Report on a Survey for Yellowfin Tuna, *Thunnus albacares* (Bonnaterre), in Queensland Waters

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DIVISION OF FISHERIES AND OCEANOGRAPHY TECHNICAL PAPER NO. 26
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION, AUSTRALIA 1968

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Technical Paper No. 26

Commonwealth Scientific and Industrial Research Organization, Australia

Melbourne 1968

Printed by CSIRO, Melbourne

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[*Manuscript received October* 4, 1967]

Summary

The first part of the survey for yellowfin tuna, *Thunnus albacares*, was conducted from August to November 1965 using a spotting aircraft and a tuna fishing boat. The second part was conducted from January to April 1967 using a spotting aircraft only. Details of survey proposals, planning, and results are given.

During the first part of the survey there were desultory catches of yellowfin tuna by the fishing boat but no sightings by the aircraft. Having regard to the surface water temperatures it was concluded that there might be a better chance of finding surface schools of yellowfin in the summer months. Accordingly, the second part was carried out in summer but very few schools of yellowfin were sighted, although surface temperatures were favourable. From the evidence available there is no way of telling whether there were very few yellowfin in the area or whether commercial quantities were present but failed to surface. In any case, the prospects for a yellowfin tuna fishery are poor.

Other species of tuna were sighted during both parts of the survey. The commonest species was the mackerel tuna (little tuna). These were sighted in commercial quantities but are unlikely to form the basis of a commercial fishery for technical reasons. Small quantities of striped tuna (skipjack) were also sighted. A few dog-tooth tuna were taken during the first part of the survey but no northern bluefin.

In general, the prospects for a tuna fishery in Queensland are poor.

PART 1—1965

I. INTRODUCTION

A survey for tuna in Queensland waters was first suggested in 1963 by the Queensland Department of Harbours and Marine. Large catches of albacore and yellowfin tuna by Japanese vessels in the Coral Sea south of New Guinea gave weight to the assumption that there would be sufficient tuna in Queensland inshore waters to support a commercial fishery.

The initial plan proposed by Harbours and Marine was for two surveys; a short preliminary survey, and a main survey over two years (two complete fishing seasons). For the preliminary survey, an expert from one of the major overseas tuna companies would be hired to take part in flights over the Great Barrier Reef. His observations would be used to plan the main survey, in which the area between Brisbane, New Guinea, and Torres Strait would be covered by a suitable fishing vessel.

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At discussions between the Department of Harbours and Marine, the Commonwealth Department of Primary Industry, and the Division of Fisheries and Oceanography, CSIRO, some parts of the initial plan were questioned. In the first place it was suggested that an overseas expert's skills might have little relevance to Australian conditions. Secondly, in view of the reasonably intensive mackerel fishery in Queensland, the suggestion was made that the only part of Queensland inshore waters that needed surveying was around the area of widely scattered reefs near the southern end of the Great Barrier Reef. It was suggested by the Division of Fisheries and Oceanography, CSIRO, that this area might yield reasonable quantities (over 1000 tons per annum) of tuna. In this area there are numerous reefs around which yellowfin (*Thunnus albacares*) and other tuna might be expected to school. Again, in this area, the water is sufficiently deep and open to permit the use of modified long-lines with shortened buoy and branch lines. It should be noted that a large part of the area initially suggested for survey was too shallow for long-lines or purse-seine nets to be used.

Subsequently, CSIRO put forward a plan for a survey of the Swain Reefs area in September–October, and because of the expected behaviour of yellowfin tuna in these waters the plan stated that both surface vessels and an aircraft would be needed. Using formulae given by Hynd (1963), it was calculated that a twin-engined aircraft flying 20 hr per week would be needed. Surface support by three vessels would also be needed.

Towards the end of 1964 formal discussions between Harbours and Marine, Primary Industry, and CSIRO were initiated, and in November the three agreed that CSIRO should develop a proposal, in collaboration with the other two, for the conduct of a tuna survey in the Swain Reefs area in October–November 1965. At the conclusion of this survey further surveys in the Coral Sea might be planned.

In February and April 1965 final plans were drawn up. It proved feasible to extend aircraft searching out to the 1000 fathom line (200–300 miles offshore) and accordingly the flight plans for the Swain Reefs area were extended to cover the outlying reefs and islands. Plans were also prepared for a survey of the outlying reefs between Cairns and Townsville.

Final cost estimate for the survey was $68,000 and on May 31, 1965, the Queensland Cabinet approved a survey costing this amount, provided the Commonwealth Government gave half from the Fisheries Development Trust Account. The Commonwealth subsequently agreed to this. To administer the survey, the Queensland Yellowfin Tuna Survey Committee was set up with members from Harbours and Marine, Primary Industry, and CSIRO. The present author was selected as project leader. The stated aims of the survey were as follows:

(1) to assess the abundance of yellowfin tuna in the waters off Queensland, and the availability of bait;
(2) to determine the best method of catching these tuna, and the type of vessel and equipment best suited for this purpose;
(3) to assess the economics of tuna fishing operations and the marketing prospects; and
(4) to determine the best location for a shore base and the type of facilities that would be required in that base.

II. Survey Planning

Figure 1 shows the Queensland coast from Cape York to Sandy Cape. The Barrier Reef, offlying reefs, and approximate 1000-fm contour are also represented. It is within this 1000-fm contour that, by analogy with the American west coast fishery, conditions favourable for the presence of juvenile yellowfin should be found. As the amount of money likely to be forthcoming for the survey would not allow of more than a few months operations in limited areas, a decision had to be made as to what these areas should be.

The Swain Reefs area had already been selected as the most promising on the grounds of topography and the fact that yellowfin tuna had already been taken there. Tuna have frequently been found to be most numerous in areas where "upwelling" occurs. The general movement of surface water in the Coral Sea is from east to west and results in convergences when the currents approach the east Australian coast. As a consequence there is no broad area of upwelling, and consequent possible enrichment, off the Queensland coast. However, localized upwellings caused by the topographical configuration of an area can occur even in regions of convergence. Typically, seamounts, submerged reefs, and emergent reefs and islands cause these upwellings. The next most suitable area (on the grounds of topography alone) was the area of outlying reefs east of Cairns and Townsville.

Flight plans covering these two areas were drawn up (Figs. 2 and 3). The area surrounded by the double line in Figure 2 is *c.* 50,000 square miles, that in Figure 3 is *c.* 60,000 square miles. An aircraft flying 25 hr per week in the Swain Reefs area and 30 hr per week in the Cairns–Townsville area has about 1 chance in 80 of detecting every appearance in daylight hours of every school, provided schools stay at the surface for 2 hr on the average and weather conditions are ideal. This is a satisfactory sample for survey purposes and the estimated cost of the operation was within the limits of the tentative budget.

Planning included the use of surface craft to fish schools located by the aircraft, to carry out independent searching for fish, and to make oceanographical observations. Such craft needed to be at least 85 ft in overall length to operate successfully. The cost of operating such vessels precluded the use of more than one.

The aircraft selected for the spotting operations was an Aero Commander 500B, registration VH-AVT, fitted with all necessary instrument flying rules gear (a Department of Civil Aviation term) and life-saving equipment. With a crew of three this aircraft had an effective range of about 850 miles. The surface craft selected was the 96 ft tuna live-bait fishing vessel *Degei.*

Final plans provided for 25–30 aircraft hours and 75 boat hours per week. The Swain Reefs section was to be surveyed in August–September and the Cairns–Townsville section in October–November. Operations in November were restricted to aircraft spotting since F.V. *Degei* was not available for charter in that month.

III. Survey Results

(*a*) *Administrative*

The survey commenced practically on schedule with F.V. *Degei* leaving Sydney on 30.vii.65 and VH–AVT on 2.viii.65. Operations proceeded as planned except that activities were transferred to the northern section after 1 month in the southern section. This was done because water temperatures found in the southern section were somewhat cooler than is believed necessary for yellowfin to exhibit rippling behaviour. Activities were transferred back to the southern section in November.

The survey concluded on 30.xi.65 when VH–AVT returned to Sydney as planned. F.V. *Degei* returned to Sydney on 3.xi.65 approximately as planned. Hours steamed by F.V. *Degei* were 1044 or 77·3 per week. This is slightly in excess of the 75 hr anticipated. Spotting hours flown by VH–AVT were 388 or 22·82 per week, slightly lower, due to operating difficulties, than the contract minimum of 24 per week and about 5 hr less than the planned average of 27·5 per week. However, the cover given was satisfactory.

Main costs of the survey were: F.V. *Degei*, $26,067; VH–AVT, $22,324. Total cost was $60,837 which is well within the budget provided.

(*b*) *Scientific*

(i) *Oceanographical Conditions*

The surface temperature observations made by F.V. *Degei* are summarized in Figures 4–9. Inspection shows a relatively uniform pattern compared with that usually found further south on the eastern Australian coast. No marked discontinuities or "fronts" were found except on 30.xi.65 when F.V. *Degei* found yellowfin associated with one to the east of Fraser I.

(ii) *Fish Sightings from Aircraft* (Figs. 10–24)

(1) *Fish Identification*.—When planning the survey it was expected that initially the spotter would have difficulty distinguishing between the various species of tuna, since there was no one available with experience in recognizing the tropical species from the air. As it turned out it took only a few days for the spotter to recognize the difference between schools of striped tuna, *Katsuwonus pelamis* (L.), and mackerel tuna, *Euthynnus alletteratus affinis* (Cantor) (which were the two most frequently observed species and which were about the same in average size of individual fish, namely *c*. 10 lb). The larger species—yellowfin, *Thunnus albacares* (Bonnaterre), dog-tooth, *Gymnosarda unicolor* (Ruppell), and northern bluefin tuna, *Thunnus tonggol* (Bleeker)—were rarely, if ever, observed, so even by the end of the survey the spotter was not certain of the distinguishing characteristics of these species. However, since no large schools of large fish were seen this uncertainty does not preclude a satisfactory assessment of the results.

Striped tuna schools are characterized by a blue colour. In addition the individual fish "shine" brightly as they turn on their sides. It is not uncommon for the majority of the individuals of a school to shine simultaneously. By contrast the mackerel tuna schools have a grey-green colour and the individual fish do not shine as brightly as do striped tuna.

Other species of fish and marine animals were recognized and recorded by the spotter. These included school mackerel, Spanish mackerel, various species of feed fish (including hardyheads and torpedo fish), porpoises, black fish, and humpback and sperm whales. Turtles and sunfish were seen but not recorded.

(2) *Yellowfin Tuna.*—No yellowfin tuna were identified by the spotter as such except those fish seen on 30.x.65 around F.V. *Dègei.* Unfortunately, the sun was low and the light poor so that the fish could not be examined closely for identifying characteristics. It is probable that some of the larger fish recognized as tuna but unidentified as to species were in fact yellowfin, but since all schools of such fish were small feeding schools it follows that the spotter saw no rippling schools or large feeding schools of yellowfin.

(3) *Mackerel Tuna.*—This was the most prolific species of tuna in the survey area. It is not possible to give accurate estimates of quantities since all fish seen from the aircraft were in the feeding phase of behaviour and quantities are difficult to estimate in these circumstances. Nevertheless, the spotter is of the opinion that the biggest school seen contained not more than a few tons and most schools were considerably smaller. The total tonnage seen in one area at one time (as, for example, at Flinders Reefs) was probably not more than 100 tons.

TABLE 1

DETAILS OF FISH CAPTURES MADE BY F.V. *DEGEI*

Date	Fishing Method	Yellowfin Tuna	Northern Bluefin Tuna	Dog-tooth Tuna	Mackerel Tuna	Striped Tuna	Other Species	Totals
1–15.viii.65	Trolling	4		2	2	1	9	18
	Poling	44					6	50
16–31.viii.65	Trolling	8		1	3		9	21
	Poling	25						25
1–15. ix.65	Trolling				1		4	5
	Poling							
16–30. ix.65	Trolling			1	1		5	7
	Poling							
1–15. x.65	Trolling			6	14	1	10	31
	Poling							
16–31. x.65	Trolling	11		6	11	1	21	50
	Poling	38				1		39
Totals	Trolling	23		16	32	3	58	132
	Poling	107				1	6	114
Grand total								246

(4) *Striped Tuna.*—Occasional rippling schools of striped tuna were identified. The largest such school was estimated to contain 20 tons. The quantity of striped tuna sighted was considerably smaller than that of mackerel tuna. No feeding schools of striped tuna were identified.

(5) *Dog-tooth and Northern Bluefin Tuna.*—Neither of these species was identified from the air.

(iii) *Fish Sightings and Catches by F.V.* Degei (Figs. 4–9; Table 1)

(1) *Yellowfin Tuna.*—Yellowfin tuna were taken by F.V. *Degei* only in the southern part of the survey area [see Figs. 4(*b*), 5(*a*), 5(*b*), 6, 7, and 9(*a*)]. No catches

or sightings were made in the central or northern part. All catches were made off the edges of isolated reefs or on the continental shelf edge. No fish were seen or taken in very deep or very shallow water.

No rippling schools of yellowfin were sighted. All catches were made by trolling or poling from feeding schools. On a few occasions fish were chummed to the surface and subsequently poled where no fish were visible but fish had been taken by trolling.

