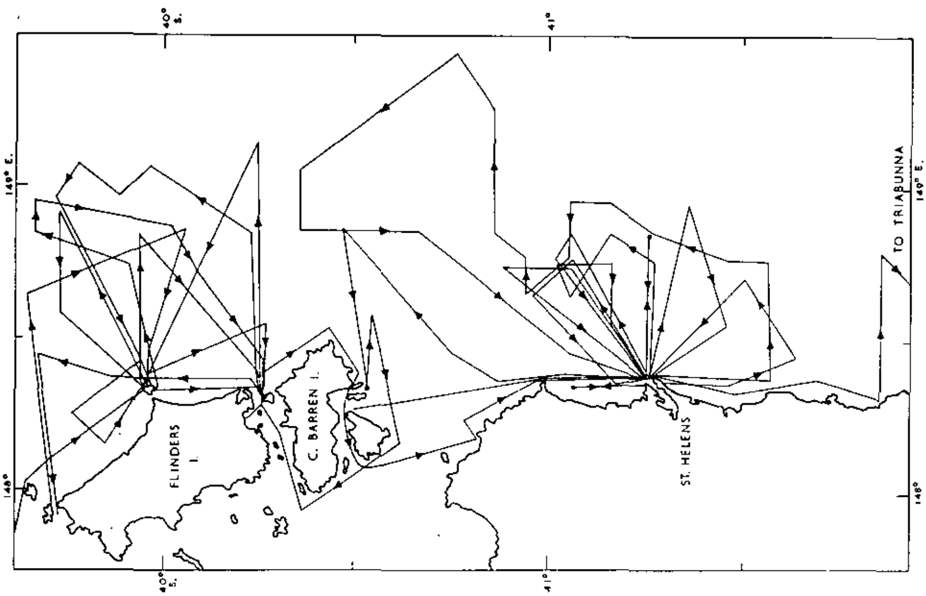

40° S.
41°
149° E.
148°
FLINDERS I.
C. BARREN I.
ST. HELENS
TO TRIABUNNA

Fig. 4(c)

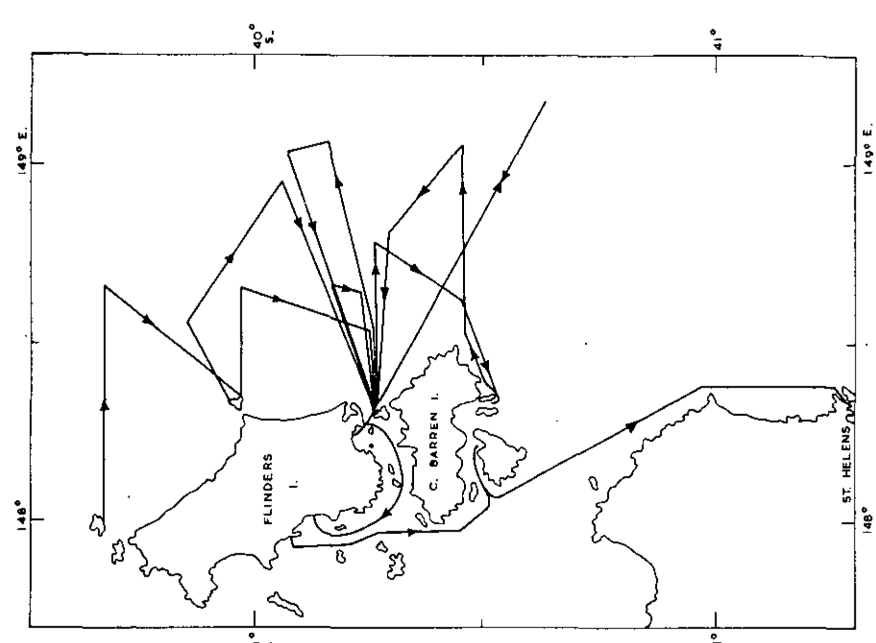

40° S.
41°
149° E.
148°
FLINDERS I.
C. BARREN I.
ST. HELENS

Fig. 4(b)

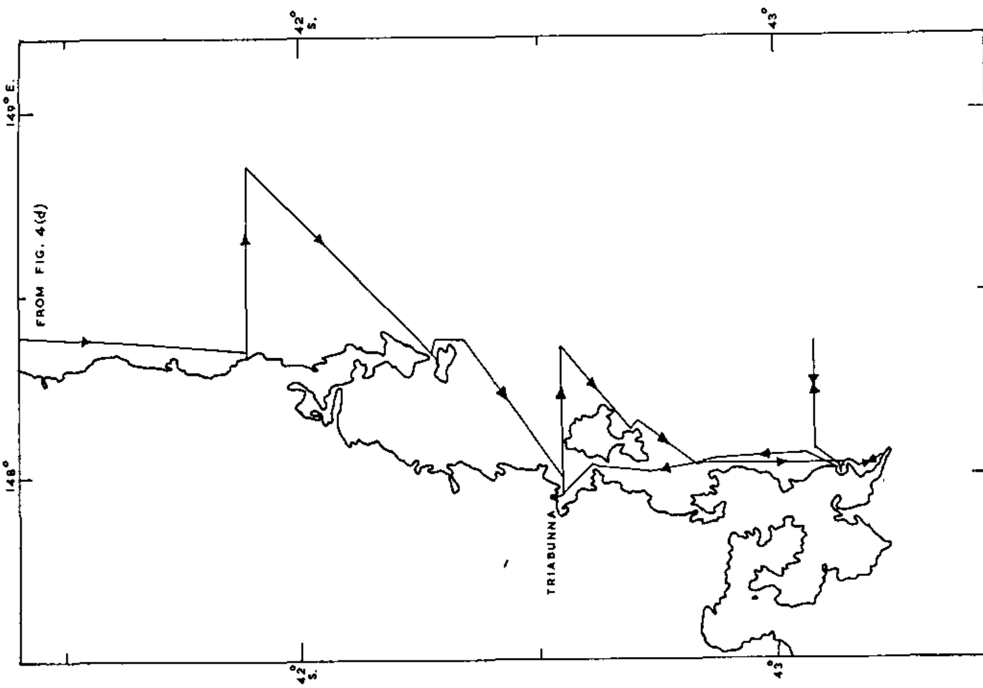

FROM FIG. 4(d)
TRIABUNNA
42° S.
43°
148°
149° E.

Fig. 4(e)

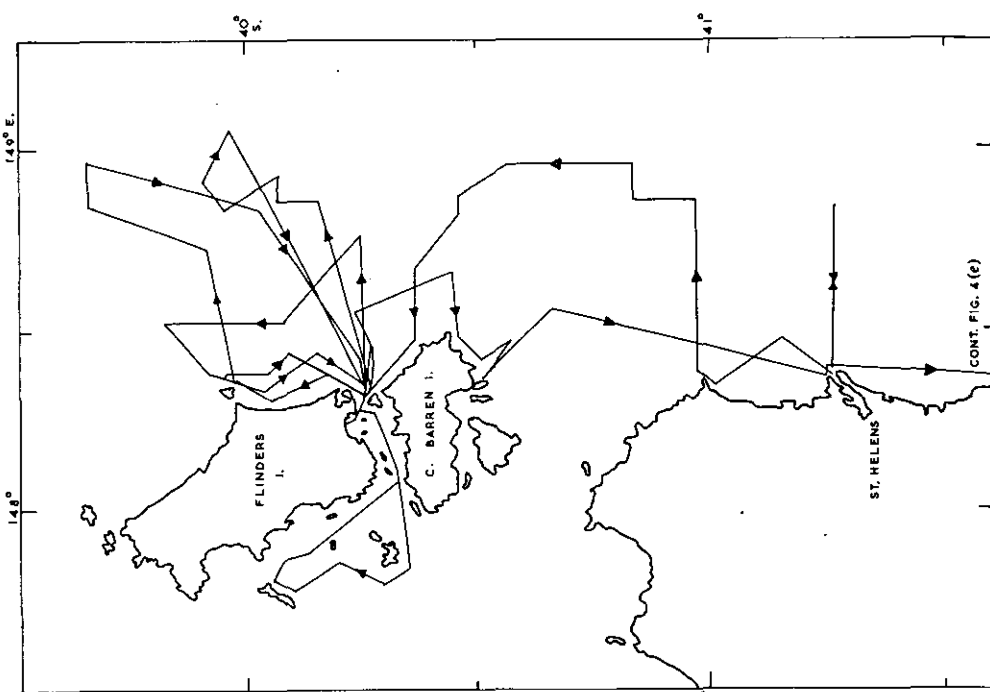

FLINDERS I.
C. BARREN I.
ST. HELENS
CONT. FIG. 4(e)
40° S.
41°
148°
149° E.

Fig. 4(d)

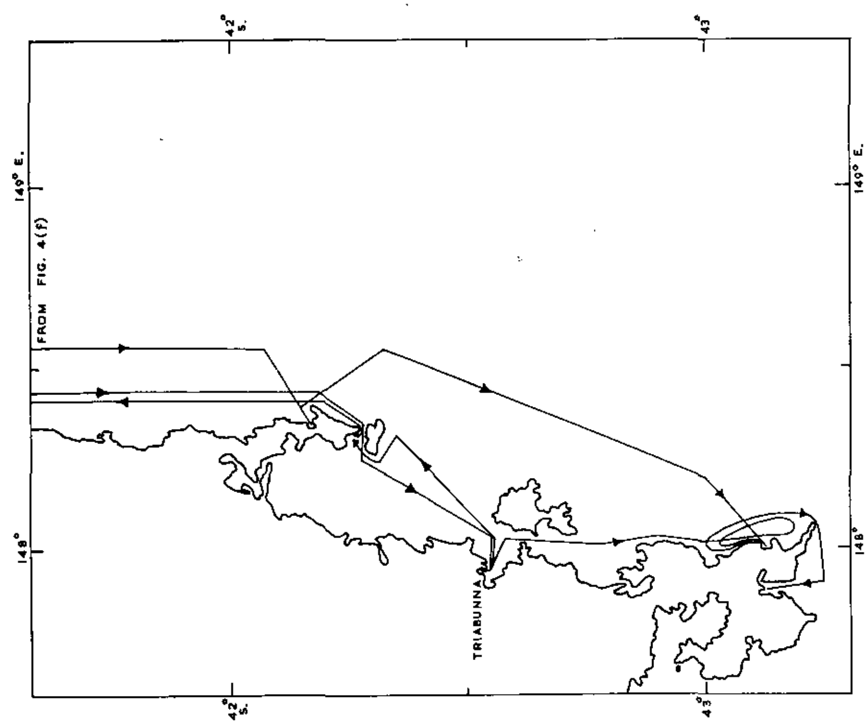

42°
S.
43°
149° E.
148°
FROM FIG. 4(f)
TRIABUNNA

Fig. 4(g)

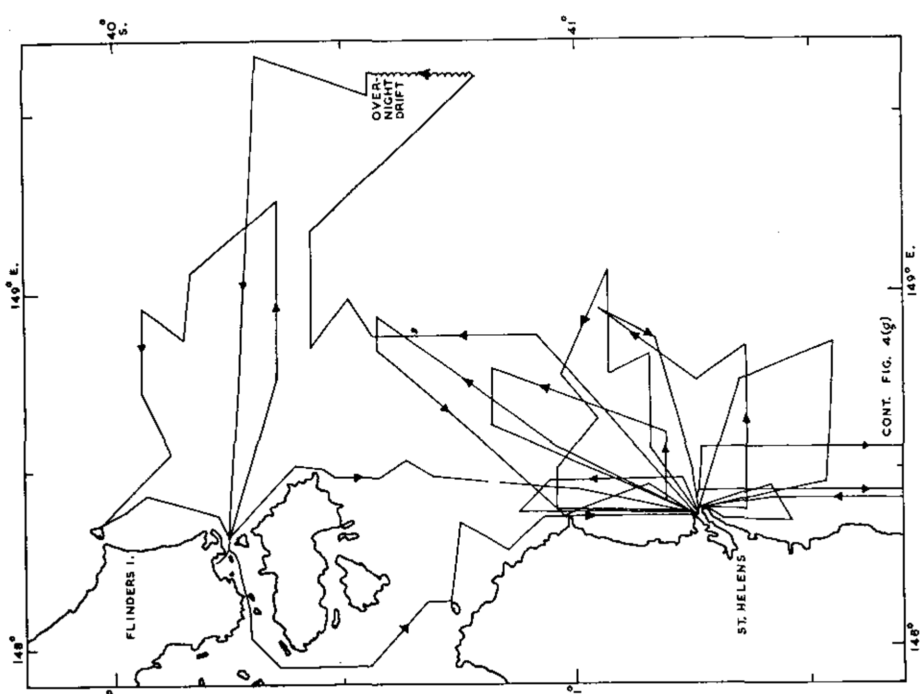

40°
S.
41°
149° E.
148°
OVER-
NIGHT
DRIFT
FLINDERS I.
ST. HELENS
CONT. FIG. 4(g)

Fig. 4(f)