The fish ranged in size (and weight) from 61 cm (10 lb) to 127 cm (75 lb). These lengths correspond to ages of 14 months and $2\frac{1}{2}$ yr, respectively, assuming the same rate of growth as Japanese yellowfin (Yabuta and Yukinawa 1962). The frequency distributions of the lengths of fish taken in two periods, one at the beginning and one at the end of the survey are given in Figure 25 (no fish were taken in the intervening period). The peak in Figure 25(*a*) at 87 cm corresponds to an age of 20 months. The peak in Figure 25(*b*) at 94 cm corresponds to an age of 22 months. Hence, the majority of fish were somewhat less than 2 yr old. Also, the assumption of a growth rate similar to that of Japanese fish is supported. However, the length distributions are skewed markedly to the left. This could be due to the presence of **X** and **Y** stocks in each year class as found in the eastern Pacific (see Davidoff 1963).

All stomachs examined (15) contained food, the bulk of which was deep-swimming organisms such as red prawns, myctophids, and squid. Some stomachs contained surface-occurring forms. The deep-swimming organisms were frequently in a good state of preservation.

Surface water temperatures when fish were caught were in the range 21·5–25·5°C. Surface water temperatures in the northern and central areas where no yellowfin were taken lay in the same range; hence it seems that the apparent relative scarcity of yellowfin in the northern and central areas was not related to surface water temperature.

A total of 39 fish were tagged and released.

(2) *Mackerel Tuna.*—Mackerel tuna schools were sighted by F.V. *Degei* more often than other tuna schools. However, catches of fish from these schools were not in proportion since the crew of F.V. *Degei* were unable to pole any fish at all and trolled only few. In fact, resort was occasionally had to hand-lines baited with live bait to obtain confirmation that the schools were of mackerel tuna. All schools seen were feeding schools and contained 10 tons or less of fish.

(3) *Striped Tuna.*—Striped tuna schools were reported nearly as often as those of mackerel tuna but confirmation by capture was rare, only four striped tuna being taken during the survey. It seems possible that, at least in the early part of the survey, some of the schools identified as striped tuna were in fact mackerel tuna. In any case the quantities in the schools reported as being of striped tuna were small (usually 10 tons or less).

(4) *Dog-tooth and Northern Bluefin Tuna.*—Dog-tooth tuna were taken occasionally (16 specimens) but no northern bluefin were caught, and no schools of either were reported by F.V. *Degei*. Since schools of dog-tooth tuna usually consist of at most five to six fish (Silas 1963) it is not surprising that F.V. *Degei* failed to report any.

(iv) *Bait Fish*

Bait fish are discussed in Part 2 of this report.

IV. Discussion

(*a*) *Yellowfin Tuna*

The virtual absence of surface-appearing schools of yellowfin tuna is both puzzling and disappointing. We know that the annual Coral Sea catch of yellowfin by Japanese long-liners is of the order of 20,000 tons, and the juveniles of these fish almost certainly inhabit the coastal waters around the Coral Sea. We also know that 3-yr-old fish form an appreciable proportion of the catch of Japanese long-liners operating in the southern part of the survey area.

It is possible that commercial quantities of yellowfin were present during the survey but did not surface during the day (some of the fish that were taken had recently surfaced after feeding deep). The range of surface temperature of waters which yellowfin tuna inhabit is 18–31°C maximum, 20–30°C optimum (Broadhead and Barrett 1964). In the eastern Pacific fishery the greater part of the catch is taken from waters with temperatures in the upper half of these ranges. Hence it may be assumed that the range 25–30°C is more favourable for the surface appearance of yellowfin than the range 20–25°C. The range of surface temperatures during the survey was 19–25°C, hence it could be inferred that had the surface temperatures been higher there might have been a better chance of observing surface schools.

There is also the possibility that fish surfaced at night. No attempt was made during the survey to investigate this possibility, mainly because of the navigational problems involved.

(*b*) *Mackerel Tuna*

Although mackerel tuna were the most prolific of tunas in the survey area it is not considered that they are likely to be of importance for canning purposes since:

(1) the flesh is very dark in colour (though it is said the colour improves on canning);

(2) the individual fish are small (average about 10 lb);

(3) they are not easily taken by poling;

(4) they are usually in a feeding phase of behaviour and therefore scattered;

(5) they are probably not present in large quantities (less than 10,000 tons).

(*c*) *Other Species*

The possibility that striped tuna might be present in the survey area in greater numbers at other periods of the year cannot be ignored. Large schools of northern bluefin are often reported by Queensland fishermen. The fact that no bluefin were taken by F.V. *Degei* though there were several small catches inshore by professional fishermen could mean that the distribution of the species in the survey area is confined to the inshore waters. In any case it is unlikely that this species would ever form the basis of a major fishery since it is limited in its distribution to continental shelf areas. Dog-tooth tuna are even less likely to form the basis of a commercial fishery.

V. Recommendations

The following recommendation was submitted by the project leader in an interim report to the committee dated 5.xii.65:

> Available evidence indicates that surface-appearing schools of yellowfin could be found in the warmer summer months. If it is decided to extend the survey, the appropriate period is therefore January to April inclusive. Further surveying can be carried out without the full-time assistance of a fishing boat provided the aircraft is fitted with an infrared radiation thermometer. If rippling schools of medium to large fish are located, they will consist of either northern bluefin or yellowfin and it should be possible to persuade one or two local fishermen to fish them with troll lines to obtain positive identification.

An estimate of costs was also submitted.

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PART 2—1967

I. Introduction

Following the reception and discussion of the project leader's report on the first part of the survey, the committee decided to recommend to Government that the survey be extended as proposed. However, due to various delays it was not possible to commence the survey until January 1967 by which time costs had risen considerably, making the estimates for the extended survey obsolete. Queensland Cabinet had in the meantime approved of the expenditure of $30,000 provided the Commonwealth gave half as before, so it became a matter of planning the survey around an expenditure of this amount.

II. Survey Planning

Original planning for the extension of the survey envisaged the use of an aircraft in Queensland and Tasmania–Victoria in alternate half months. A considerable amount of ferry time which would largely be wasted was involved. However, due to the delay of 12 months in commencing the second part of the survey, during which time the Tasmanian–Victorian survey was completed, it became possible to plan for full utilization of the aircraft in Queensland. A new contract with the owners of the aircraft was negotiated on the basis of a minimum flying time of 90 hr a month. At this rate it was estimated that available funds would be sufficient for a 3½-month survey only.

A series of 13 basic flight plans were drawn up covering the whole of the survey area. These are shown in Figure 26. These or similar plans were to be flown once a month as close together in time as possible so that a surface isotherm map of the whole area could be constructed. Flying time required was estimated at 65 hr. The remaining 25 hr were to be spent searching in areas that appeared to be favourable for the appearance of yellowfin tuna as judged from the results of the first 65 hr flying.

An infrared radiation thermometer (Barnes Engineering Model IT3) was installed in the aircraft. This instrument had been used fairly successfully in the earlier Tasmanian–Victorian survey where it had proved feasible to construct surface isotherm maps from the temperature trace produced by the instrument, provided calibration checks could be made with surface craft. A device was built into the instrument to provide a direct measurement of instrument error, thus eliminating most of the uncertainty in adjusting instrument readings and making the aircraft largely independent of surface craft for calibration checks.

III. Survey Results

(a) *Administrative*

The aircraft VH–AVT left Sydney on 3.i.67 and commenced the survey proper on 4.i.67. Operations were terminated on 1.v.67 and the aircraft returned to Sydney. A total of 312 hr 45 min were flown on survey flights and a further 5 hr 10 min on ferry flights. This is very close to the 315 hr planned. The survey took slightly longer to carry out than the planned 3½ months due to operating difficulties. Total cost of the survey was $29,876 of which aircraft charter was $20,618.

(b) *Scientific*

Aircraft flight paths, sightings, and surface isotherms are shown in Figures 27–33.

(i) *Oceanographic Conditions*

As predicted in Part 1 the surface temperatures lay in the range 25–30°C. The pattern of distribution of surface temperature was relatively uniform as found previously. However, temperature "fronts" were found during the second half of March (Fig. 31) and the second half of April (Fig. 33) between Cato and Fraser islands. In addition, a patch of relatively cool surface water was located during the first half of January in the same area and traced through to the second half of February. This patch of cool water could have arisen by upwelling. Very shallow inshore water (less than 10 fm) tended to be about 1 degC warmer than water further offshore.

(ii) *Fish Identification*

Aircraft flight paths and sightings are shown in Figures 27–33. While there was still some uncertainty as to the distinguishing characteristics of yellowfin, northern bluefin, and dog-tooth tuna, as a result of talks with the skipper and crew of F.V.

Degei, the spotter started the second part of the survey in a much better position than he started the first. The crew of F.V. *Degei* noticed that all yellowfin taken had approached the boat from below and deep down, which is in contrast to the behaviour of southern bluefin and striped tuna which approach more or less horizontally. The reaction of northern bluefin and dog-tooth tuna to live bait is not known.

If feeding schools of about 12 or more fish each of 40 lb or more in weight were observed, these would almost certainly be yellowfin, since northern bluefin are usually much smaller than 40 lb and dog-tooth tuna do not form schools of more than about six fish. In addition, if the fish were approaching the surface almost vertically, this would be additional evidence in support of the identification. In this way the spotter was able to identify feeding yellowfin on several occasions with certainty. Further, if rippling schools containing over 1 ton or more of large fish were seen these would be yellowfin schools for the same reasons.

(iii) *Yellowfin Tuna Sightings*

Fish definitely identified as yellowfin tuna were located on only four occasions, (1) near Breaksea Spit on 4.i.67 (Fig. 27); (2) at Flinders Reefs on 21.ii.67; (3) at Marion Reef on 4.iii.67 (Fig. 30); and (4) west of Marion Reef on 19.iii.67 (Fig. 31). The latter sighting was the only one made in deep water (perhaps 300–400 fm) but the depth is uncertain because of the sparsity of soundings in this area. The biggest sighting was at Marion Reef. This consisted of 12 schools of feeding fish, none containing more than 2 tons of fish and most of them less. The other three sightings were considerably smaller than this.

All fish were in the feeding condition and most exhibited the characteristic behaviour of rising more or less vertically from deep water when attacking surface feed then returning the same way to deep water. An exception was the mixed school seen near Breaksea Spit in which mackerel tuna were schooled at the surface attacking (along with sharks) a patch of feed and the yellowfin were schooled below the mackerel tuna. No sightings were made in the southern part of the survey area which, in the first part of the survey, was the only area to yield yellowfin.

No sightings were made of large quantities of unidentified tuna that could have been yellowfin. Hence it must be concluded that the total sightings of yellowfin would not have filled a moderate-sized tuna fishing boat.

(iv) *Mackerel Tuna Sightings*

As in the first part of the survey mackerel tuna was the most prolific species. Also as before, quantities greater than about 100 tons were not seen on any one flight.

Mackerel tuna were frequently found in Barrier Reef waters in mixed schools along with school mackerel and Spanish mackerel, all attacking food organisms. The abundance of mackerel tuna as judged by sightings was greater in Barrier Reef waters than in the deeper waters and those around offlying reefs.

(v) *Striped Tuna Sightings*

Striped tuna were sighted on four occasions only; (1) at Lihou Reef on 8.ii.67 (Fig. 29); (2) north-east of Mackay in outer Barrier waters on 19.iii.67 (Fig. 31);

(3) off Fraser I. on 23.iii.67 (Fig. 31); and (4) east of Flinders Reefs on 5.iv.67 (Fig. 32). The largest school sighted (8.ii.67) was estimated to contain 10 tons. The fish seen on 19.iii.67 and 5.iv.67 were mixed with mackerel tuna and mackerel, and small in quantity. The fish seen on 23.iii.67 were feeding fish, again only in small quantity. It is unlikely that an appreciable proportion of the unidentified tuna was in fact striped tuna, so we must conclude that the total sightings of striped tuna were less than 100 tons, i.e. of the same order as yellowfin.

(vi) *Northern Bluefin and Dog-tooth Tuna Sightings*

No schools or individuals of these species were recognized.

(vii) *Mackerel Sightings*

No distinction is made in any of the figures between school and Spanish mackerel. Both were seen by the aircraft in both parts of the survey and both were taken by F.V. *Degei* in the first part of the survey. All sightings and catches were confined to Barrier Reef waters with the exception of occurrences at Holmes and Flinders reefs. Considerably greater quantities of both types were sighted during the second part of the survey than during the first.

(viii) *Bait Fish*

During the first part of the survey F.V. *Degei* did not experience great trouble in obtaining live bait. The principal species taken was the tropical hardyhead, *Pranesus capricornensis* Woodland, which was obtained mainly by beach seining on mainland or coastal island beaches during daylight. The next commonest species were the pilchards, *Amblygaster sirm* (Walbaum) and *A. clupeoides* Bleeker, which were taken at night by purse-seine with the aid of a bait lamp. Other species taken were the spotted herring, *Harengula koningsbergeri* (Weber & de Beaufort), and the sprat, *Dussumieria hasselti* Bleeker. An attempt was made to take the banana fish (torpedo fish), *Caesio* sp., during the day by purse-seine but failed when the net became foul of a niggerhead of coral. Subsequent discussion with local fishermen confirmed that it is the habit of this species to school around niggerheads. Both the hardyhead and the northern pilchard (*A. sirm*) were found to be satisfactory bait. However, the *A. clupeoides* taken were rather large and did not keep well.