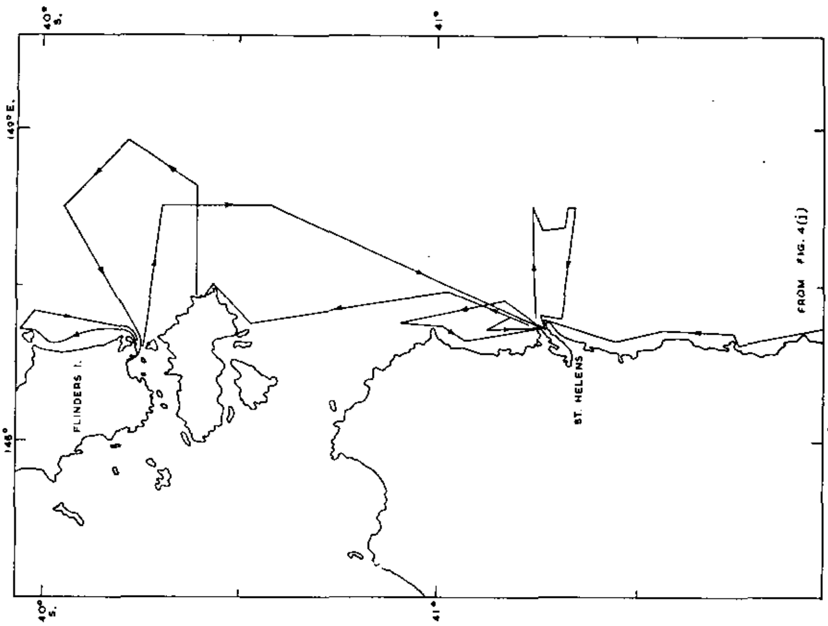

40° S.
41°
149° E.
148°
FLINDERS I.
ST. HELENS
FROM FIG. 4(j)

Fig. 4(i)

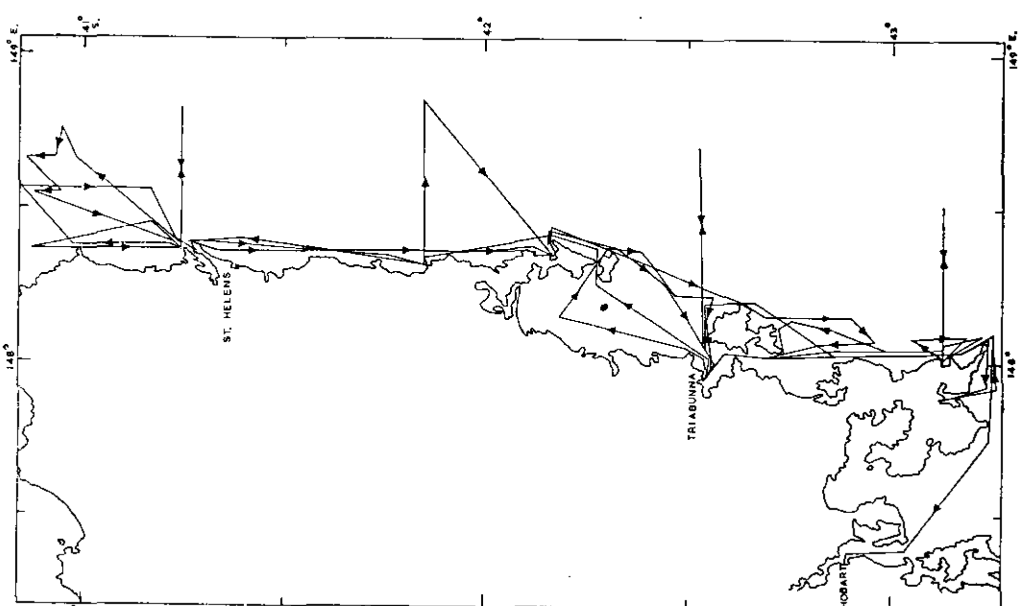

41° S.
42°
43°
149° E.
148°
ST. HELENS
TRIABUNNA
HOBART

Fig. 4(h)

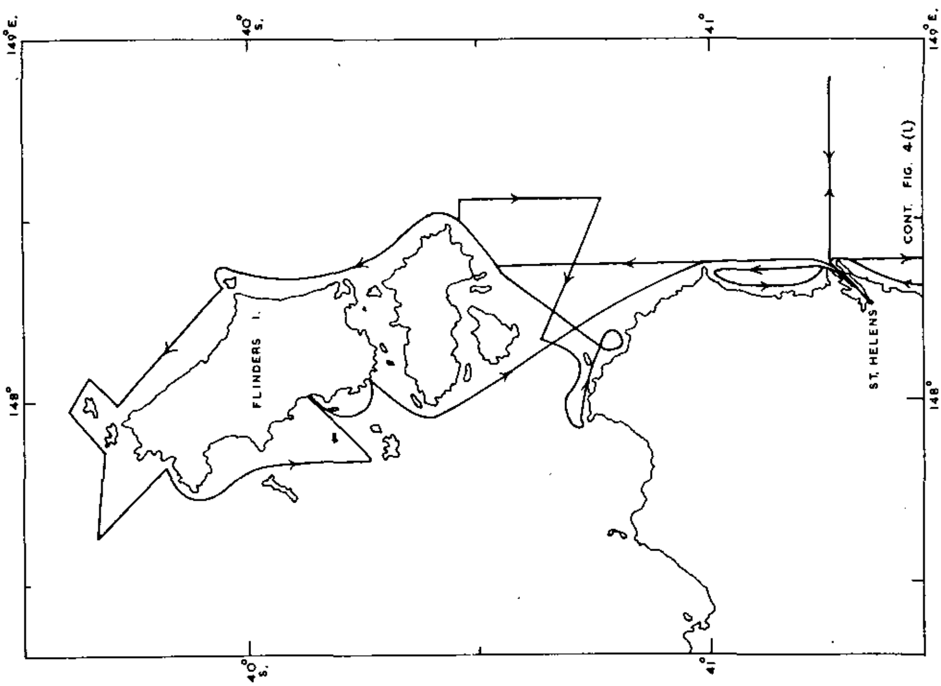

149°E.
40° S.
41°
148°
FLINDERS I.
ST. HELENS
CONT. FIG. 4(l)

Fig. 4(k)

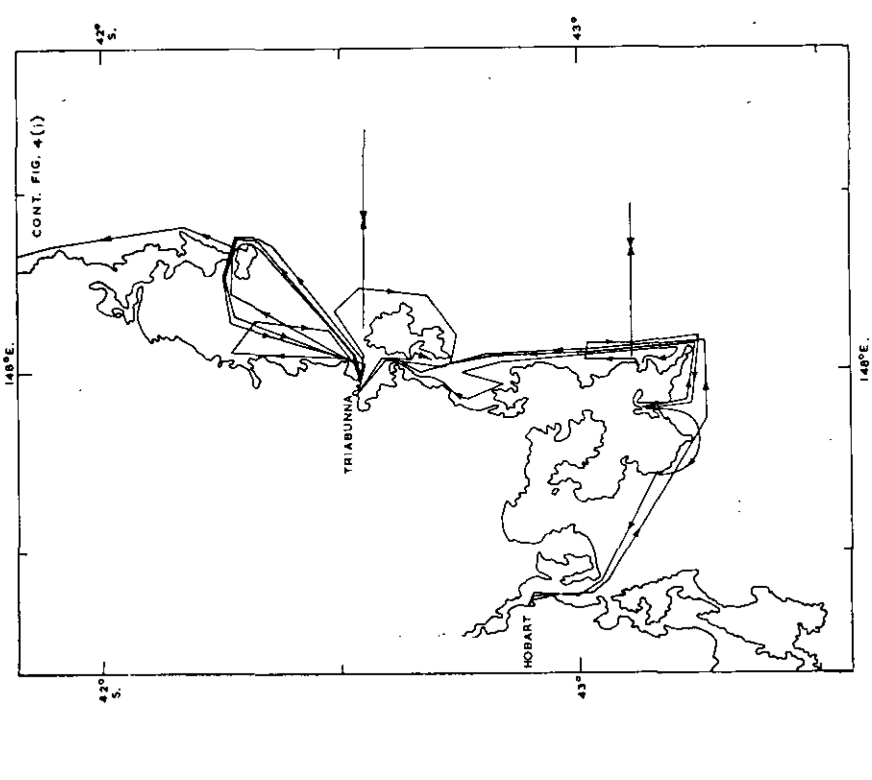

42° S.
43°
148°E.
CONT. FIG. 4(i)
TRIABUNNA
HOBART

Fig. 4(j)

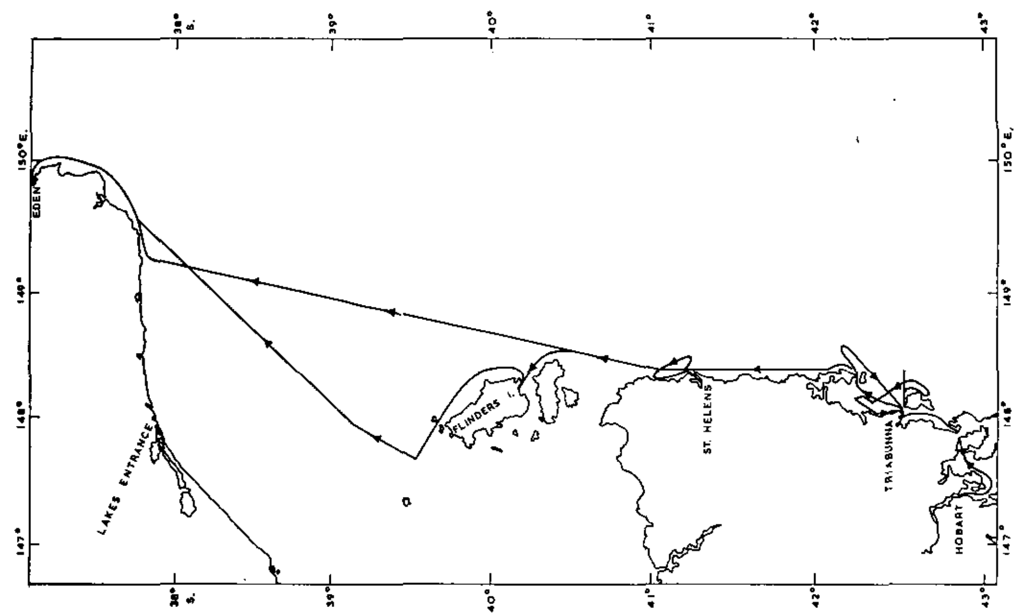

EDEN
LAKES ENTRANCE
FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART

Fig. 4(m)

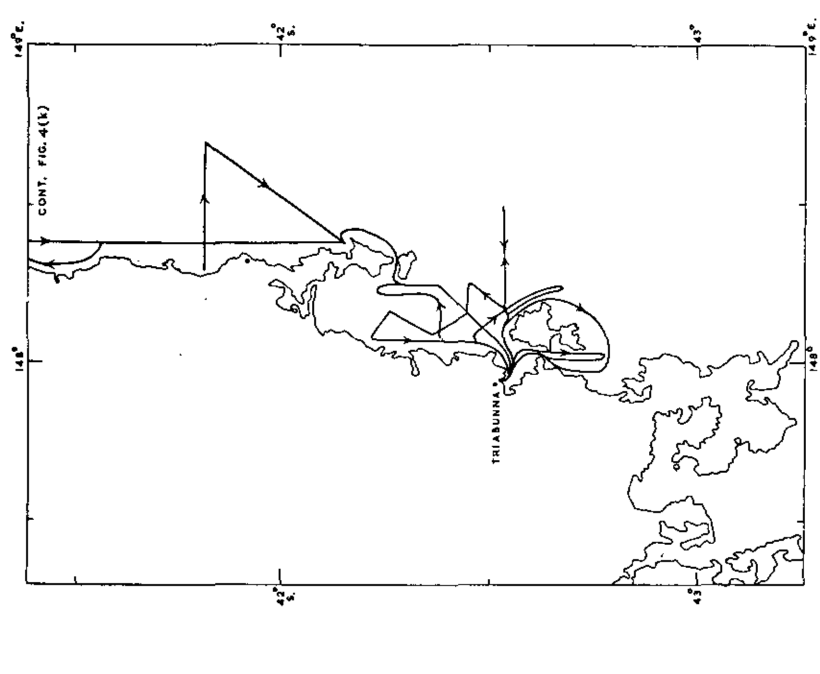

CONT. FIG. 4(k)
TRIABUNNA

Fig. 4(l)