In the first part of the survey the fish spotter learned to identify hardyheads and banana fish. The hardyhead schools are a dark colour while the banana fish schools are golden green. Quantities of hardyheads estimated at 1000 tons were seen on the mainland coast north of Yeppoon on one occasion.

In the second part of the survey other colours of food organisms were distinguished. A light-blue-coloured school is believed to be that of the fish called a sardine around Cairns (probably *H. koningsbergeri*) while a purple-coloured school could be, on the basis of quantity seen, that of the northern pilchard (*A. sirm*).

In the second part of the survey large quantities of food organisms, chiefly schools of small fishes of various species, were sighted in the central and southern part of Barrier Reef waters.

IV. Discussion

In the two parts of the survey a total of about 700 hr was flown by VH-AVT. This time was spread over 8 months of the year, only the late autumn and winter periods not receiving any attention. During these 8 months the surface temperature ranged from 19 to 30°C which is not only the most favourable range for yellowfin tuna, but is probably the average annual range of the area surveyed.

This searching effort detected at the most a few hundred tons of commercially acceptable species of tuna scattered widely both in time and area. By contrast the same amount of searching time spent in the New South Wales or South Australian bluefin fisheries would be expected to reveal thousands, if not tens of thousands, of tons of fish.

It is clear then, that provided fish behaviour in the autumn and winter periods each year does not differ from that in spring and summer and that the years chosen for the survey were not abnormal in some way, there is no basis for a commercial tuna fishery, either live-bait or purse-seine, which relies on existing spotting methods for the detection of fish.

It is possible that there was a commercial quantity of yellowfin or striped tuna or both in the area and that for some reason the fish failed to behave as they do in southern waters. Striped tuna are frequently seen by spotting planes in large quantities in the rippling phase of behaviour in New South Wales waters. Yellowfin tuna are occasionally seen in the same behavioural phase in summer in the same waters. Again, unless the behaviour of the fish was abnormal, there is no basis for an industry using existing methods. It is conceivable that methods of detection other than surface spotting could reveal the presence of tuna. Sonar searching is an obvious choice if such a task were to be attempted. In the event that fish are located and can be taken by the live-bait method, it seems that with a little more experience there would be no major problems with bait supplies.

V. Recommendations

At its present stage of development and use, sonar searching for tuna must be regarded as a relatively unproven technique. Certainly I could not recommend that a further extension of the survey be undertaken using such a technique, unless it had been tried extensively and been shown to work satisfactorily in the southern bluefin fishery (or overseas tuna fisheries).

If it is decided to extend the survey to cover that part of the year not yet investigated, then aircraft spotting as carried out in Part 2 of the survey would suffice.

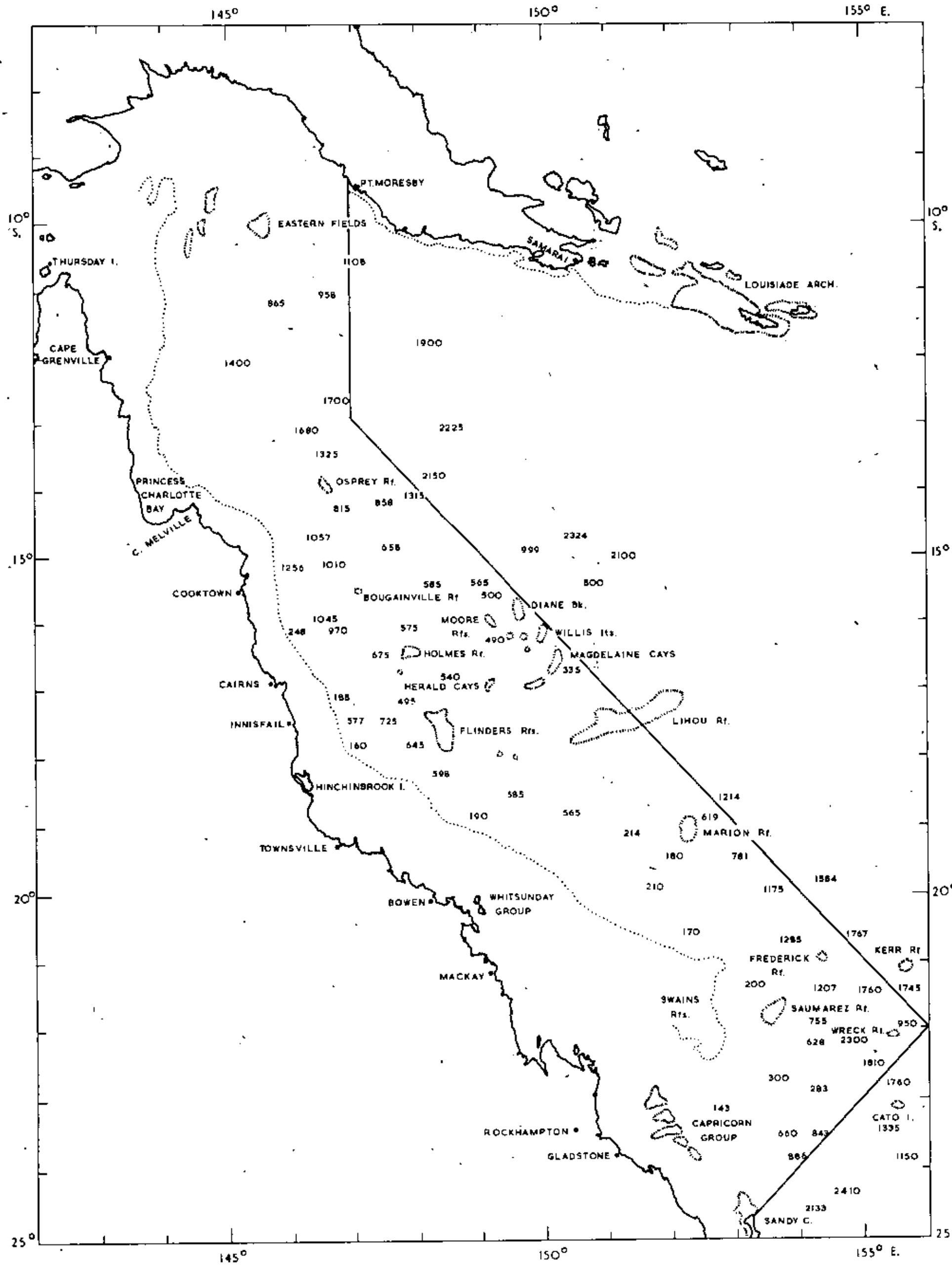

Fig. 1.—Queensland coastal and offshore waters showing the outer barrier (broken line) and approximate 1000 fm contour (full line). Soundings in fathoms.

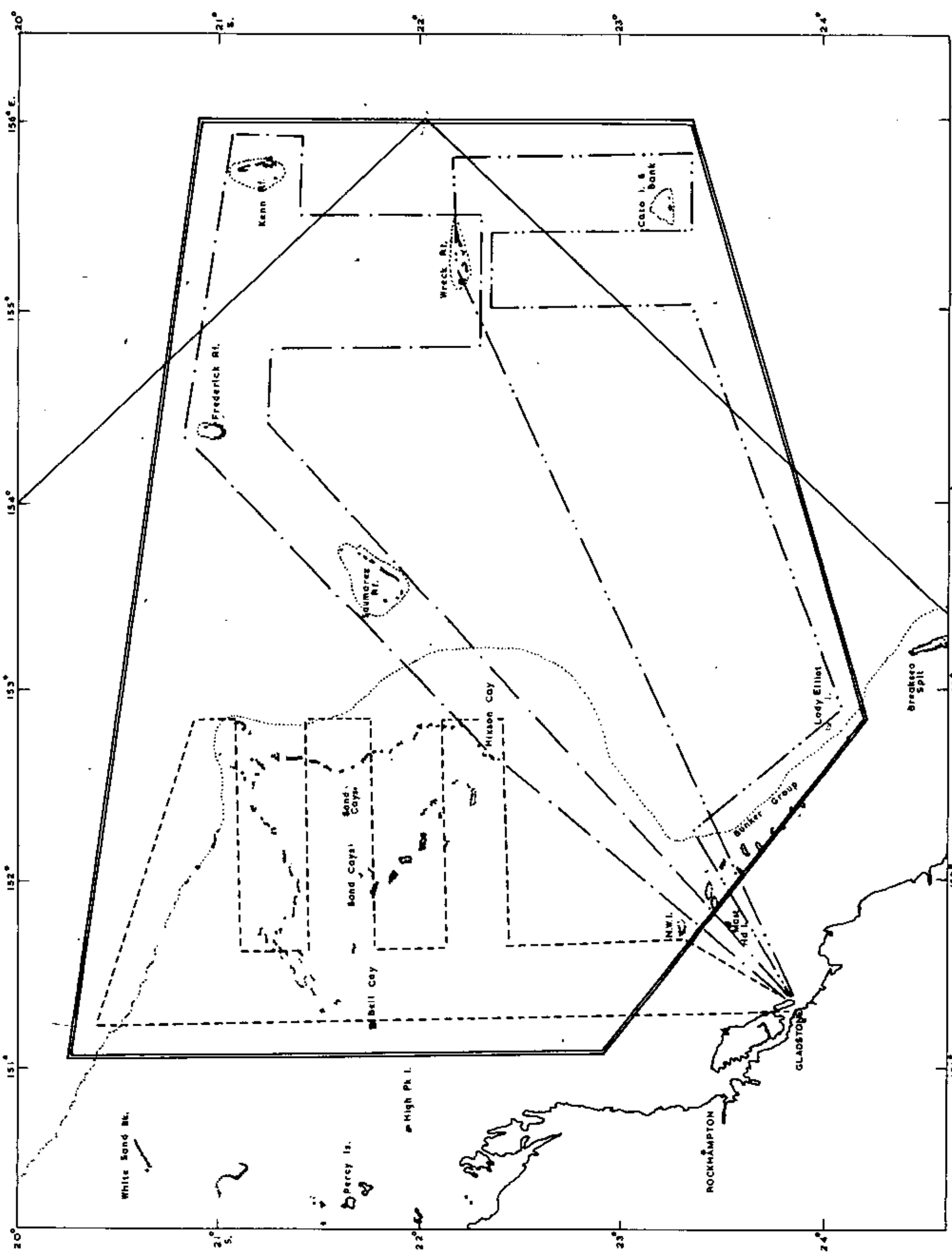

Fig. 2.—Queensland Yellowfin Tuna Survey 1965. Tuna spotting flight plans for Swain Reefs sector of Queensland coastal waters. Area in double rule = 50,000 sq miles. Full line was outer limit of waters to be surveyed.

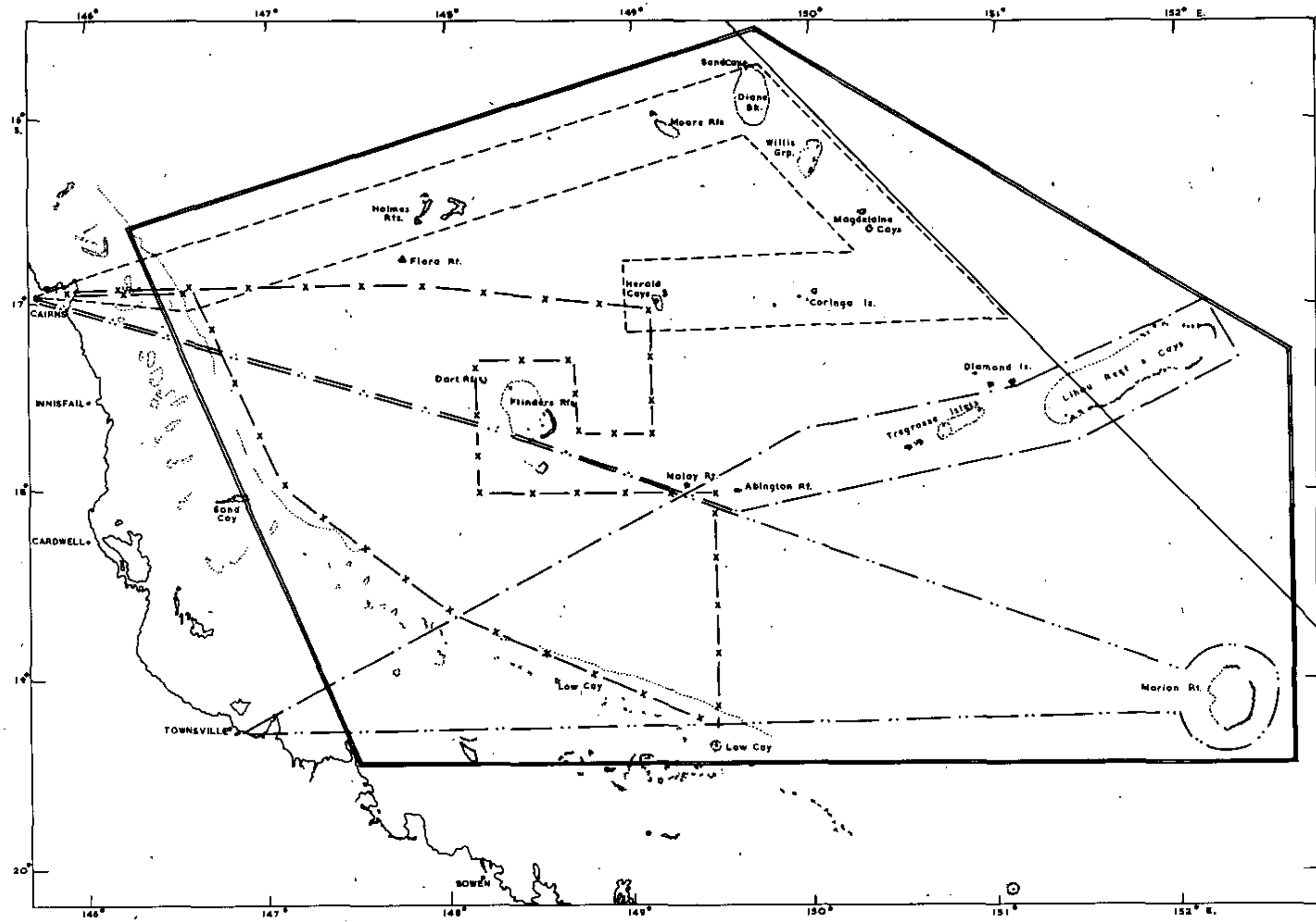

Fig. 3.—Queensland yellowfin tuna survey, 1965. Tuna spotting flight plans for Cairns–Townsville sector of Queensland coastal waters. Area in double rule = 60,000 sq miles. Full line was outer limit of waters to be surveyed.

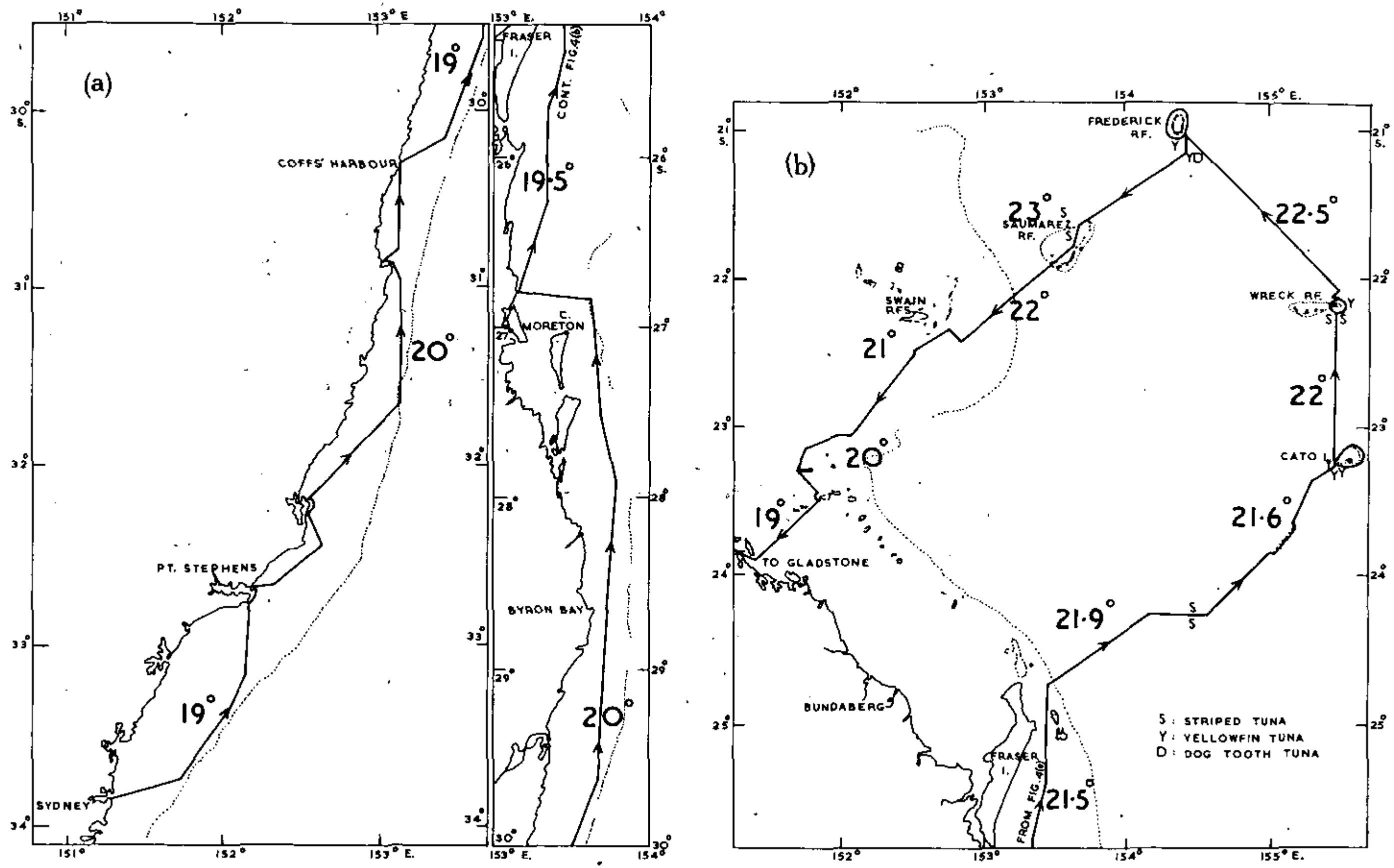

Fig. 4.—(*a*) Track of F.V. *Degei* 30.vii–3.viii.65 (left) and 3–5.viii.65 (right), and surface temperatures. (*b*) Track of F.V. *Degei* 5–12.viii.65, surface temperatures, and tuna sightings and catches.

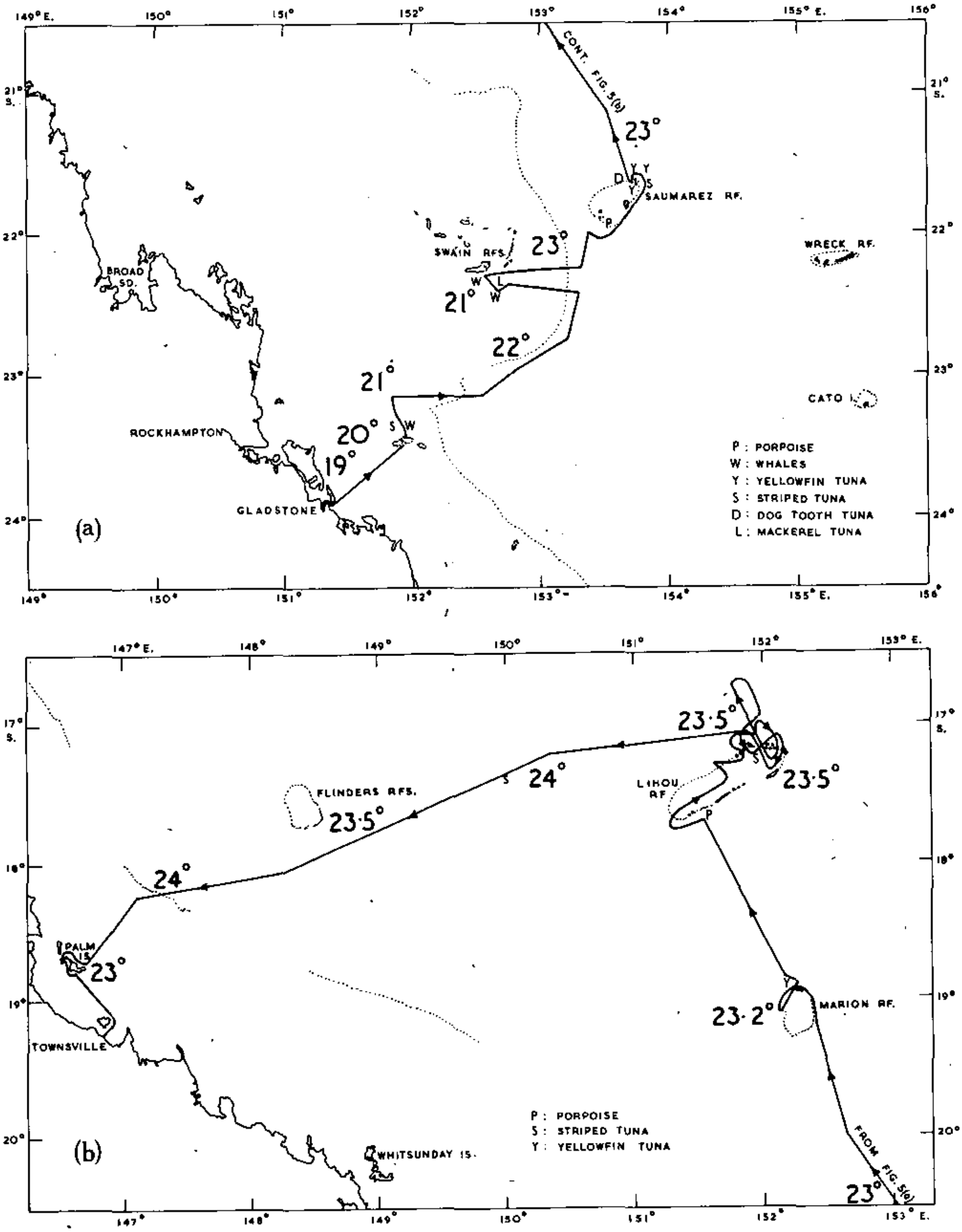

Fig. 5.—Track of *F.V. Degei*, surface temperatures, tuna sightings and catches, and other sightings for 15–20.viii.65 (*a*) and for 20–28.viii.65 (*b*).

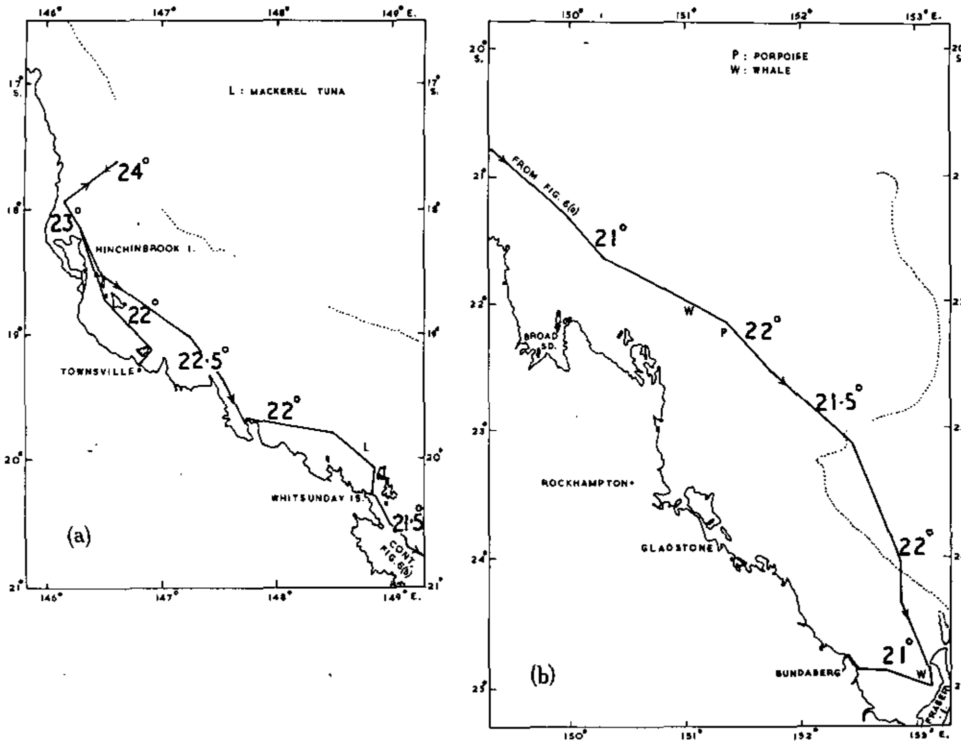

Fig. 6.—(*a*) Track of F.V. *Degei* 1–8.ix.65, surface temperatures, and tuna catches. (*b*) Track of F.V. *Degei* 8–12.ix.65, surface temperatures, and sightings.