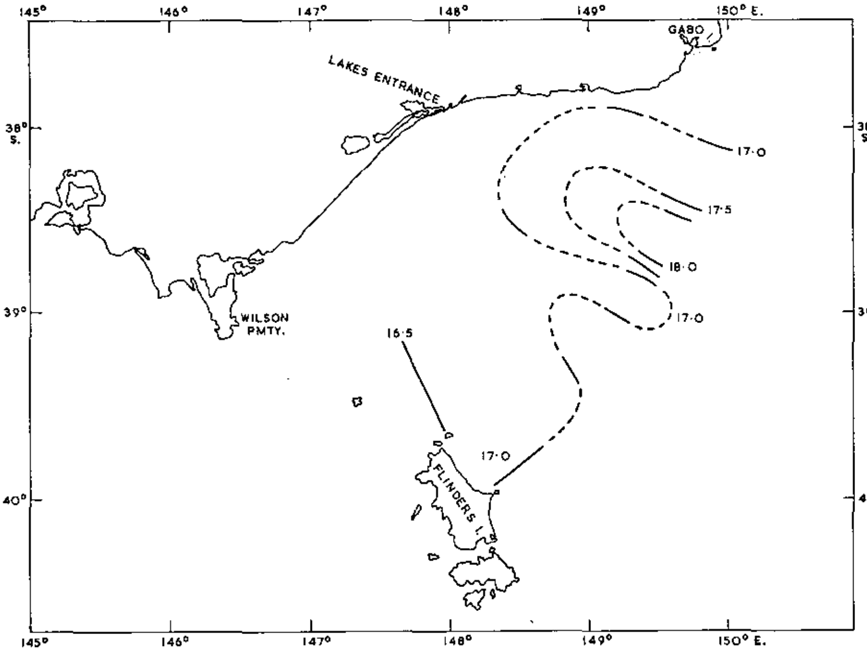
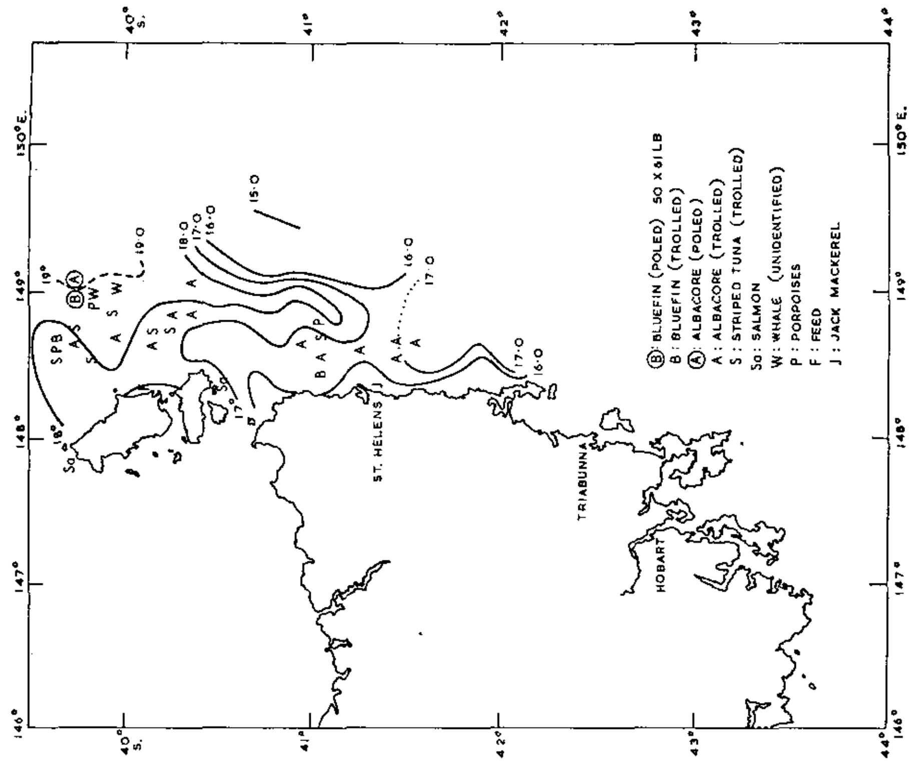


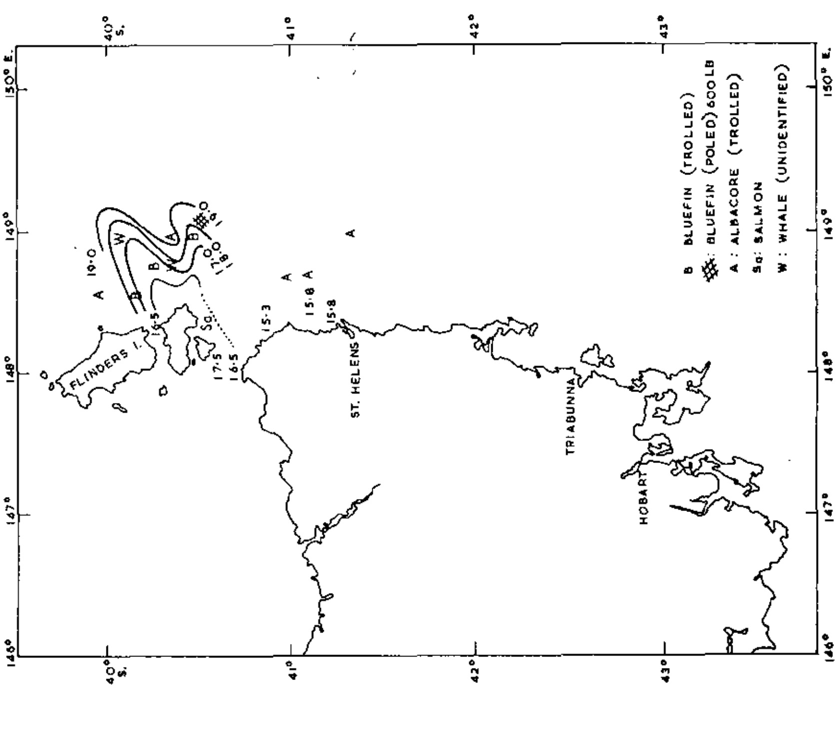
Fig. 5(*a*)

Figs. 5(*a*)–5(*i*).—Surface isotherms (°C) and fishing boat tuna catches and sightings of other fish, whales, etc. on (*a*) February 1–3, (*b*) February 5–13, (*c*) February 18–28, (*d*) March 1–15, (*e*) March 16–26, (*f*) April 1–15, (*g*) April 16–30, (*h*) May 1–15, and (*i*) May 16–31; 1965.



ST. HELENS
TRIABUNNA
HOBART
Ⓑ: BLUEFIN (POLED) 50 X 61 LB
B : BLUEFIN (TROLLED)
Ⓐ: ALBACORE (POLED)
A : ALBACORE (TROLLED)
S : STRIPED TUNA (TROLLED)
Sa: SALMON
W : WHALE (UNIDENTIFIED)
P : PORPOISES
F : FEED
J : JACK MACKEREL

Fig. 5(c)



FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
B : BLUEFIN (TROLLED)
BLUEFIN (POLED) 600 LB
A : ALBACORE (TROLLED)
Sa: SALMON
W : WHALE (UNIDENTIFIED)

Fig. 5(b)

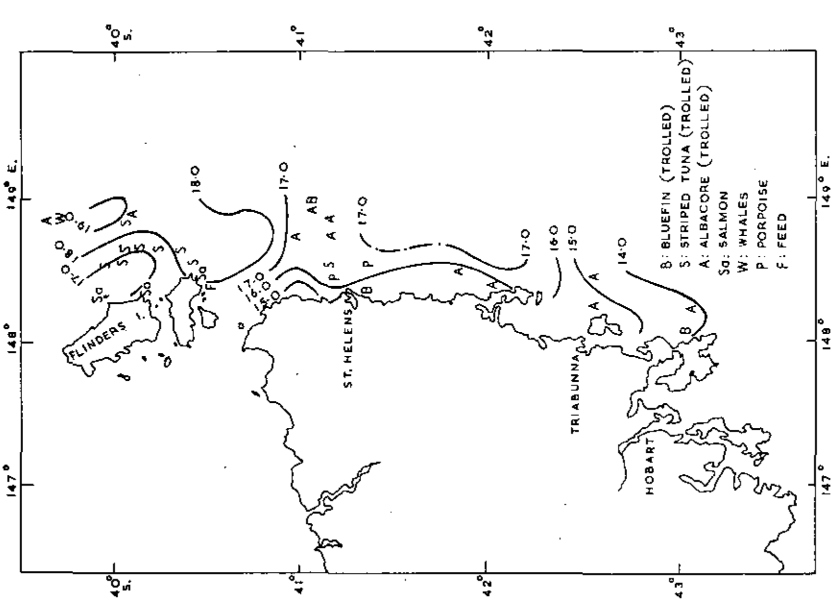

FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
B: BLUEFIN (TROLLED)
S: STRIPED TUNA (TROLLED)
A: ALBACORE (TROLLED)
Sa: SALMON
W: WHALES
P: PORPOISE
F: FEED
147°
148°
149° E.
40° S.
41°
42°
43°

Fig. 5(d)

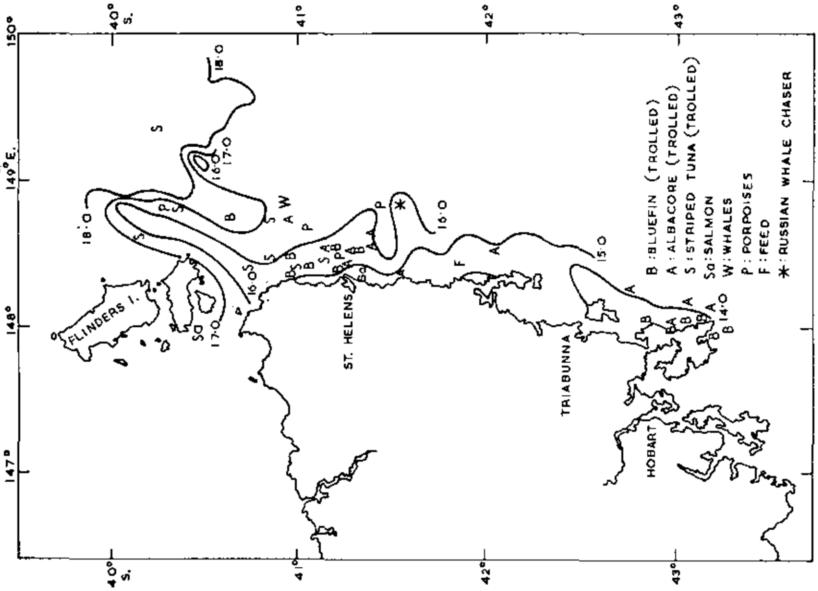

FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART
B: BLUEFIN (TROLLED)
A: ALBACORE (TROLLED)
S: STRIPED TUNA (TROLLED)
Sa: SALMON
W: WHALES
P: PORPOISES
F: FEED
*: RUSSIAN WHALE CHASER
147°
148°
149° E.
150°
40° S.
41°
42°
43°

Fig. 5(e)

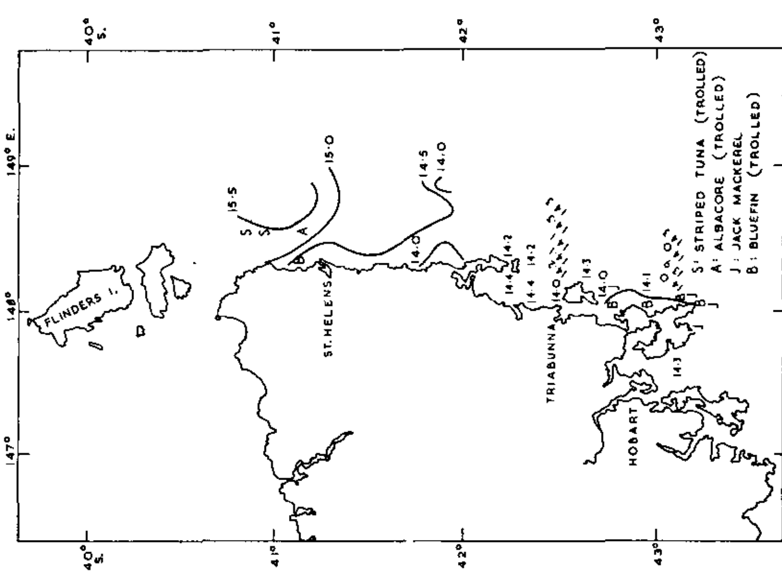

S: STRIPED TUNA (TROLLED)
A: ALBACORE (TROLLED)
J: JACK MACKEREL
B: BLUEFIN (TROLLED)
FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART

Fig. 5(*f*)

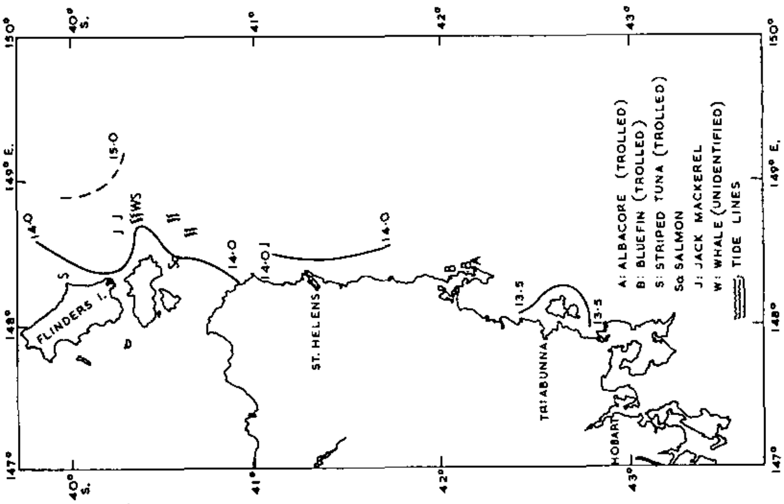

A: ALBACORE (TROLLED)
B: BLUEFIN (TROLLED)
S: STRIPED TUNA (TROLLED)
Sa SALMON
J: JACK MACKEREL
W: WHALE (UNIDENTIFIED)
TIDE LINES
FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART

Fig. 5(*g*)

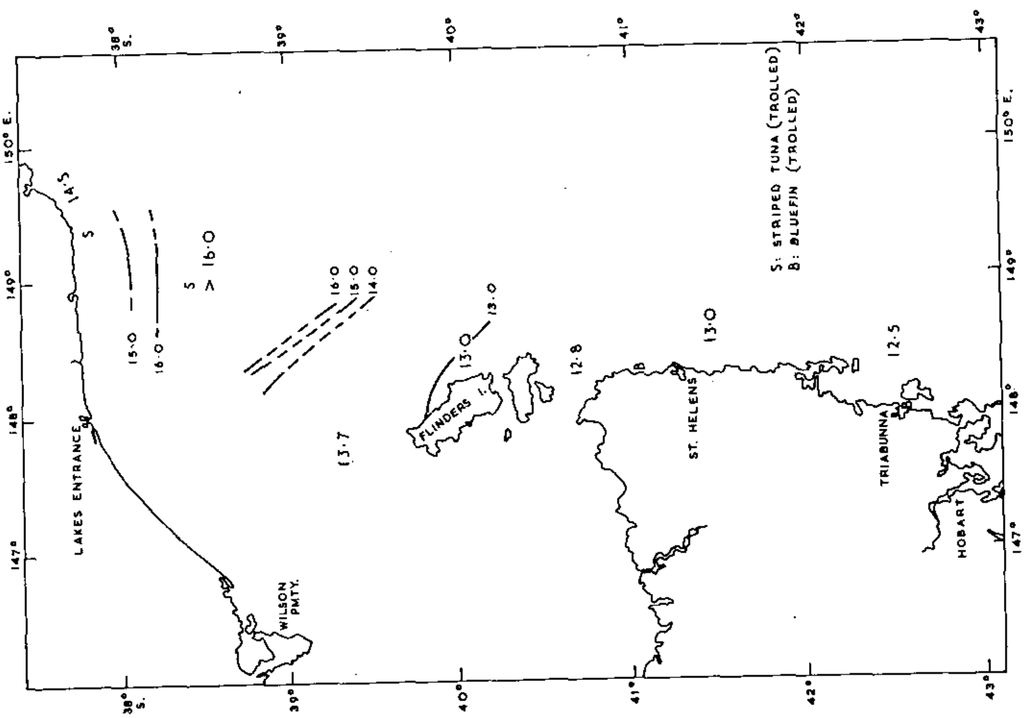

S: STRIPED TUNA (TROLLED)
B: BLUEFIN (TROLLED)
LAKES ENTRANCE
WILSON PMTY.
FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART

Fig. 5(i)

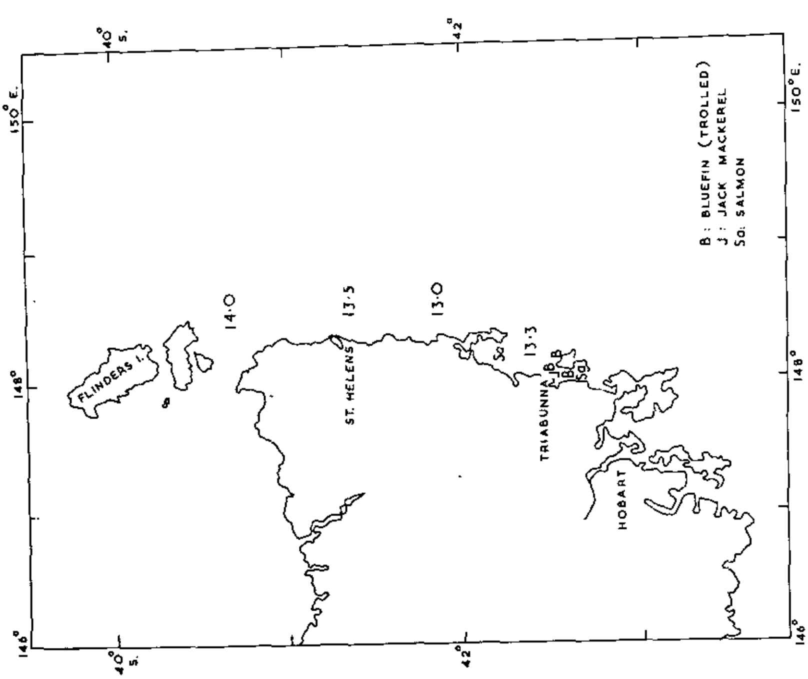

B: BLUEFIN (TROLLED)
J: JACK MACKEREL
Sa. SALMON
FLINDERS I.
ST. HELENS
TRIABUNNA
HOBART

Fig. 5(h)

(*e*) *Tagging Releases and Recaptures*

One hundred and forty-seven southern bluefin tuna were tagged and released. Details of date and region of capture and of length are given in the Appendix. Recapture data for the seven fish recovered to November 20, 1965, are also given, along with release–recapture data for the one tagged fish taken during the survey.

TABLE 4

SUMMARY OF TUNA CATCHES AND BLUEFIN SIGHTINGS BY MONTHS

Aircraft or Vessel	Month	Tuna Catch (No. of Fish)			Southern Bluefin Sightings	
		S.B.F. Tuna	Albacore	Striped Tuna	No. of Rippling Schools	No. of Scattered Schools
VH-RLB	Feb.	—	—	—	3	4
	Mar.	—	—	—	2	0
	Apr.	—	—	—	0	3
	May	—	—	—	0	37
Two Freddies	Feb.	5	32	1	4	1
	Mar.	10	27	90	0	0
	Apr.	3	2	22	0	0
	May	2	0	12	0	0
Rosebud	Feb.	62	36	9	13	0
	Mar.	22	6	9	0	4
	Apr.	17	0	0	0	1
	May	5	0	0	0	7
Marelda	Feb.	0	4	0	0	0
	Mar.	47	24	0	0	0
	Apr.	14	6	0	0	0
	May	13	0	0	0	0
Totals	Feb.	67	72	10	20	5
	Mar.	79	57	99	2	4
	Apr.	34	8	22	0	4
	May	20	0	12	0	44
Grand total		200	137	143	22	57

IV. DISCUSSION

The primary objective of the survey was to test the commercial possibilities of inshore fishing for southern bluefin tuna. As the survey progressed it became obvious that fish of species other than bluefin tuna, notably striped tuna (skipjack) and jack mackerel (*Trachurus declivis*), were very numerous in the area. Since both these (or allied) species support major fisheries elsewhere in the world, consideration is also given in this report to their commercial possibilities.

TABLE 5

DETAILS OF STRIPED TUNA SIGHTINGS BY AIRCRAFT

Date	Area	No. of Schools	Size of Schools	Estimate of Total Tonnage	School Behaviour	Water Temp. (°F)
25.ii.65	Off Vansittart Shoals, Furneaux Group	1	—	—	—	63
26.ii.65	Off Vansittart Shoals, Furneaux Group	1	—	—	—	67
16.iii.65	Eddystone Pt. to E. Sister I.	Many	—	—	—	66
19.iii.65	Eddystone Pt. to C. Barren	Dozens	Up to 20 tons	200	Rippling schools	63
25.iii.65	St. Helens to Swan I.	Dozens	—	—	Large schools rippling, small schools feeding	61
26.iii.65	St. Helens to Eddystone Pt.	Hundreds	Small	—	Feeding schools	61
2.iv.65	Eddystone Pt. to Banks Strait	2 large, many small	Up to 50 tons	150–200	Large schools rippling	59
15.iv.65	E. of Banks Strait	8	Up to 5 tons	15	Rippling schools	—
15.iv.65	Off Wineglass Bay	2	Small	—	Feeding schools	—
28.iv.65	Vansittart Shoals to E. Sister I.	Hundreds	—	—	Feeding schools	58
29.iv.65	Vansittart Shoals to Babel I.	—	—	—	—	58
1.v.65	Vansittart Shoals to E. Sister I.	60–80	Up to 30 tons	1500	Rippling and feeding schools	—
2.v.65	Vansittart Shoals to E. Sister I.	80	Up to 30 tons	1500	Rippling and feeding schools	—
14.v.65	Off SE. Cape	12	—	—	Feeding schools	—
15.v.65	SE. Cape to Maatsuyker I.	A few	—	—	Feeding schools	—

TABLE 6

DETAILS OF JACK MACKEREL SIGHTINGS BY AIRCRAFT

Date	Area	No. of Schools	Size of Schools
5. ii.65	St. Helens to Eddystone Pt.	—	—
6. ii.65	St. Helens	—	—
13. ii.65	E. of Swan I.	—	—
14. ii.65	Maria I.	Extremely thick	—
18. ii.65	Maria I.	—	—
24. ii.65	Maria I.	Extremely thick	—
	St. Helens	—	—
25. ii.65	C. Barren	—	—
	Babel I.	Plenty	—
26. ii.65	St. Helens	—	—
	Maria I.	—	—
	Schouten I.	—	—
11.iii.65	St. Helens to Eddystone Pt.	2	Small schools
19.iii.65	Maria I.	—	—
20.iii.65	Schouten I.	—	—
23.iii.65	Maria I.	Plenty	—
26.iii.65	Schouten I. to Forestiers Pen.	—	—
9.iv.65	Maria I. to Forestiers Pen.	—	—
13.iv.65	Hippolite Rocks to Maria I.	Plenty	—
14.iv.65	Hippolite Rocks to Maria I.	Plenty	—
15.iv.65	Eagle Hawk Neck to Schouten I.	—	—
27.iv.65	E. of Swan I.	—	Big schools
	Eddystone Pt.	1	—
	Scamander	—	—
28.iv.65	Vansittart Shoals to E. Sister I.	Hundreds	—
29.iv.65	Vansittart Shoals to Babel I.	Plenty	—
	St. Helens to St. Patricks Hd.	—	—
1. v.65	Maria I.	—	—
	C. Barren	25	3–40 tons
	Babel I.	Too many schools to estimate	Up to 30 tons
2. v.65	C. Barren to Vansittart Shoals	500–600	3–50 tons
	Babel I. to E. Sister I.	2000	3–50 tons
6. v.65	Forestiers Pen.	1	—
	Long Pt.	1	—
	Babel I.	50	10–40 tons
	N. of W. Sister I.	30	3–30 tons
	Swan I.	1	—
7. v.65	Babel I.	12	—
	Hippolite Rocks	6	—
14. v.65	Hippolite Rocks to Eagle Hawk Neck	25	—

(a) Intensity of Cover Given

The aerial cover aimed at for the survey area off the east coast was 0·028. The actual levels of cover attained during each half-monthly period are listed in Table 3. In four periods the cover attained was greater than that aimed at, in the other four less. In all except the last half month the level of cover is acceptable as defined in Section II(*a*) (p. 8). During this period the weather was bad, the first flight being postponed till May 25, 1965. Since the fishing boats were preparing to leave the area by this time, the aerial spotting program was abandoned after this flight.

The track charts of the fishing vessels and *Marelda* show that except in the early part of the survey all vessel movements were within the area west of 149° E. longitude, so that in fact the boats surveyed only waters up to 25 miles offshore, not 50 as planned. Moreover, within this area the cover was heaviest close to the coast. This had been brought about by adverse weather conditions. This uneven distribution of effort is unfortunate in that oceanographical data obtained in the strip 25–50 miles offshore are very scant. At the same time this experience clearly illustrates the fact that boats 60 ft L.O.A. are unable to work any more than 25 miles offshore on a regular basis.

TABLE 7

NUMBERS OF OCEANOGRAPHICAL OBSERVATIONS

Vessel	Month	Surface Samples Salinity	Surface Samples Oxygen	Subsurface Samples Salinity	Subsurface Samples Oxygen	Bathythermograms
Two Freddies	February	60	—	—	—	25
	March	40	—	—	—	5
	April	20	—	—	—	1
	May	26	—	—	—	0
Rosebud	February	67	—	—	—	26
	March	46	—	—	—	3
	April	63	—	—	—	0
	May	53	—	—	—	0
Marelda	February	8	5	38	38	0
	March	22	12	85	86	27
	April	30	20	146	149	10
	May	11	11	79	51	0
Total		446	48	348	324	97

Cover given to the area by the three boats has not been calculated, as they were acting in a supporting role to the aircraft.

(*b*) *Oceanographical Conditions*

As stated above, only scant oceanographical data were obtained in the strip of water 25–50 miles offshore. Even within the first 25 miles there were so few bathythermograms and subsurface samples that the vertical structure of the water could not be determined; hence no attempt has been made to do so. However, there were sufficient surface observations taken to allow description of the broad oceanographical features of the area and changes in these features during the survey.

Newell (1961) showed that the hydrological characteristics of the surface waters off the eastern Tasmanian coast in summer are determined by the depth of penetration of the East Australian Current. He states (1961, p. 10) that "the penetration . . . is limited by the northward movement of sub-Antarctic water". He has chosen (1961, Fig. 1(*b*)) a chlorinity of 19·3‰ and a temperature of 13·7°C as representative of this sub-Antarctic (East Tasmanian) water in summer. This agrees with the limits given by Rochford (1958, Fig. 1) for sub-Antarctic (Tasman) water in summer (chlorinity 19·15–19·30‰, temperature 12–14°C). Newell also set limits for the chlorinity and temperature of the East Australian Current. He gave (1961, Table 3) chlorinity 19·63–19·76‰ as the range of average monthly values observed at the seaward stations (i.e. outside the continental shelf) off Eden in February–May in the years 1957–60. Since he also states that surface chlorinities of greater than 19·80‰ or less than 19·60‰ are rarely found at these stations at any time of the year, it may be concluded that the range of chlorinity 19·60–19·80‰ includes the majority of surface chlorinities of the East Australian Current off Eden in February–May. The range of average summer temperatures is stated to be 20–22°C.

The chlorinities and temperatures of surface samples taken by the survey vessels at stations more than 8 miles off the eastern Tasmanian coast are plotted in Figure 6. (In order to eliminate the effects of fluvial dilution, data obtained closer inshore have not been used.) The characteristic values given by Rochford and Newell for the various water types discussed above are also plotted. It will be seen that the data obtained during the survey can be adequately represented by a straight line running from the point (temperature 14°C, chlorinity 19·35‰) to the point (temperature 18·5°C, chlorinity 19·7‰). The first point is representative of the majority of samples taken off the east coast between latitudes 42 and 43° S. in March and April (temperatures 13·5–14·5°C, chlorinities 19·3–19·4‰). The second point is representative of a group of samples with temperatures of 18–19·5°C and chlorinities of 19·6–19·8‰ taken off north-east Tasmania between latitudes 39·5 and 41° S. in February and March. The remainder of the samples taken in February–April were intermediate in geographical position.