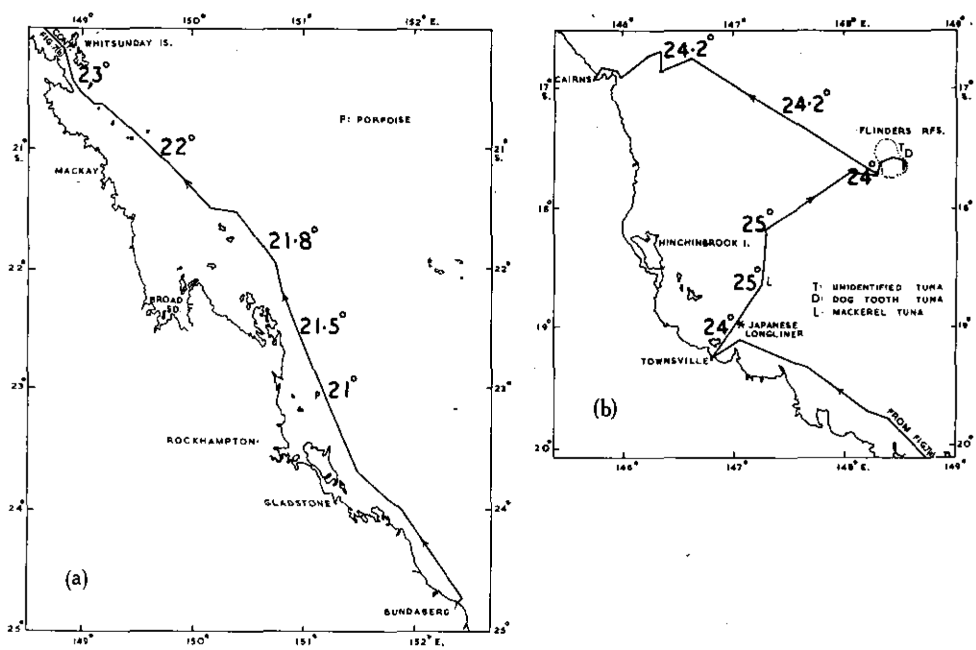

Fig. 7.—(*a*) Track chart of F.V. *Degei* 13–15.ix.65, surface temperatures, and sightings. (*b*) Track of F.V. *Degei* 15–23.ix.65, surface temperatures, and tuna catches and sightings.

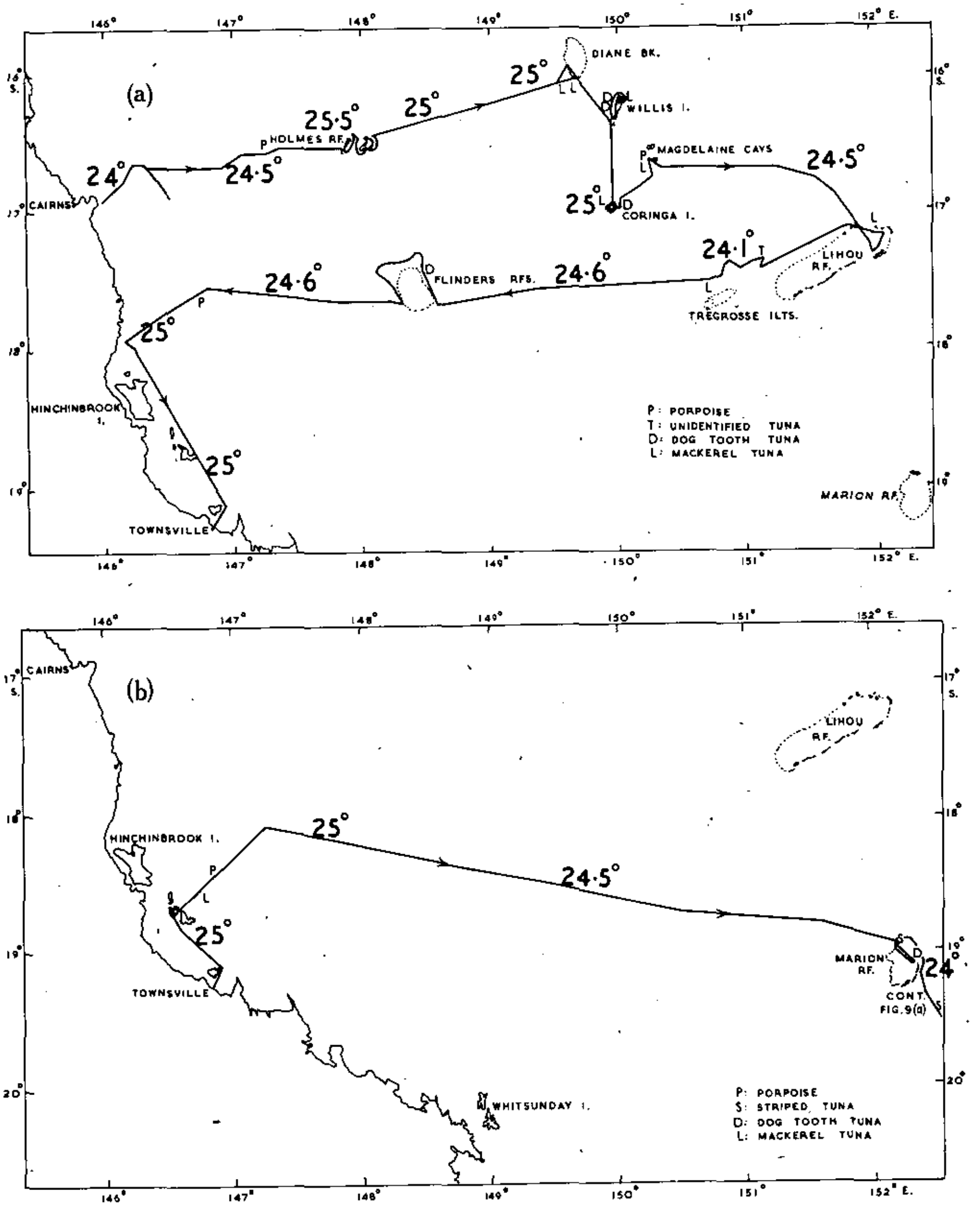

Fig. 8.—Track chart of F.V. *Degei*, surface temperatures, tuna catches and sightings, and other sightings for 27.ix–12.x.65 (*a*) and for 16–21.x.65 (*b*).

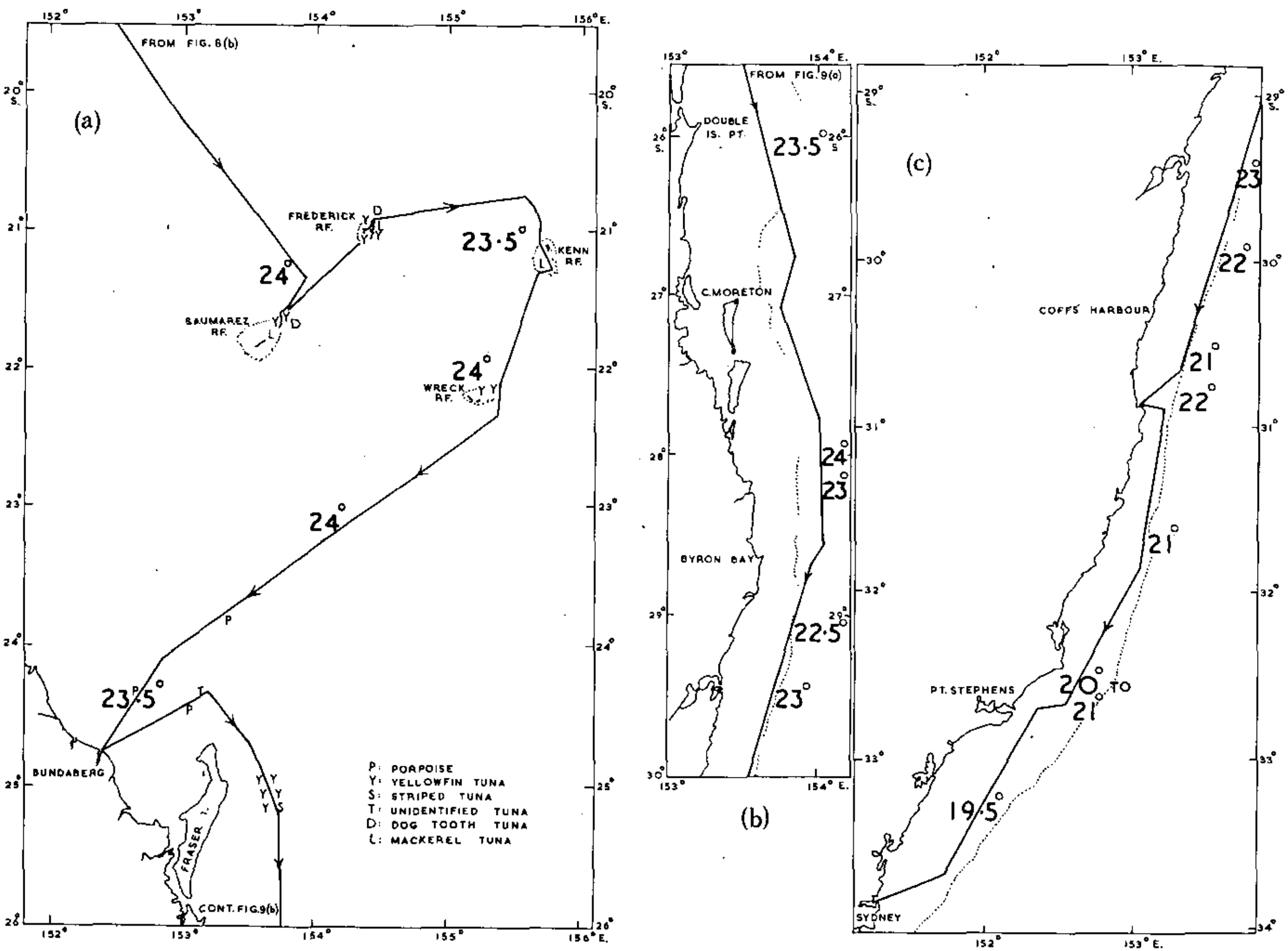

Fig. 9.—(*a*) Track chart of F.V. *Degei* 21–30.x.65, surface temperatures, tuna catches and sightings, and other sightings. (*b*, *c*) Track charts of F.V. *Degei* and surface temperatures for 30 and 31.x.65 (*b*) and for 31.x–3.xi.65 (*c*).

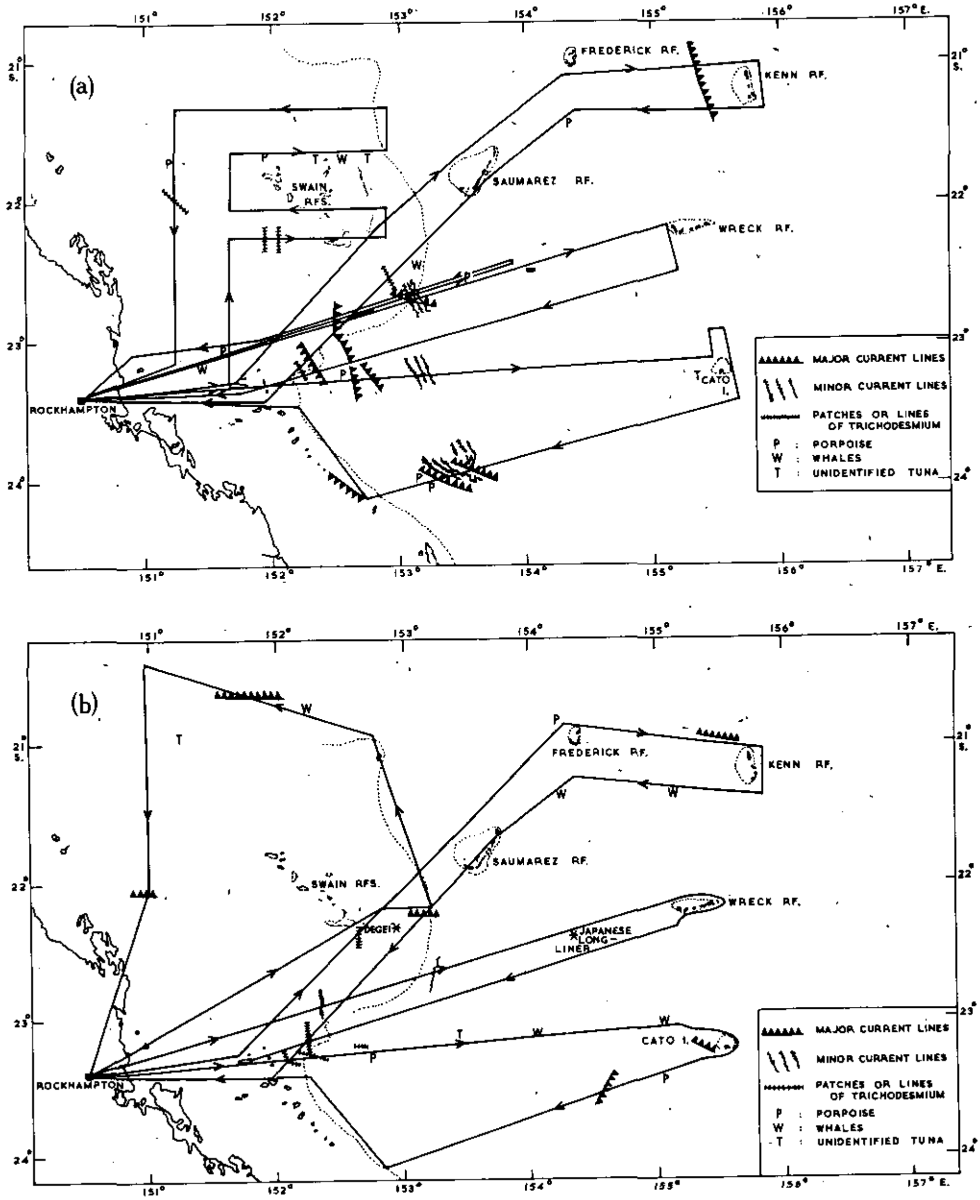

Fig. 10.—Aircraft flight paths and sightings for 5–8.viii.65 (*a*) and for 10–12.viii.65 (*b*).