This distribution of chlorinities and temperatures is consistent with the hypothesis that the surface waters sampled were made up by mixing between two basic types — the colder less saline type conforming to the requirements of sub-Antarctic (East Tasmanian) water and the warmer more saline type to East Australian Current water slightly cooler than that found off Eden. In view of Newell's statement quoted above, we therefore assume that the conditions found were produced by a penetration of what was essentially East Australian Current water into a body of water that was sub-Antarctic (East Tasmanian) in character. This situation existed up until the end of March, after which water with the characteristics of the East Australian Current was no longer found in the area, presumably having been forced out by sub-Antarctic water. In May the majority of samples taken had chlorinities lying in the range 19·3–19·4‰ and temperatures around 13°C. They are plotted as solid squares in Figure 6. Water with these characteristics could have been produced by cooling of the sub-Antarctic water present in the previous months or could have arrived by advection of cooler water from the south.

The mixing line drawn in Figure 6 indicates that samples with a temperature of 18°C were composed on the average of 90% of East Australian Current water while samples with a temperature of 19°C were exclusively East Australian Current water. Since the 18 and 19°C isotherms were always relatively close together when present, it follows that the 18°C isotherm represents for practical purposes the boundary of undiluted East Australian Current water. The mixing line also indicates that samples with a temperature of 62°F (16·7°C), the lowest temperature at which bluefin ripple, were composed on the average of 60% of East Australian Current water.

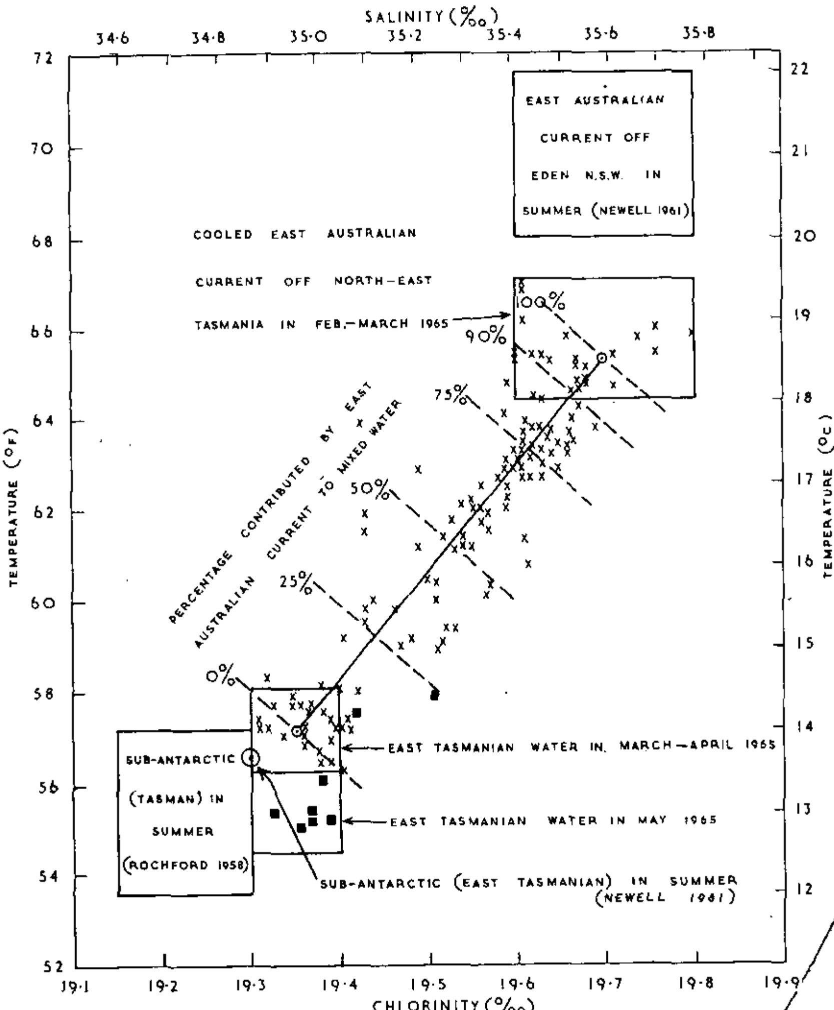


Fig. 6.—Temperature–salinity plot of surface samples taken more than 8 miles offshore; ×, samples taken in February, March, and April; ■, samples taken in May.

It follows therefore that, if southern bluefin in Tasmanian waters respond to temperature as they do in New South Wales waters, ripplers could have been expected only in the East Australian Current water or its half-diluted fringe. This water was found only in the northern part of the survey area during February and March.

(c) *Fish Occurrences and Fishery Prospects*

(i) *Southern Bluefin Tuna*

Rippling schools of bluefin were sighted only in the northern portion of the survey area east of the Furneaux Group in February and March. As shown in the previous section, water temperatures were suitable for rippling behaviour only in that area at that time if Tasmanian fish behave similarly to New South Wales fish. (Water temperatures at the time the rippling fish were sighted were 64–68°F (17·8–20°C).) Some of the schools were easy to chum and hold, others were shy; size of school ranged from about 30 tons to a half dozen fish. In these respects the fish were similar to New South Wales fish. All fish taken from the schools were of medium to large size (45–100 lb). In this respect the fish differed from New South Wales fish, which are rarely over 45 lb in weight.

Scattered feeding schools of bluefin were found mostly in the central and southern portion of the survey area and off the southern tip of Tasmania. On almost all occasions the water temperature was 60°F (15·6°C) or lower. Individual weights of fish taken ranged from 20 to 45 lb. Several unsuccessful attempts were made to attract fish away from their natural feed by chumming. These scattered feeding fish resembled, in individual size and behaviour, the fish taken off Eden in the early part of the New South Wales season when the water is cold.

From this evidence it seems that southern bluefin tuna in Tasmanian waters respond to temperature exactly as they do in New South Wales waters.

The first seven tag returns listed in the Appendix clearly show that the stocks of bluefin present on the eastern Tasmanian coast in March, April, and May during the survey were intimately related to the stocks present on the New South Wales coast in the following October. The single tag released in New South Wales in November 1964 and recovered in March during the survey indicates that these stocks may have been present in New South Wales in the November before the survey. Since other tagging work has shown (Robins, unpublished data) that southern bluefin tuna seen on the New South Wales and South Australian coasts are of common stocks and that there are annual migrations from one fishery to the other, the question arises as to the relation between these migrating fish and the fish that appear to have moved from New South Wales to Tasmania and then back to New South Wales.

Robins postulated that movement between the two commercial fisheries takes place via southern Tasmanian waters, since bluefin three years old and older are rarely seen or taken in Bass Strait. This is confirmed by Figure 7, which represents the migration of a large body of fish down the west coast of Tasmania and up the eastern coast. This migration is reasonably well known to west coast fishermen and appears to be an annual phenomenon occurring at the same time each year. It seems likely that the tagged fish released at Albany and recovered towards the end of the survey in eastern Tasmania (see Appendix) took part in this migration.

While this body of fish was making its way down the west coast, the east coast stocks were being fished by the charter vessels. The two stocks are therefore not identical. Further, there is evidence that the east coast stocks may have moved off the east coast to New South Wales before the fish that travelled down the west coast reached the east coast. In June 1965 *Marelda* tagged off Lakes Entrance, Victoria, 11 fish in the same size range as those tagged by the charter vessels off the eastern Tasmanian coast. Two of these fish were subsequently recovered in October in New South Wales in the same area as that in which eastern Tasmanian tagged fish were recovered. There is a possibility therefore that the eastern Tasmanian stocks had migrated to Bass Strait by June, at which time the west coast fish had reached no further than Freycinet Peninsula.

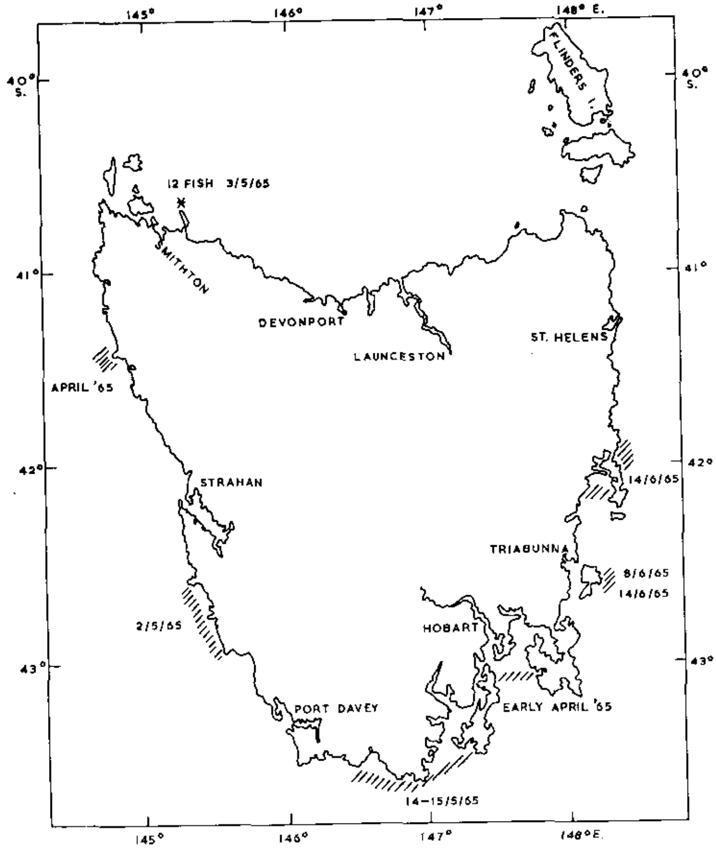


Fig. 7.—Sightings of southern bluefin tuna in Tasmanian waters in April, May, and June 1965 by aircraft and fishermen (excluding sightings in April by survey vessels operating on the east coast).

It seems then that in any one year the New South Wales stocks contain fish that have migrated both from South Australia via Tasmania and from Tasmania. Also it is clear that the fish that migrate from New South Wales move to both Tasmania and South Australia. Hence the most likely interpretation of the eastern Tasmanian summer stocks is that they represent that part of the New South Wales stocks that does not make the annual migration to South Australia.

Whether this interpretation is correct or not, it remains that there is a stock of fish resident in eastern Tasmanian waters in summer and that they behave as do the fish in New South Wales. It follows that a pole fishery or a purse-seine fishery operating on them would be defined geographically by the extent of the annual summer intrusion of warm water from the north. In order to judge the probable extent of this intrusion, surface temperature records going back to 1950 were examined. These records were taken from research vessel log books and the logs of several trading vessels operating out of Tasmanian ports. Those from the eastern half of Tasmania have been summarized in Figure 8(*a*), which shows plots, by 1° rectangles of latitude and longitude, of the mean, highest, and lowest temperature for each month. Examination of these plots shows that surface temperatures of 62–68°F (16·7–20°C) are likely to occur regularly in the summer months only in the waters to the north and north-east of Tasmania. Off the eastern coast (St. Helens to Maria Island) the temperature could be expected to reach or exceed 65°F (18·3°C) in January–March, in about one year only in every two. (The temperatures found in this area during the survey were about 1–1·5°C lower than the average; hence 1965 must be regarded as an unusually cold year.) It follows that a regular summer fishery could exist only in the waters to the north and north-east of Tasmania.

The size of this fishery would of course be dependent on the size of the resident stocks. There is very little evidence available on this point. Four year old fish (35 lb weight approximately) form a large proportion of the Japanese longline catch in May and June each year off the Tasmanian coast. The Japanese catch in 1963 was of the order of 150 tons of four year old fish, but there is no evidence of the proportion of the total four year old population that this value represented. The sightings in February and March during the survey were such as to indicate that catches somewhat smaller than those made in the present New South Wales fishery could result if sufficient searching were carried out.

At the request of the Committee, figures similar to Figure 8(*a*) were prepared for the western half of Tasmania and the coastal waters of western Victoria and south-eastern South Australia. These are reproduced here as Figures 8(*b*) and 8(*c*). Figure 8(*b*) reveals that the surface temperatures off the west coast of Tasmania are unlikely ever to be high enough to permit the rippling behaviour of bluefin. Figures 8(*b*) and 8(*c*) in conjunction reveal that the surface temperatures in the western approaches to Bass Strait rarely reach a temperature high enough for rippling behaviour, but that the summer temperatures off the western Victorian and south-eastern South Australian coasts regularly reach a level where bluefin might ripple if present in the area. There is therefore a possibility that the present South Australian fishery could be extended to the south-east.

However, closer examination of Figure 8(*c*) reveals a peculiarity in the distribution of temperatures which could have a major influence on the behaviour of bluefin in the area. The graphs for the Kingston–Portland area show that the range of summer temperatures was far greater than that of winter temperatures and that in fact the lowest summer temperature was about the same as the lowest winter temperature. The original data from which Figure 8(*c*) was derived showed that these low summer temperatures were observed when the sampling vessels passed through a body of water (off Kingston–Portland) that was lower in temperature than Bass Strait waters and the water off Cape Jervis–Kangaroo Island. This body of cold water appears to be a permanent feature of the area in summer, since the lowest temperature

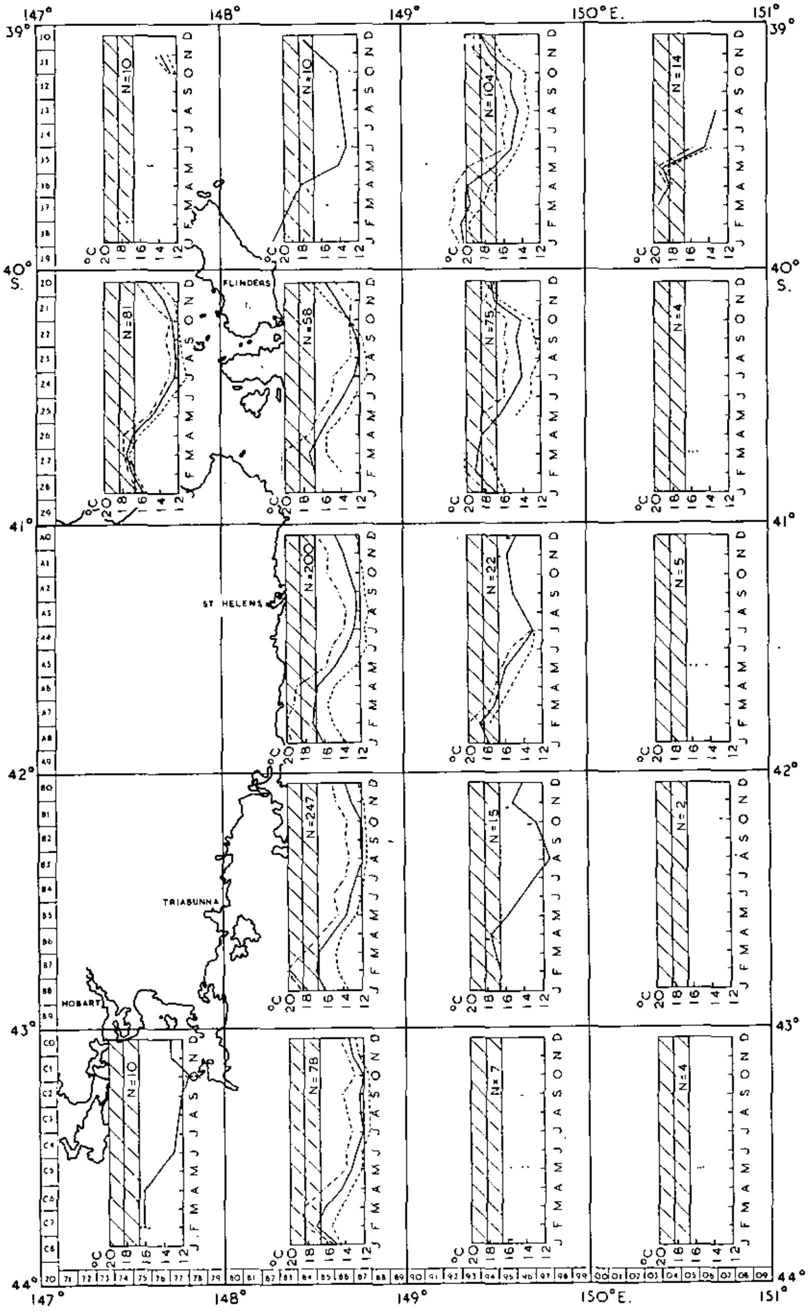


Fig. 8(*a*)

Figs. 8(*a*)–8(*c*).—Mean, highest, and lowest sea-surface temperatures off (*a*) the eastern coast of Tasmania, (*b*) the western coast of Tasmania, and (*c*) the south-eastern coast of South Australia and the western coast of Victoria by months and 1° squares for the years 1950–62 inclusive; – . – . – lines join highest readings, ——— lines join mean values, – – – – lines join lowest readings. *N* is the total number of observations. The hatched area is the range of temperature within which rippling bluefin tuna are found.

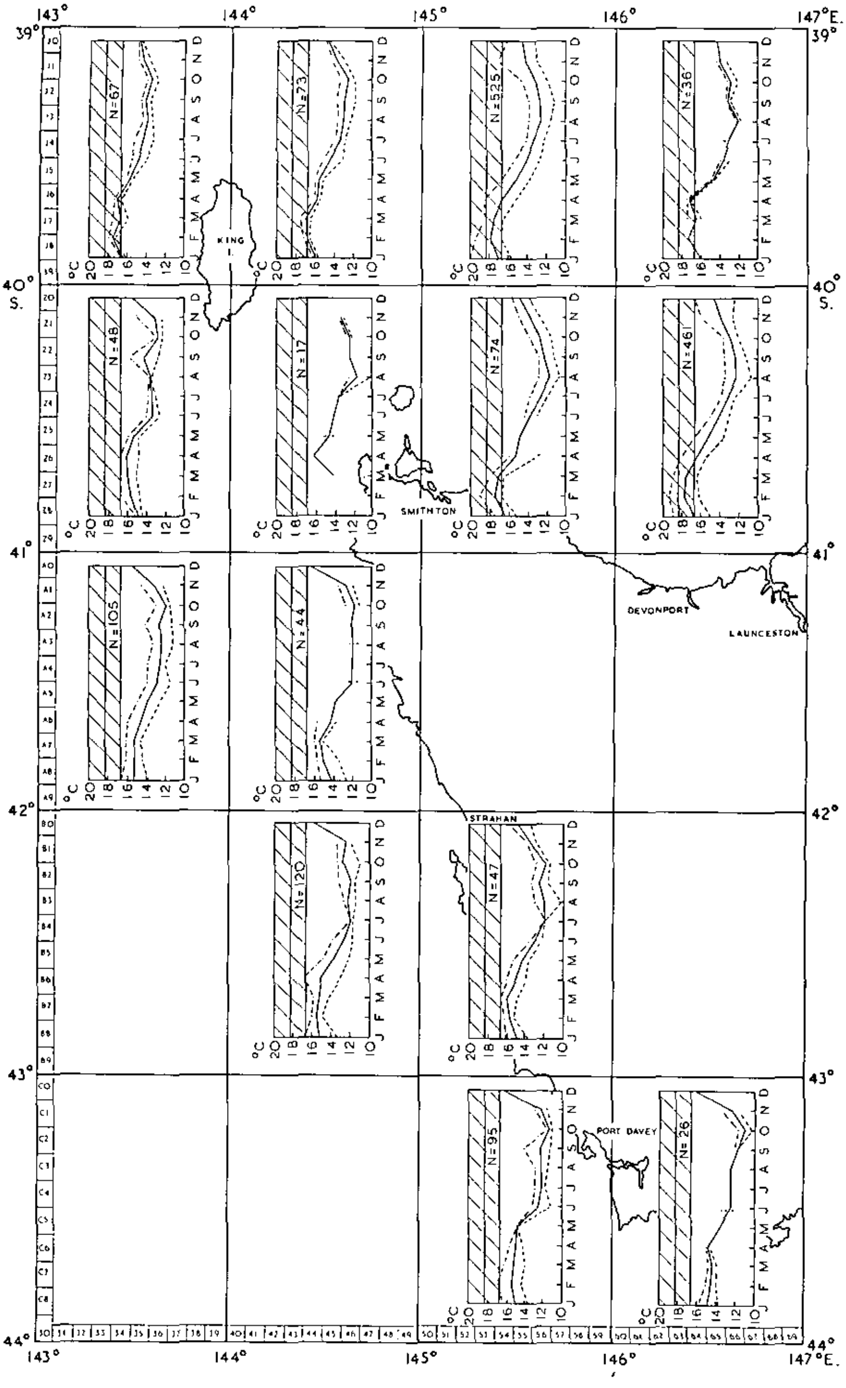
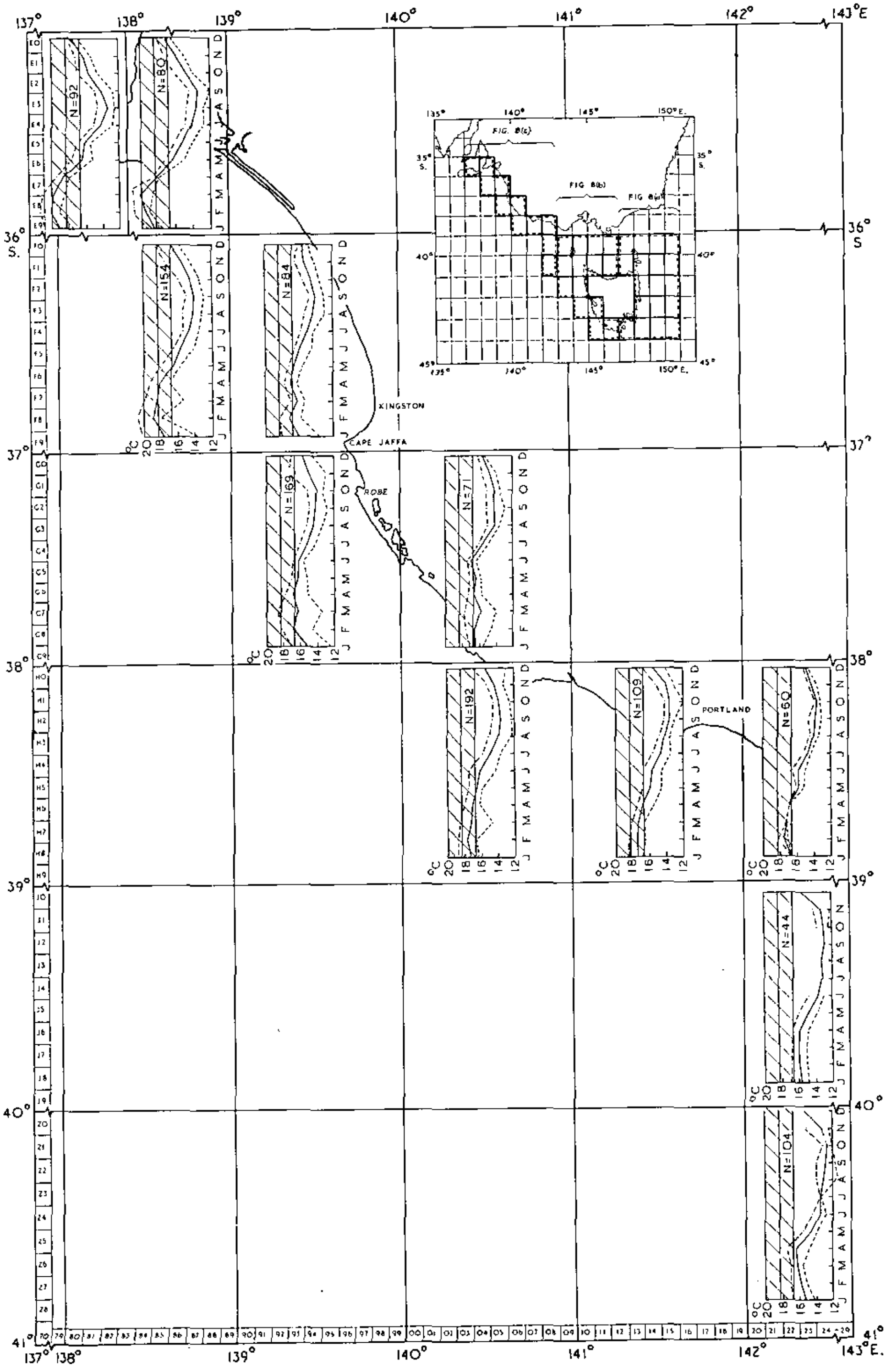

143°
144°
145°
146°
147°E.
39°
40° S.
41°
42°
43°
44°
N=67
N=23
N=525
N=36
N=48
N=17
N=74
N=461
N=105
N=44
N=120
N=47
N=95
N=26
J F M A M J J A S O N D
°C 20 18 16 14 12 10
KING I.
SMITHTON
DEVONPORT
LAUNCESTON
STRAHAN
PORT DAVEY

Fig. 8(*b*)



KINGSTON
CAPE JAFFA
ROBE
PORTLAND
N=92
N=80
N=154
N=84
N=169
N=71
N=192
N=109
N=60
N=44
N=104
FIG. 8(c)
FIG. 8(b)
FIG. 8(a)

Fig. 8(c)

encountered off Kingston–Portland in 23 transects made by the vessels in the months January–March inclusive was on 17 occasions 1°C or more lower than the temperature of Bass Strait water. These data cover the years 1957–62 inclusive except 1959. In all these years there was evidence of the presence of cold water at some time during the summer. The lowest temperature recorded by the sampling vessels in the months January–March of 1957–62 inclusive was 12·4°C on January 27, 1962, at grid reference G596. At the same time the temperature in the western approaches to Bass Strait was greater than 17°C, a difference of about 5°C. The temperature of the water off Kangaroo Island at the same time was around 19°C, a difference of about 7°C. The greatest gradient encountered was a difference of 4·2°C over a distance of 30 miles, the distance between adjacent sampling stations. These two samples were taken at grid references G901 and H305 on February 17, 1961. The most northerly position where water colder than 15°C was recorded was at grid reference F789, the most southerly at grid reference H810.

Since the above transects were all made by trading vessels travelling roughly parallel to the coast and near to the continental shelf edge, they give no evidence of the width in a north-east–south-west direction of the body of cold water. However, two trading vessel transects were made at a time when H.M.A.S. *Gascoyne* was working in the area and the combined data give a fairly clear picture of the distribution of surface temperatures at the time (early March 1961). These data are plotted in Figure 9.

Examination shows a body of cold water with temperatures mostly lower than 15°C in the Cape Jaffa–Rivoli Bay area. It is surrounded by water mostly over 17°C. The one north-east–south-west transect made by H.M.A.S. *Gascoyne* showed that on March 11–12, 1961, the cold water was confined to the inshore waters off Rivoli Bay, but at the same time M.V. *Risdon* was encountering the cold water out towards the continental shelf edge to the north-west.

Vertical sampling carried out by H.M.A.S. *Gascoyne* indicated that this body of cold water is formed by upwelling. At most of the stations occupied by *Gascoyne* the 15°C isotherm was situated at approximately 50 metres. On the Rivoli Bay transect, however, the 15°C isotherm rose steeply from about 50 metres at the outer station to reach the surface between the two inner stations.

Thus there is fairly clear evidence that upwelling of cold water was a permanent summer feature of the continental shelf waters on the Kingston–Portland area in the years 1957–62. That cold surface water can be more extensively distributed in this general area in summer is shown by data collected before 1950, not included in Figures 8(*b*) and 8(*c*). The data are plotted in Figure 10. All the surface temperatures taken in the western approaches to Bass Strait in January 1948 and in February 1949 were lower than 15°C. This indicates a far more extensive distribution of cold surface water in these years than in the years 1957–62.