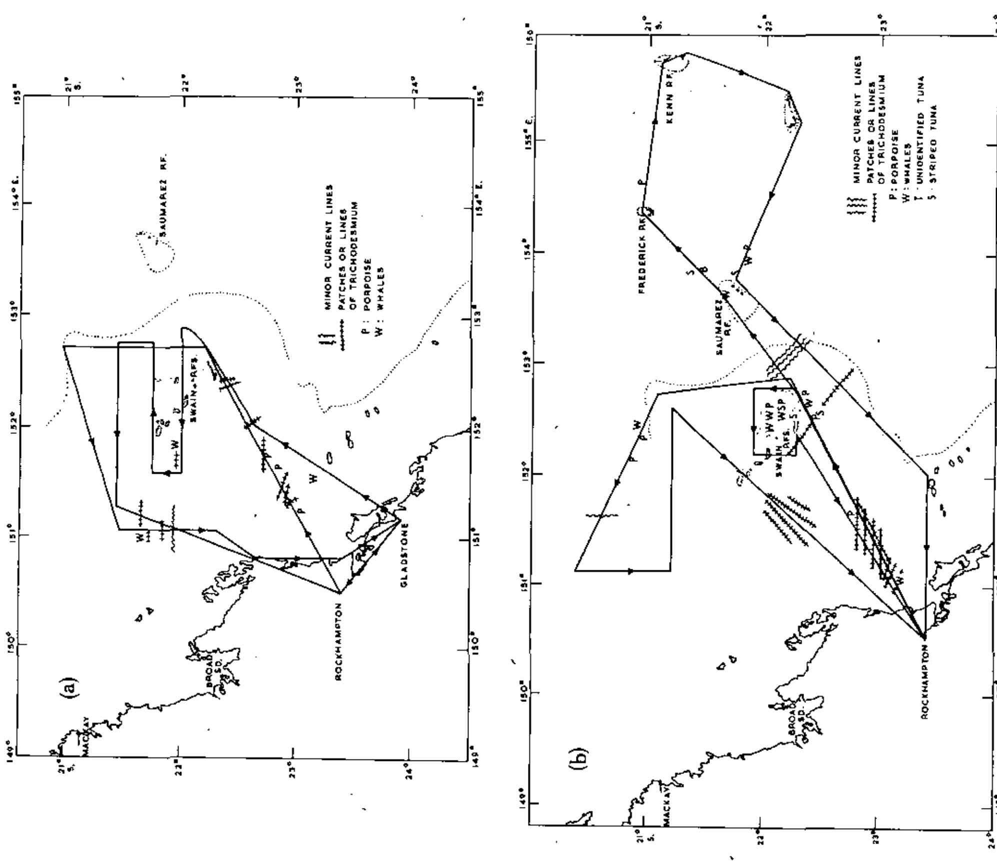

Fig. 11.—Aircraft flight paths and sightings for 13–16.viii.65 (*a*) and for 17, 18, and 24.viii.65 (*b*).

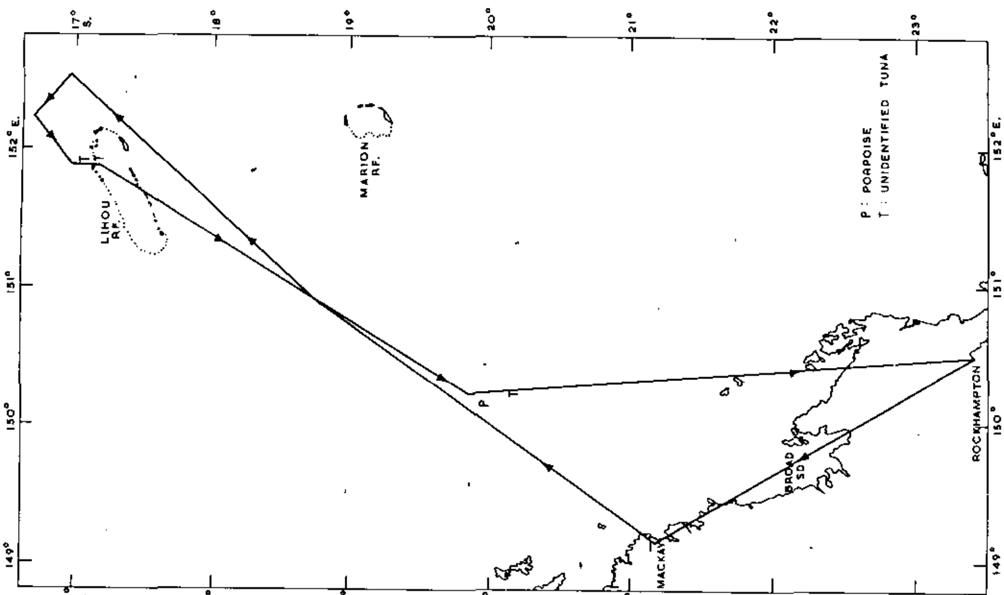

Fig. 12.—Aircraft flight paths and sightings 23.viii.65.

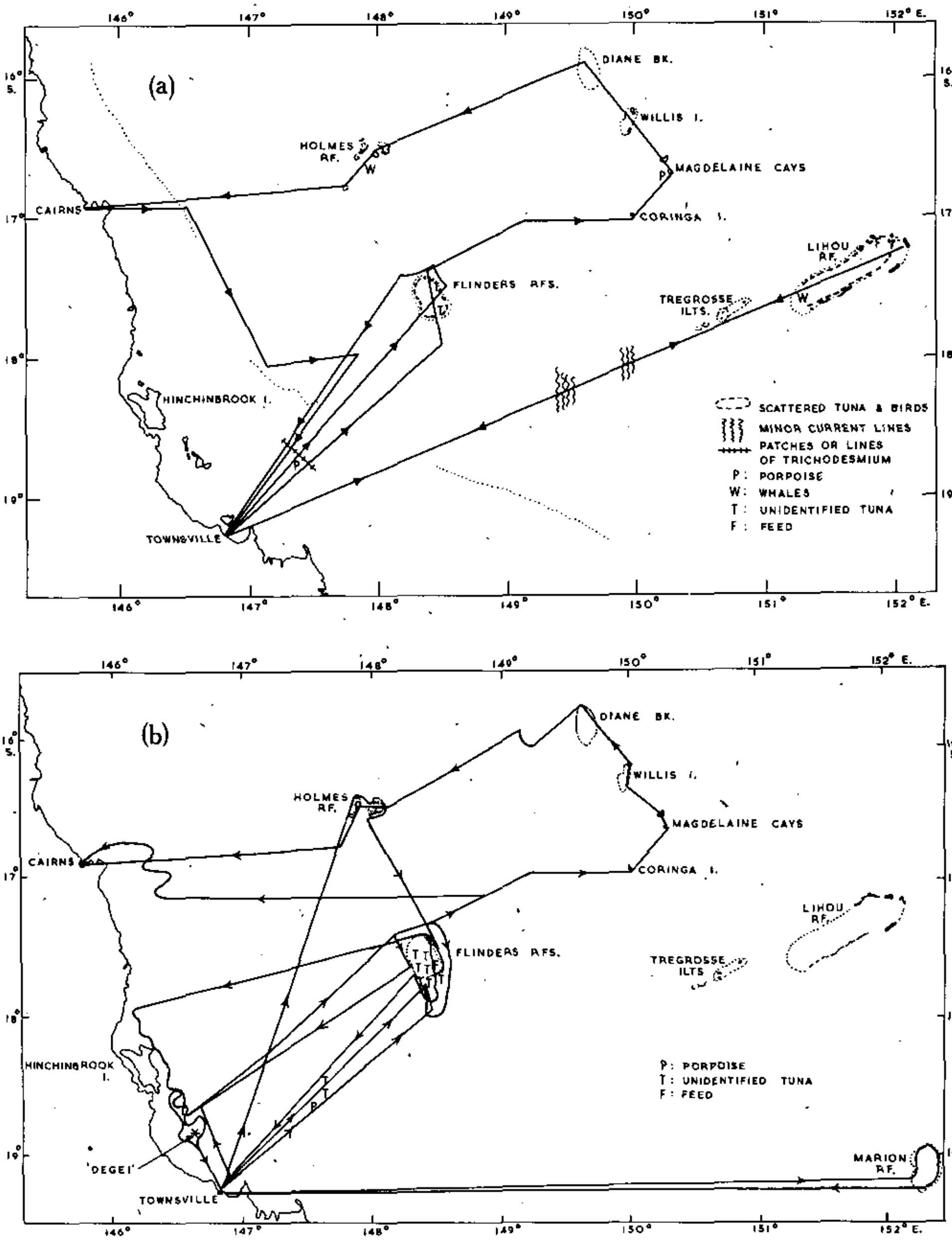

Fig. 13.—Aircraft flight paths and sightings (*a*) 26–28.viii.65; (*b*) 31.viii–4.ix.65, and 9,10.ix.65.

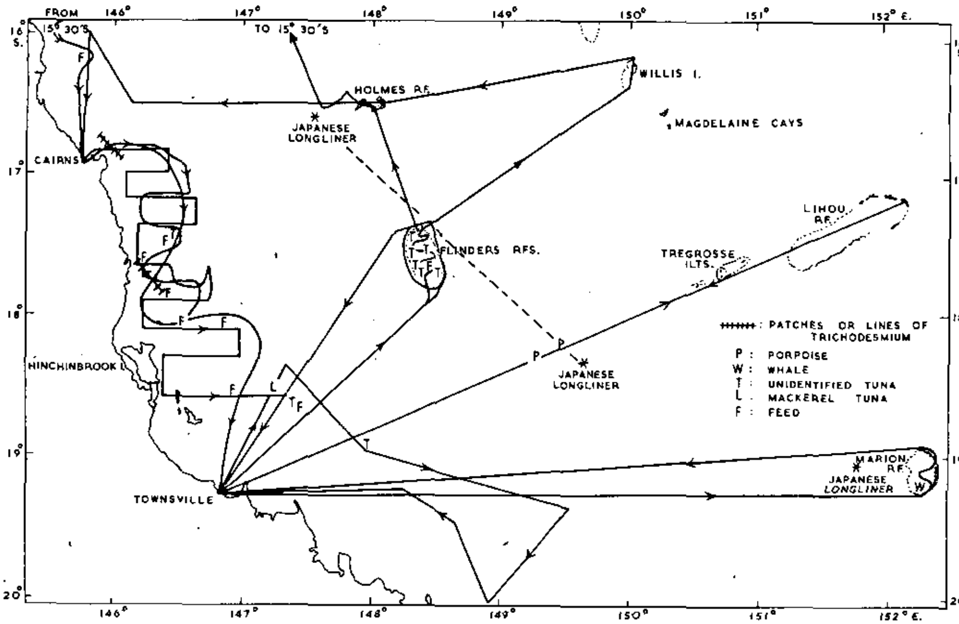

Fig. 14.—Aircraft flight paths and sightings 10–14.ix.65.

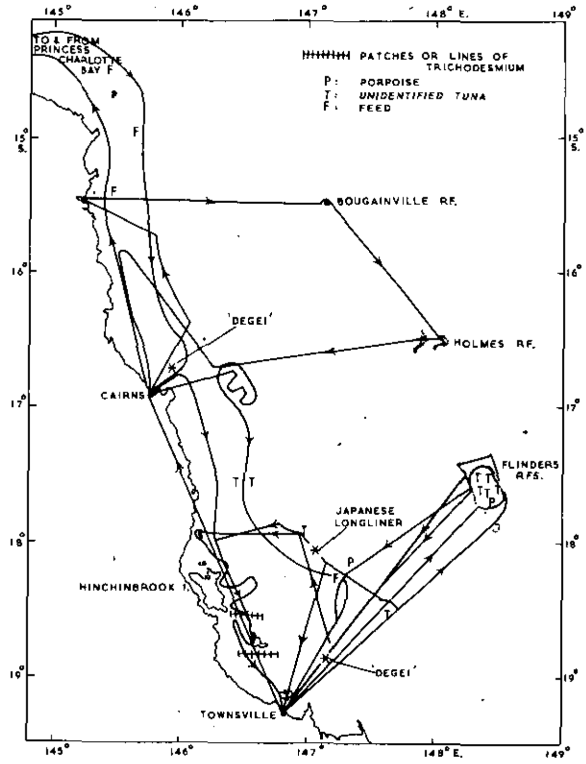

Fig. 15.—Aircraft flight paths and sightings 17–25.ix.65 and 28–30.ix.65, in part.