The effect of this cold water on the behaviour of bluefin tuna could of course be expected to be considerable. In the first place, if the temperatures are lower than 15°C (59°F) rippling schools would be unlikely to appear. The areas of steep temperature gradient between the cold water and the surrounding warm water would, however, be ideal places to look for rippling schools. In the second place, if the water is upwelled it may cause enrichment thus supporting a food chain to produce, eventually, concentrations of organisms on which the bluefin tuna would feed. These concentrations could be of course some distance from the site of upwelling.

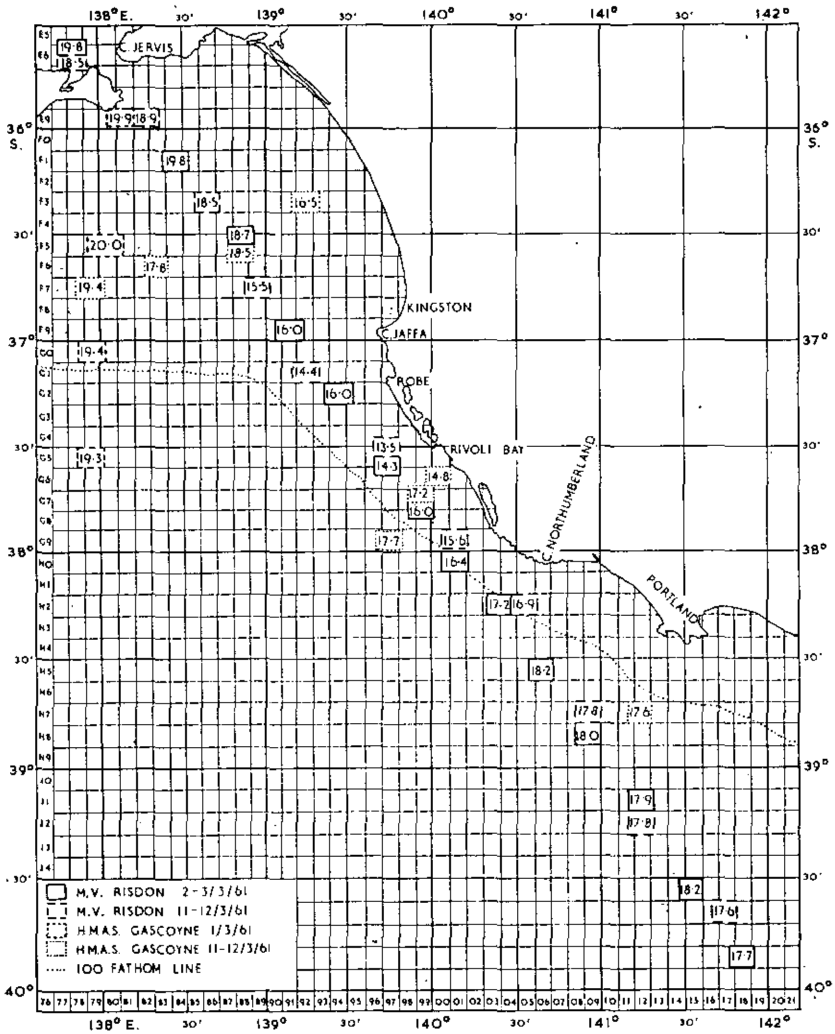


Fig. 9.—Distribution of temperatures (°C) from Kangaroo Island to western approaches to Bass Strait in early March 1961.

(ii) *Striped Tuna*

In assessing the sightings and catches of striped tuna made during the survey, several important differences between southern bluefin and striped tuna have to be taken into account.

The first is that no fishery for striped tuna exists in Australia, so that there has never been an opportunity for fish spotters to relate the appearance or "colour" of a school with the catch subsequently taken from it, and hence the estimates of tonnages are even more unreliable. However, for the purpose of this survey the spotter was instructed to assess the tonnages in the striped tuna schools as though they were bluefin.

The second difference is that striped tuna are not affected by temperature in their behaviour and distribution as are bluefin. Striped tuna occur in tropical as well as temperate waters and are therefore much wider ranging. Their rippling behaviour is not restricted to a narrow band of water temperature. In this survey

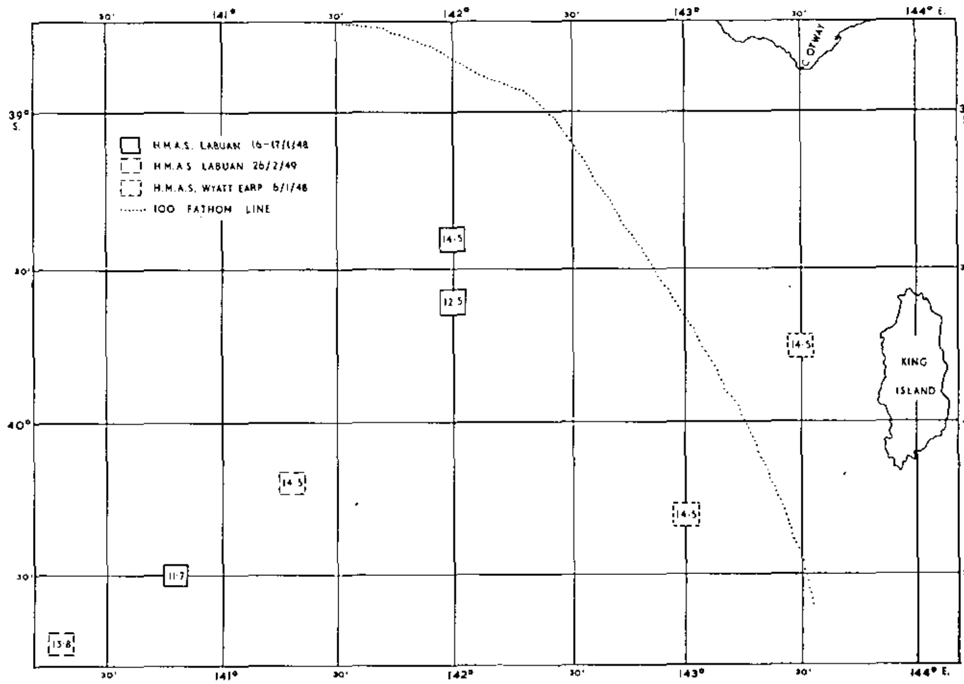


Fig. 10.—Summer surface water temperatures in the western approaches to Bass Strait in 1948 and 1949.

striped tuna were found alone more often than with bluefin. The result was that, while the survey cover given by the aircraft was the same for striped tuna as for bluefin, the cover given by the fishing boats was much less, since the boats were concentrating on areas where bluefin were either located or, on the basis of water temperatures, expected. Hence the ratio of numbers of striped tuna to bluefin caught reflects neither the relative accessibility nor the relative abundance of the two species.

The third difference is that the fishability of striped tuna is considerably lower than that of bluefin. This applies particularly to rippling schools of striped tuna, from which it is often rather difficult to pole fish. It also applies to scattered fish, since the striped tuna's mouth is very soft and many trolled fish are lost while being hauled in. This occurred many times during the survey and is a further reason why the ratio of striped tuna catch to bluefin catch reflects neither relative accessibility nor relative abundance.

Finally the size of fish is important in assessing the prospects for a fishery. Canneries do not like to handle tuna under 10 lb weight and prefer not to handle any under 15 lb weight. Their reason is that small fish give low recovery rates and require more labour in processing a given tonnage. It is sometimes possible to market these small fish at prices somewhat lower than those received for average-sized bluefin.

Examination of Table 4 shows that slightly less striped tuna than bluefin were taken by the boats during the survey. As explained above, this does not reflect the relative accessibility of the two species. A truer picture is given by the sightings made by the spotting aircraft. The tonnage of rippling bluefin sighted was about 10, and of scattered feeding fish about 100. The numbers of schools of rippling and scattered striped tuna sighted and estimates of their tonnages are given in Table 5. For a number of reasons the spotter could not estimate the total tonnage seen on every occasion. On two occasions, however, the total tonnage was estimated to be hundreds of tons and on two others, thousands. It is probable that several of these sightings were of the same group of fish on different days, since the area in which they were made was relatively small. Nevertheless, it is clear that there was at least 1000 and probably 2000 tons of striped tuna in the area.

In the present state of our knowledge it is impossible to take the next step and estimate the probable abundance of striped tuna and consequently the size of the fishery that the stock could support. It is, however, possible to make estimates of the minimum catch that could be maintained under certain circumstances. If the observed 2000 tons constitutes an entire unit stock, which is unlikely, it should be possible to take of the order of 500 tons a year without overfishing. If, however, the 2000 tons was merely a part of a much larger stock, which is likely, probably the whole of the 2000 tons or as much as shows up each year, could be removed with safety. A closer estimate could be made only after a more intensive study of the stocks.

The majority of the sightings were in an area where the water temperatures ranged from 58 to 67°F (14·4–19·4°C) (see Table 5). If this is a regular feature of striped tuna behaviour in Tasmanian waters, any fishery for them would then be defined geographically by the annual summer intrusion of warm water, as would be a bluefin fishery, except that the striped tuna fishery would in general be further south than the bluefin fishery although possibly overlapping it.

Striped tuna taken by the fishing boats during the survey ranged from 9 to 14 lb weight and thus should have been satisfactory for canning. By Australian standards these were relatively large fish. New South Wales fish for example range from 5 to 13 lb with 7 lb the commonest size. Fish taken on earlier surveys referred to above were frequently under 10 lb weight. Hence it must be assumed that Tasmanian striped tuna are not consistently large and therefore perhaps would not always attract a price satisfactory to fishermen.

(iii) *Jack Mackerel*

Assessing the sightings of jack mackerel poses even more of a problem than assessing the striped tuna sightings. As in the case of striped tuna, there is no Australian fishery for jack mackerel. In addition the spotters have had no experience in estimating tonnages of a similar species, such as there was to assist the estimates of striped tuna.

During the first few months of the survey no attempt was made to quantify the sightings. However, when it became apparent that jack mackerel was the most prolific fish species in the area and could have important commercial prospects, an attempt was made to obtain systematic observations. In the absence of any better system, the spotter was instructed to estimate the tonnages in jack mackerel schools as if they were bluefin. It is unlikely that this system has produced assessments that are wrong by one order of magnitude.

Jack mackerel sightings were made only in the continental shelf waters. The greatest distance offshore at which a school was found was 30 miles. The majority of the sightings were within 10 miles of the shore and most of these were made within 5 miles. Most of the fish, therefore, are easily accessible to boats about 60 ft L.O.A.

The sightings are listed in Table 6. Examination shows that the fish were seen everywhere from West Sister Island in the north to Hippolite Rock in the south. However, there were two areas where fish were seen consistently and often in large quantities. These were the east coasts of Flinders and Cape Barren Islands in the north and Maria Island in the south. Both places offer reasonable shelter and facilities for boats of the size mentioned above.

The quantities of fish seen on the one day in these areas were often estimated to be in the hundreds of tons range and, on occasions in the northern area, in the thousands if not tens of thousands of tons. This is in contrast to the results obtained by Blackburn and Tubb (1950), who found that schools of jack mackerel were more prevalent in south-eastern Tasmania than in north-eastern Tasmania during the years 1938–44.

As in the case of striped tuna, it is impossible in the present state of our knowledge to relate these sightings to the abundance of jack mackerel. However, the most likely interpretation is that there is a tonnage available that is about one order of magnitude greater than that of striped tuna. If so the sustainable yield could be of the order of 10,000 tons per year.

Whether an estimate of a consistent yield of this magnitude is realistic depends on a number of factors, economic as well as biological. Firstly, although jack mackerel are reported to be present consistently in the southern area from year to year in the months January–June (Blackburn and Tubb 1950, p. 43), there is no evidence that they are consistently present in the northern area. Sightings of large quantities in the northern area were made during the present survey only on February 25 and from April 27 to May 6. Secondly, it seems likely on available evidence (Blackburn and Tubb 1950) that there would be no fishery from July to December (although it might be possible to shift operations to southern New South Wales during part of this period). Thirdly, it might be necessary for the processing plant to cope with short-term fluctuations in supply of the raw material. Table 6 gives only the sightings of jack mackerel. It does not list the days (12 in number) on which no sightings were made. In 34 days flying in the southern area, sightings were made on 16 days only—about

1 day in 2. However, Blackburn and Tubb (1950, p. 45) state that jack mackerel appear at the surface in fine weather only. Therefore it is possible that submarine searching using sonar detection gear could smooth out much of this irregularity of supply.

Purse-seining seems to be the appropriate method for catching these fish. There has been a considerable amount of work done on this already as reported by Blackburn and Olsen (1947). These authors concluded that the smallest effective net measures 250 fathoms by 20 fathoms. Nets somewhat smaller than this were used in preliminary fishing tests and proved effective on occasions. These nets were of cotton. Modern synthetic nets should prove to be much easier to handle and more effective. It is possible that improved efficiency could also be obtained by using lights to attract the fish at night.

V. Recommendations

While the survey has not shown conclusively that a fishery for southern bluefin is or is not a commercial proposition, it has indicated quite clearly what must be done next if such a conclusion is to be reached. Further, it has confirmed the presence and given some tentative estimate of two other major resources, striped tuna and jack mackerel, in the area, both of at least the same order of magnitude as bluefin tuna and in the case of jack mackerel probably very much greater. Since further exploration of each of these resources should follow rather different lines, each is treated separately below.