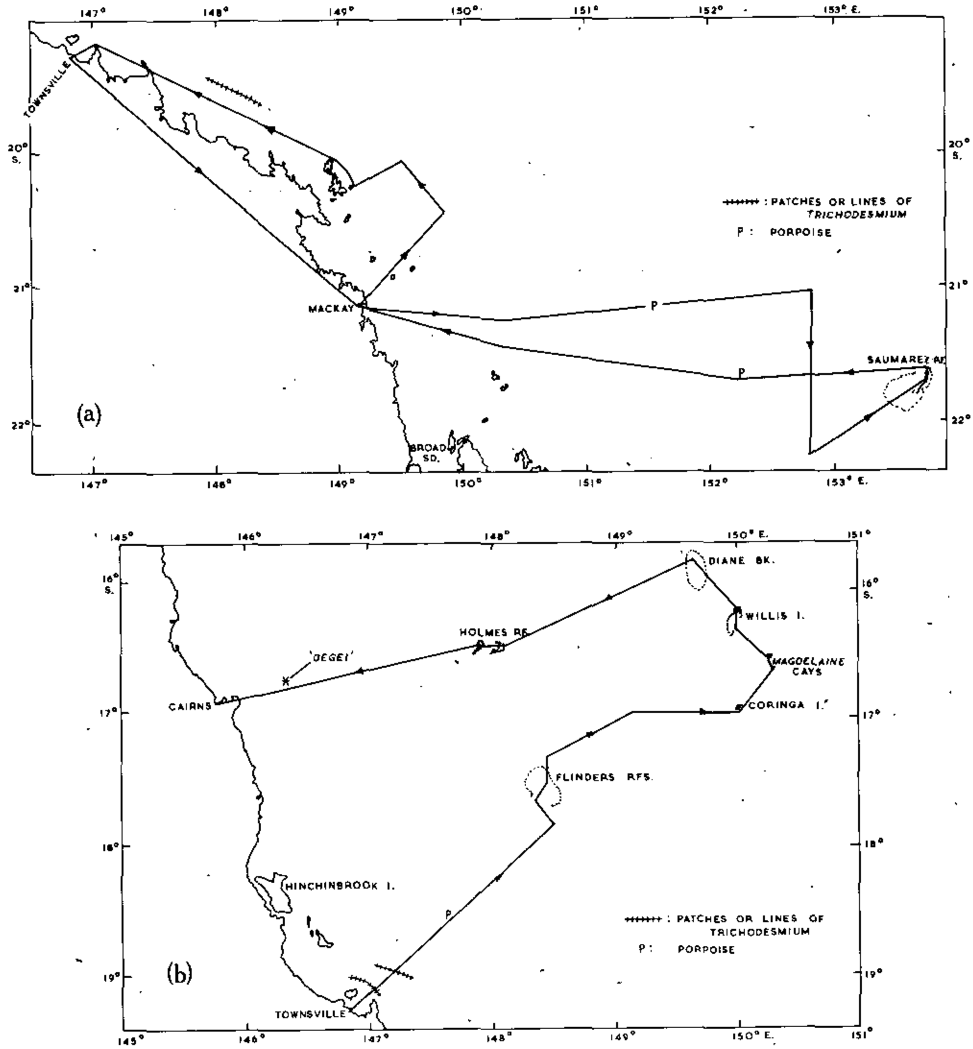

Fig. 16.—Aircraft flight paths and sightings (*a*) 27.ix.65; (*b*) 30.ix.65, in part.

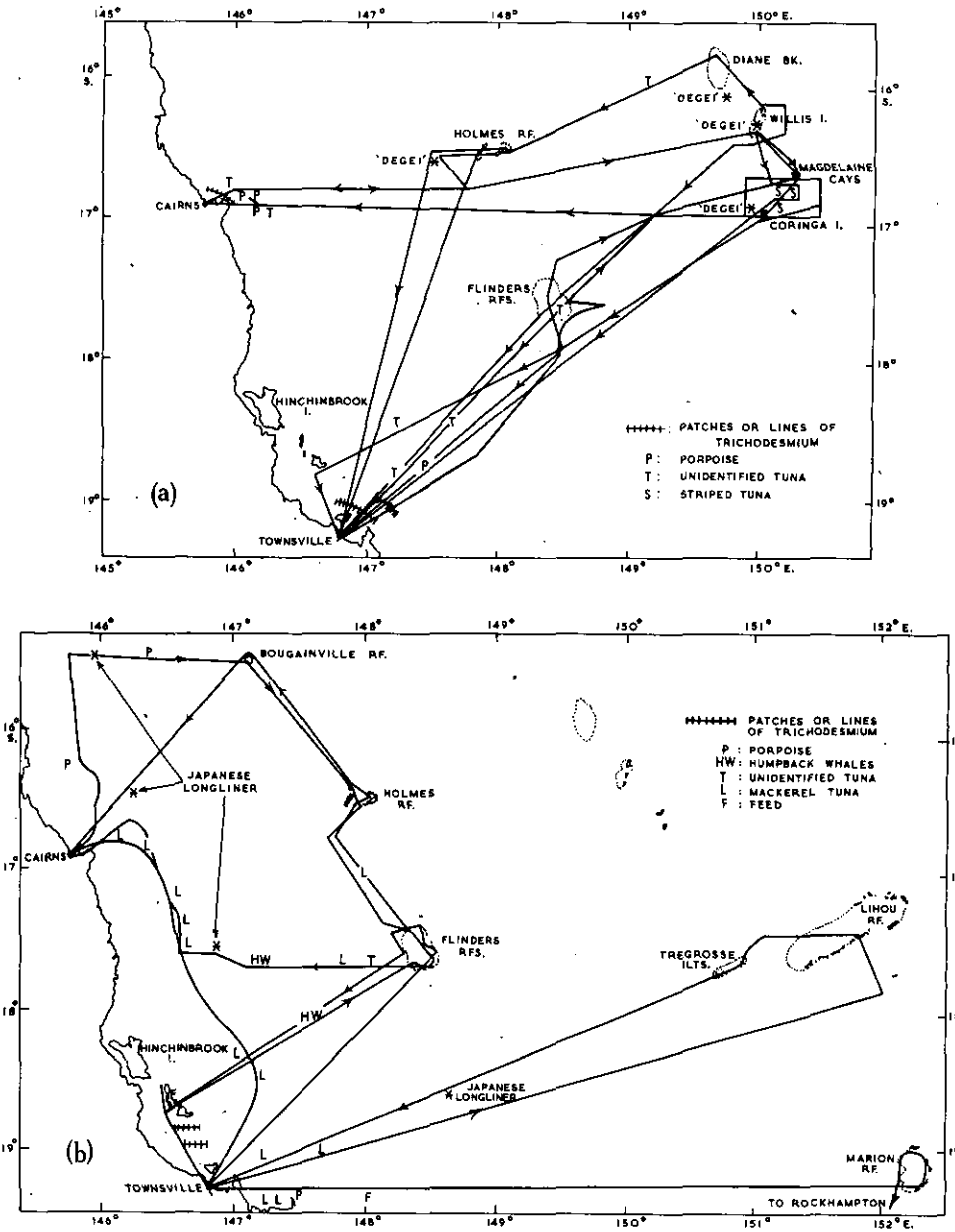

Fig. 17.—Aircraft flight paths and sightings (*a*) 8.x.65, (*b*) 16–20.x.65.

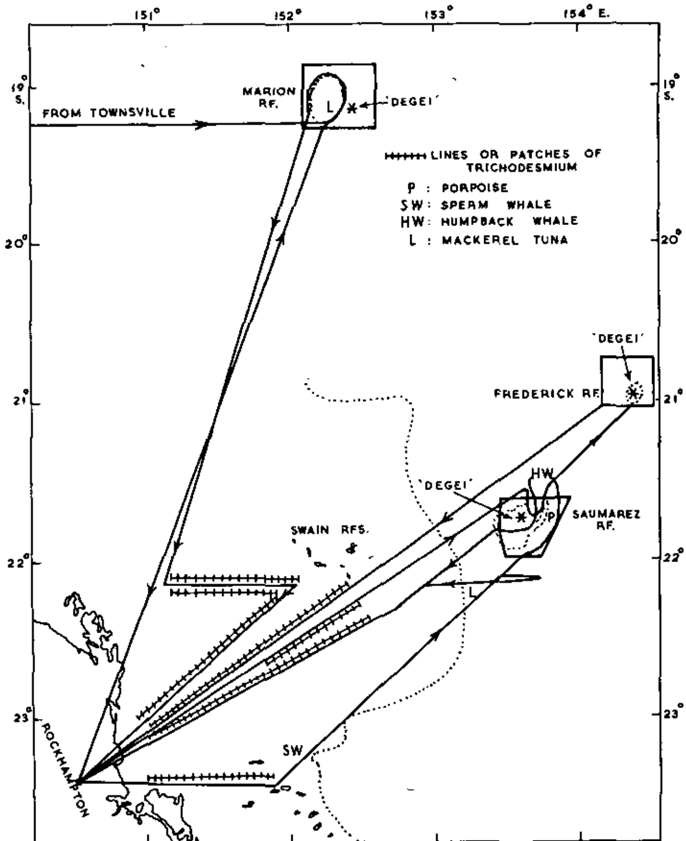

Fig. 18.—Aircraft flight paths and sightings 20–24.x.65.

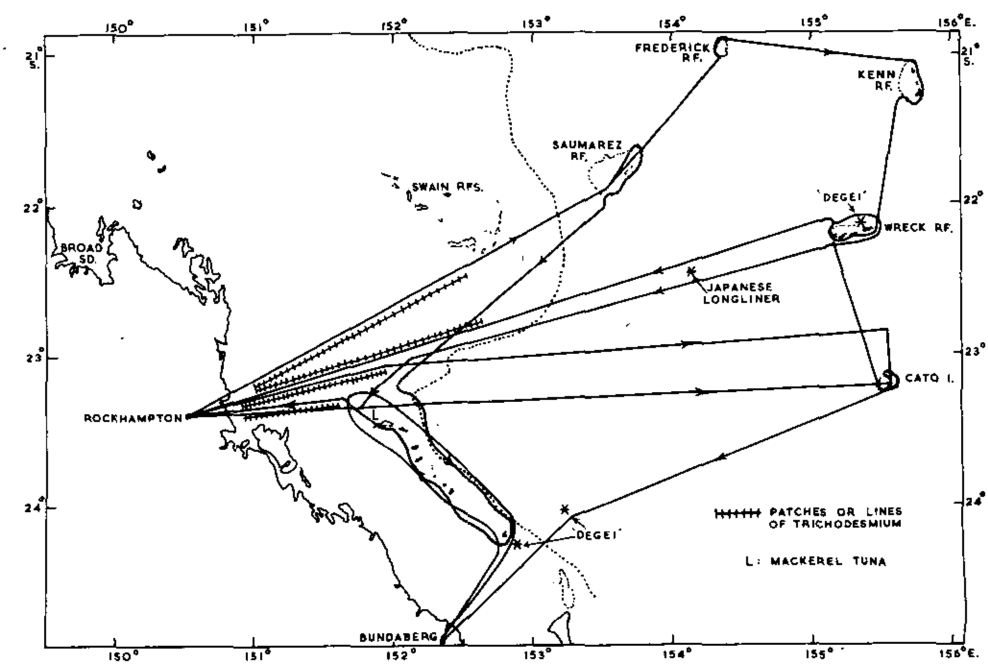

Fig. 19.—Aircraft flight paths and sightings 25–28.x.65.

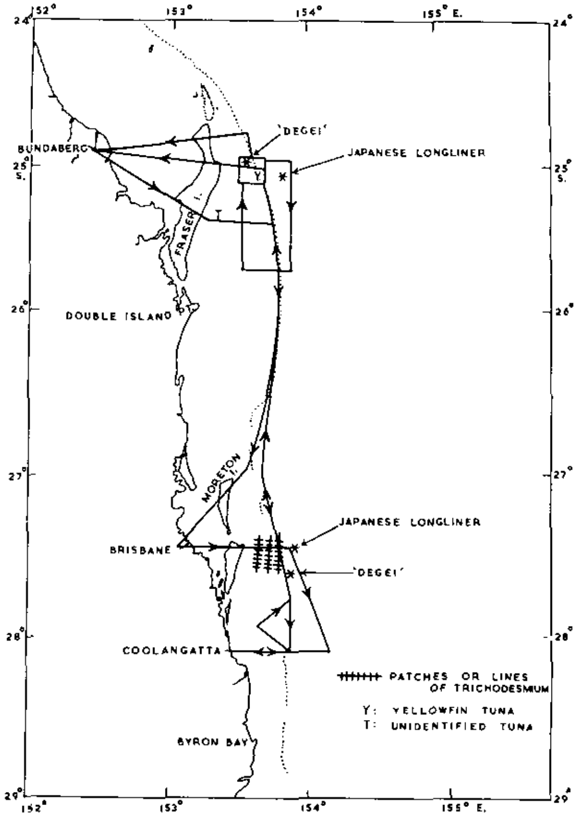

Fig. 20.—Aircraft flight paths and sightings 30 and 31.x.65.