(*a*) *Southern Bluefin Tuna*

The next step in prospecting this resource is to determine whether the east coast summer resident stock forms rippling schools in north-east Tasmanian waters and, if so, the quantities available. The strategy to be employed in this operation should consist of locating the area (or areas) with optimum water temperature and flying sufficient hours in these areas to obtain estimates of the quantities of accessible fish. This operation should not differ greatly from the one already carried out. However, it will differ in details because:

(1) as a result of the completed operation it is known that bluefin can be relied on to behave in Tasmanian waters as they do elsewhere — hence likely fishing grounds can be located simply by measuring surface temperatures;

(2) surface temperatures can be determined by an infrared radiation thermometer carried in the spotting aircraft;

(3) fishing boats, which were essential in the completed operation, can now be dispensed with, since an aircraft so fitted can carry out sufficiently well all the functions still required of the fishing boats, except that of air–sea rescue and the need for this can be minimized by using a larger aircraft.

Accordingly it is proposed that the survey be extended by having an Aerocommander 500 B, fitted with an infrared radiation thermometer and carrying a spotter, fly 40 hr per month in two lots of 20 hr each fortnight in an area off the north-east Tasmanian coast approximately 120 miles deep by 200 miles wide in the months January–April inclusive of 1966. The exact area will be determined by the prevailing oceanographical conditions and will be located each fortnight by the aircraft making its first flight in a north–south direction to find the positions of the 62 and 68°F (16·7 and 20°C) isotherms. Subsequent flights can then be made with legs parallel and at right angles to the original flight path, in an area bounded roughly by the 62 and 68°F isotherms, the coast, and a line situated 200 miles to seaward.

Ten hours flying per fortnight will permit the isotherms in this area to be mapped with sufficient accuracy and the remaining 10 hr can be spent in searching selected areas with promising fronts and other indicators.

Costs per month are estimated at:

Aircraft		
surveying	40 hr at $56 per hr	$2240
ferrying	20 hr at $50 per hr	$1000
Spotter	$4\frac{1}{2}$ weeks at $60 per week	$270
Travelling, accommodation, etc.		$490
		$4000

Total cost of the survey is therefore:

4 months at $4000 per month	$16,000
Radiometer	$4000
CSIRO overhead (10% of $16,000)	$1600
	$21,600

(*b*) *Striped Tuna*

Provided there are reasonable prospects of a market being found for the catch, further prospecting of the striped tuna resource would be warranted, but this should be effected by commercial fishing operations. Purse-seining and gill-netting, rather than livebait-and-pole fishing, are the appropriate fishing methods. A spotting aircraft would probably reduce searching time considerably.

(*c*) *Jack Mackerel*

The principal difficulty in the way of development of a jack mackerel fishery lies in the expected irregularity of supply of the raw material. If the stocks are migratory and in fact travel between New South Wales and Tasmania each year, regularity of supply can be obtained only by shifting the fishery from one State to the other twice a year. This of course means increased transportation costs and larger vessels. If, however, there is a permanent resident stock in Tasmanian waters, then it might be possible to conduct operations throughout the year. This will depend on whether the winter stocks are accessible or not.

Aircraft spotting will determine whether there are surface-appearing schools. A few hours flying per week with a single-engined plane along the coast from Tasman Island to East Sister Island, preferably in the late afternoons, will provide estimates of the quantities of readily accessible fish. If, however, the results of this searching should be negative, it would be necessary to resort to sonar searching. This would involve the use of equipment that is relatively expensive and has not previously been used in Australia. Experience in the use of such gear would probably take at least one season to acquire.

VI. References

Blackburn, M., and Olsen, A. M. (1947).—Recent progress with pelagic fishing in Tasmanian waters. *J. Coun. scient. ind. Res. Aust.* **20**, 434–44.

Blackburn, M., and Tubb, J. A. (1950).—Measures of abundance of certain pelagic fish in some south-eastern Australian waters. CSIRO Aust. Bull. No. 251. 74 pp.

Hynd, J. S. (1963).—On the number of tuna vessels or aircraft required to search a given area effectively. Rep. Proc. Fisheries Management Seminar, 1963, pp. 64–71. (Mimeo.)

Hynd, J. S., and Vaux, D. (1963).—Report of a survey for tuna in Western Australian waters. CSIRO Aust. Div. Fish. Oceanogr. Rep. No. 37.

Newell, B. S. (1961).—Hydrology of south-east Australian waters: Bass Strait and New South Wales fishing area. CSIRO Aust. Div. Fish. Oceanogr. Tech. Pap. No. *10*.

Rochford, D. J. (1958).—The seasonal circulation of the surface water masses of the Tasman and Coral seas. CSIRO Aust. Div. Fish. Oceanogr. Rep. No. 16.

Serventy, D. L. (1947).—A report on commercial tuna trolling tests in south-eastern Australia. *J. Coun. scient. ind. Res. Aust.* **20**, 1–16.

Appendix

Southern Bluefin Tag Releases and Recoveries

Table A1

releases

Tag No.*	Date	LCF (cm)	Grid Ref.	Tag No.*	Date	LCF (cm)	Grid Ref.
X6816, 6816	6.iii.65	93	C080	X6862, 6862	27.iii.65	86	C180
X6817, 6817	10.iii.65	83	C080	X6863, 6863	27.iii.65	74	C080
X6818, 6818	20.iii.65	94	A385	X6864, 6864	28.iii.65	97	C080
X6819, 6819	23.iii.65	90	C080	X6865, 6865	1.iv.65	83	B183
X6820, 6820	23.iii.65	81	C180	X6866, 6866	1.iv.65	74	A783
X6821, 6821	23.iii.65	94	B979	X6867, 6867	2.iv.65	80	A783
X6822, 6822	23.iii.65	99	C080	X6868, 6868	2.iv.65	82	A783
X6823, 6823	24.iii.65	96	C080	X6869, 6869	2.iv.65	88	A483
X6824, 6824	24.iii.65	88	C080	X6870, 6870	3.iv.65	80	A283
X6825, 6825	24.iii.65	90	C080	X6871, 6871	3.iv.65	80	A283
X6826, 6826	24.iii.65	83	C080	X6872 6872	6.iv.65	76	A283
X6827, 6827	24.iii.65	77	C080	X6873, 6873	9.iv.65	79	B283
X6828, 6828	24.iii.65	82	C080	X6874, 6874	15.iv.65	96	C180
X6829, 6829	24.iii.65	91	C080	X6875, 6875	15.iv.65	97	C180
X6830, 6830	24.iii.65	95	C180	X6876, 6876	19.iv.65	82	C080
X6831, 6831	24.iii.65	96	C180	X6877, 6877	19.iv.65	94	C080
X6832, 6832	24.iii.65	93	C080	X6878, 6878	25. v.65	87	C080
X6833, 6833	24.iii.65	90	C080	X6879, 6879	25. v.65	95	C080
X6834, 6834	24.iii.65	100	C080	X6880, 6880	26. v.65	96	C080
X6835, 6835	24.iii.65	88	C080	X6881, 6881	26. v.65	95	C080
X6836, 6836	24.iii.65	95	C080	X6882, 6882	26. v.65	95	C080
X6837, 6837	24.iii.65	79	C080	X6883, 6883	26. v.65	100	B880
X6838, 6838	24.iii.65	84	C080	X6884, 6884	26. v.65	93	B880
X6839, 6839	24.iii.65	88	C080	X6885, 6885	26. v.65	100	B880
X6840, 6840	25.iii.65	79	C080	X6886, 6886	26. v.65	101	B880
X6841, 6841	25.iii.65	83	C080	X6887, 6887	28. v.65	95	A283
X6842, 6842	25.iii.65	91	C080	X6888, 6888	29. v.65	91	A083
X6843, 6843	25.iii.65	91	C180	X7901, 7901	5. ii.65	92	B185
X6844, 6844	25.iii.65	98	C180	X7902, 7902	6. ii.65	76	B207
X6845, 6845	26.iii.65	83	C179	X7903, 7903	7. ii.65	111(est)	B489
X6846, 6846	26.iii.65	75	C180	X7904, 7904	11.iii.65	74	B984
X6847, 6847	26.iii.65	93	C180	X7905, 7905	11.iii.65	75	B984
X6848, 6848	26.iii.65	81	C180	X7907, 7907	13.iii.65	79	A383
X6849, 6849	26.iii.65	84	C180	X7908, 7908	15.iii.65	76	A089
X6850, 6850	26.iii.65	89	C180	X7910, 7910	21.iii.65	92	A084
X6851, 6851	26.iii.65	93	C180	X7911, 7911	22.iii.65	63	B984
X6852, 6852	26.iii.65	95	C180	X7912, 7912	22.iii.65	77	B983
X6853, 6853	26.iii.65	79	C080	X7913, 7913	25.iii.65	77	B687
X6854, 6854	26.iii.65	78	C080	X7914, 7914	25.iii.65	81	B687
X6855, 6855	26.iii.65	84	C080	X7915, 7915	25.iii.65	80	B687
X6856, 6856	26.iii.65	96	C080	X7916, 7916	1.iv.65	79	A183
X6857, 6857	26.iii.65	74	C080	X7917, 7917	1.iv.65	75	A183
X6858, 6858	27.iii.65	79	C080	X7918, 7918	1.iv.65	76	A183
X6859, 6859	27.iii.65	95	C080	X7920, 7920	27.v.65	100	A083
X6860, 6860	27.iii.65	84	C080	X8001, 8001	26. ii.65	75	J686
X6861, 6861	27.iii.65	80	C080	X8002, 8002	28. ii.65	—	J788

TABLE A1 (*Continued*)

Tag No.*	Date	LCF (cm)	Grid Ref.	Tag No.*	Date	LCF (cm)	Grid Ref.
X8003, 8003	28. ii.65	—	J788	X8032, 8032	31.iii.65	93	C180
X8004, 8004	28. ii.65	—	J788	X8034, 8034	31.iii.65	97	C180
X8005, 8005	28. ii.65	—	J788	X8035, 8035	31.iii.65	95	C180
X8006, 8006	28. ii.65	—	J788	X8036, 8036	31.iii.65	92	C180
X8007, 8007	28. ii.65	—	J788	X8037, 8037	31.iii.65	84	C180
X8008, 8008	28. ii.65	—	J788	X8038, 8038	31.iii.65	97	C180
X8009, 8009	28. ii.65	98	J788	X8039, 8039	1.iv.65	93	C180
X8010, 8010	28. ii.65	100	J788	X8040, 8040	1.iv.65	80	C180
X8012, 8012	28. ii.65	—	J788	X8041, 8041	1.iv.65	97	C280
X8013, 8013	28. ii.65	—	J788	X8042, 8042	2.iv.65	95	C180
X8014, 8014	28. ii.65	—	J788	X8043, 8043	2.iv.65	94	C180
X8015, 8015	28. ii.65	—	J788	X8044, 8044	2.iv.65	93	C180
X8016, 8016	28. ii.65	—	J788	X8045, 8045	5.iv.65	94	B780
X8017, 8017	21.iii.65	86	A182	X8046, 8046	6.iv.65	84	B980
X8018, 8018	24.iii.65	99	B880	X8047, 8047	7.iv.65	83	C180
X8019, 8019	24.iii.65	95	C180	X8048, 8048	7.iv.65	93	C180
X8020, 8020	24.iii.65	83	C180	X8049, 8049	9.iv.65	91	C180
X8021, 8021	25.iii.65	85	C180	X8050, 8050	14.iv.65	75	B980
X8022, 8022	25.iii.65	92	C180	X8051, 8051	14.iv.65	78	B980
X8023, 8023	25.iii.65	90	C180	X8052, 8052	14.iv.65	75	B980
X8024, 8024	25.iii.65	90	C180	X8053, 8053	14.iv.65	97	C278
X8025, 8025	26.iii.65	97	C280	X8054, 8054	14.iv.65	95	C278
X8026, 8026	26.iii.65	79	C180	X8055, 8055	19.iv.65	95	C180
X8027, 8027	26.iii.65	97	C180	X8056, 8056	2. v.65	80	B480
X8028, 8028	26.iii.65	89	C180	X8057, 8057	2. v.65	79	B480
X8029, 8029	26.iii.65	91	C180	X8058, 8058	3. v.65	76	B580
X8030, 8030	26.iii.65	80	C180	X8059, 8059	7. v.65	84	B580
X8031, 8031	31.iii.65	80	C180				

*All fish were double tagged with one yellow and one blue tag; X denotes the yellow tag.

TABLE A2

RECOVERIES

Tag No.	Release Data				Recovery Data				
	Date	Position	State	LCF (cm)	Date	Position	State	LCF (cm)	Vessel*
X6853, 6853	26.iii.65	C080	Tas.	79	30.x.65	6402	N.S.W.	81	C
X6866, 6866	1.iv.65	A089	Tas.	76	28.x.65	6402	N.S.W.	82	C
X7908,† 7908	15.iii.65	A089	Tas.	76	28.x.65	6402	N.S.W.	82	C
X7916, 7916†	1.iv.65	A183	Tas.	79	20.xi.65	6304	N.S.W.	—	C
X8040, 8040	1.iv.65	C180	Tas.	80	27.x.65	6303	N.S.W.	81	C
X8047, 8047	7.iv.65	C180	Tas.	83	29.x.65	6303	N.S.W.	85	C
X8058, 8058	3.v.65	B580	Tas.	76	30.x.65	Area III‡	N.S.W.	82	C
16059, 16060†	23.vi.63	Albany	W.A.	64	18.v.65	C180	Tas.	99	G
X5774, 5774†	16.xi.64	7103	N.S.W.	71	20.iii.65	C183	Tas.	—	G

* C, commercial fishing vessel; G, game fishing boat.

† Tag missing on recovery.

‡ Between latitudes 36° and 37° S.