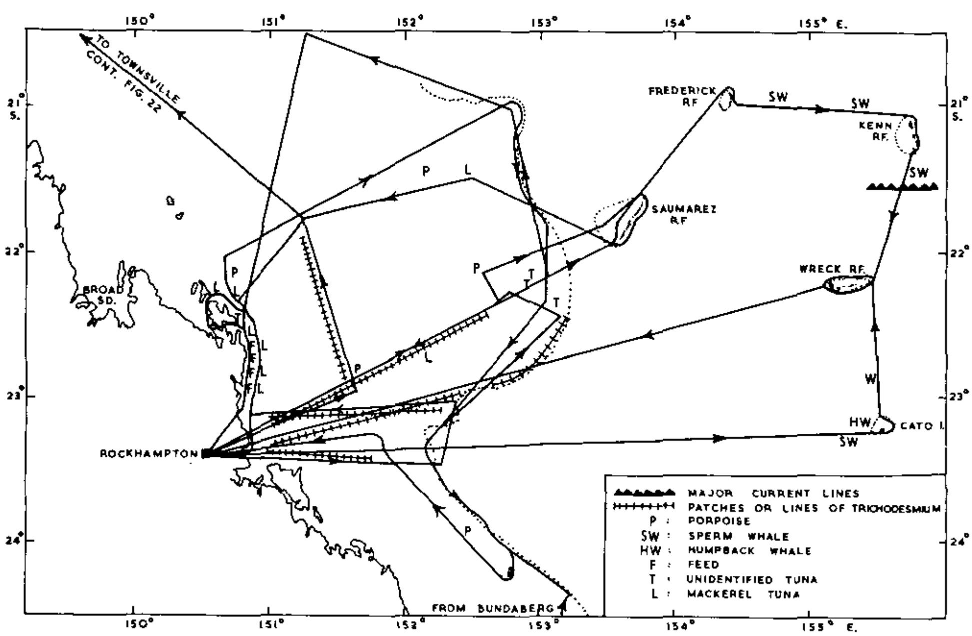

Fig. 21.—Aircraft flight paths and sightings 1–7.xi.65.

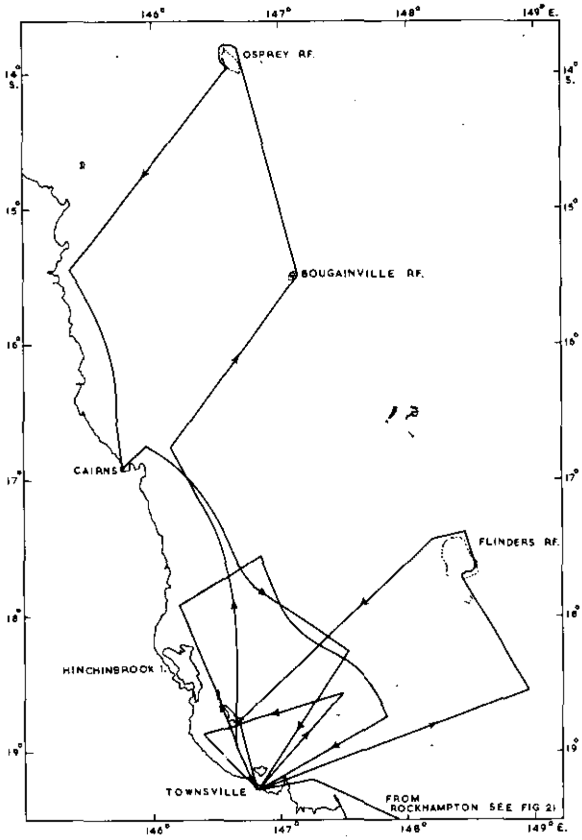

Fig. 22.—Aircraft flight paths and sightings 7–15.xi.65.

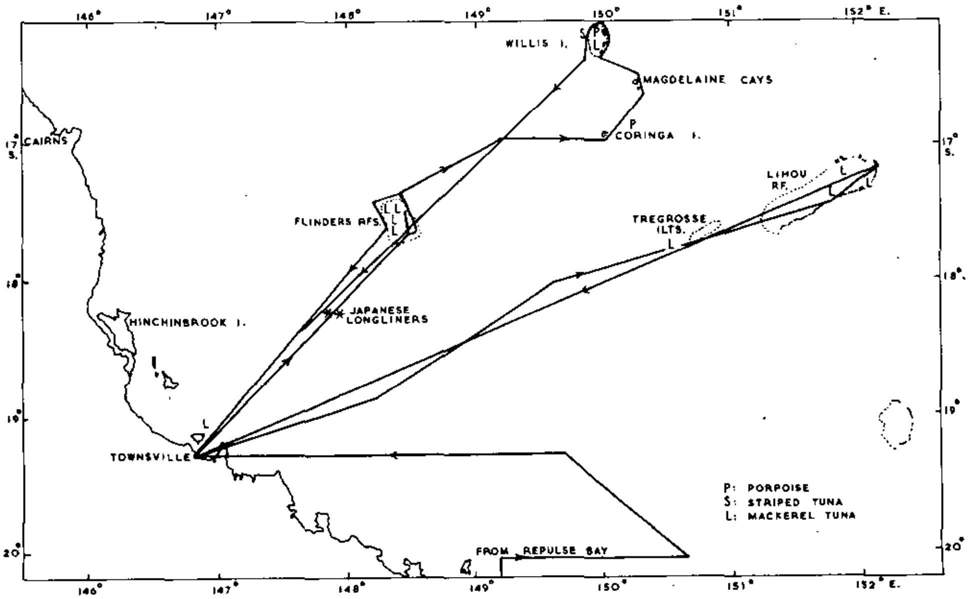

Fig. 23.—Aircraft flight paths and sightings 16 and 17.xi.65.

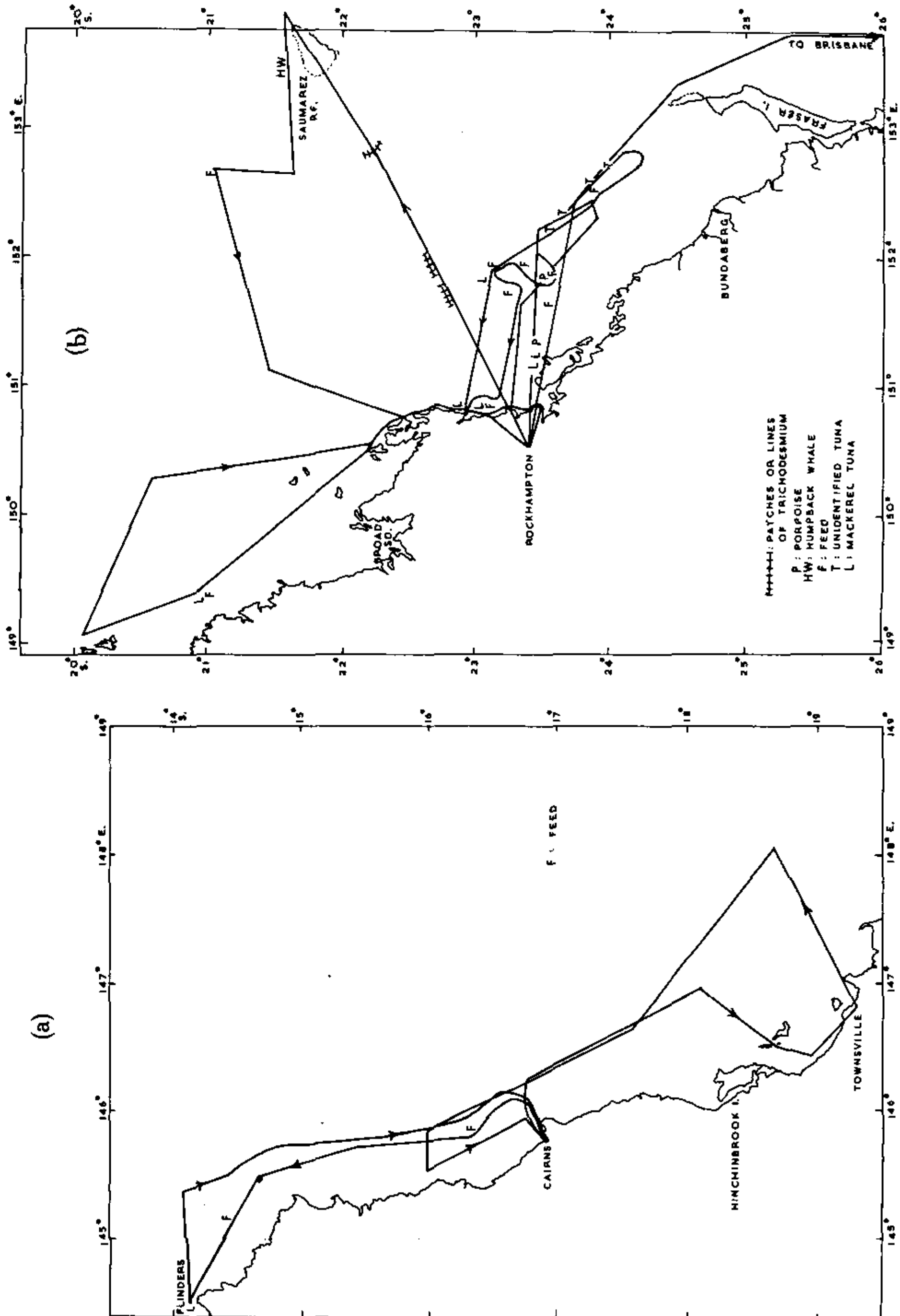

Fig. 24.—Aircraft flight paths and sightings (*a*) 20 and 21.xi.65, (*b*) 23–30.xi.65.

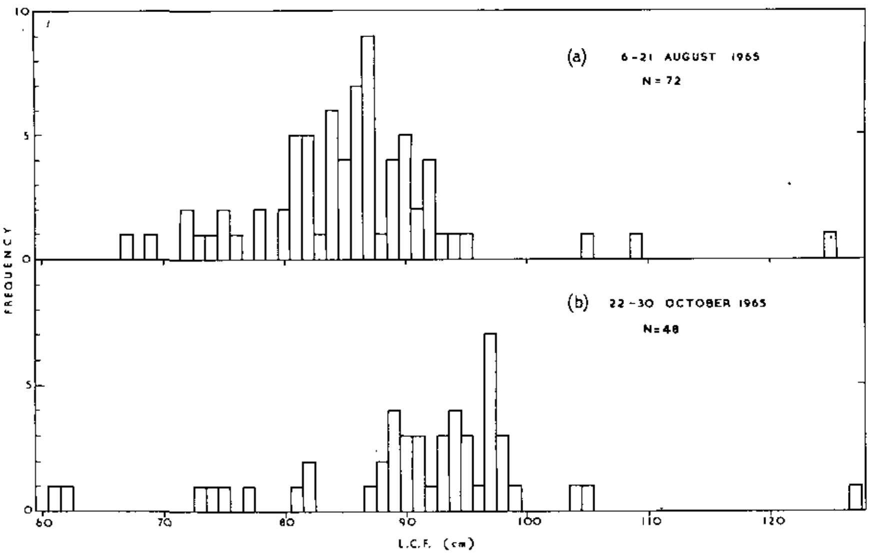

Fig. 25.—Length–frequency histograms of yellowfin tuna taken during two periods of the survey.

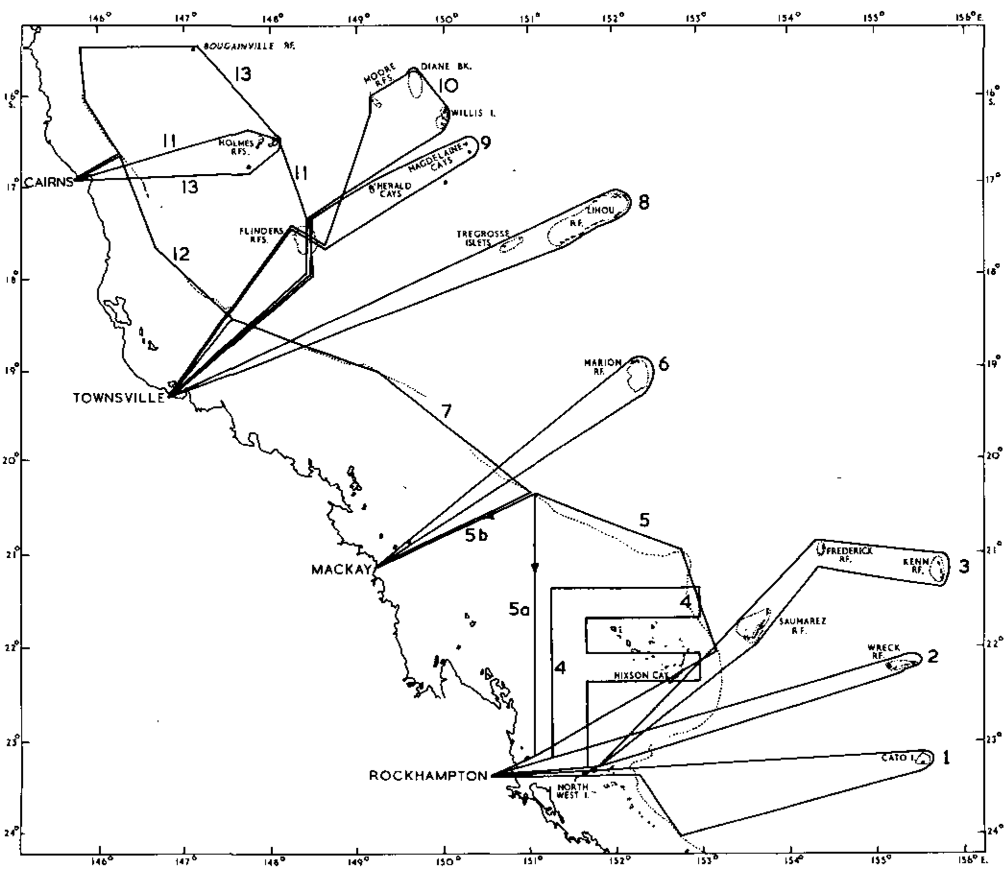

Fig. 26.—Queensland yellowfin tuna survey 1967; basic flight plans.

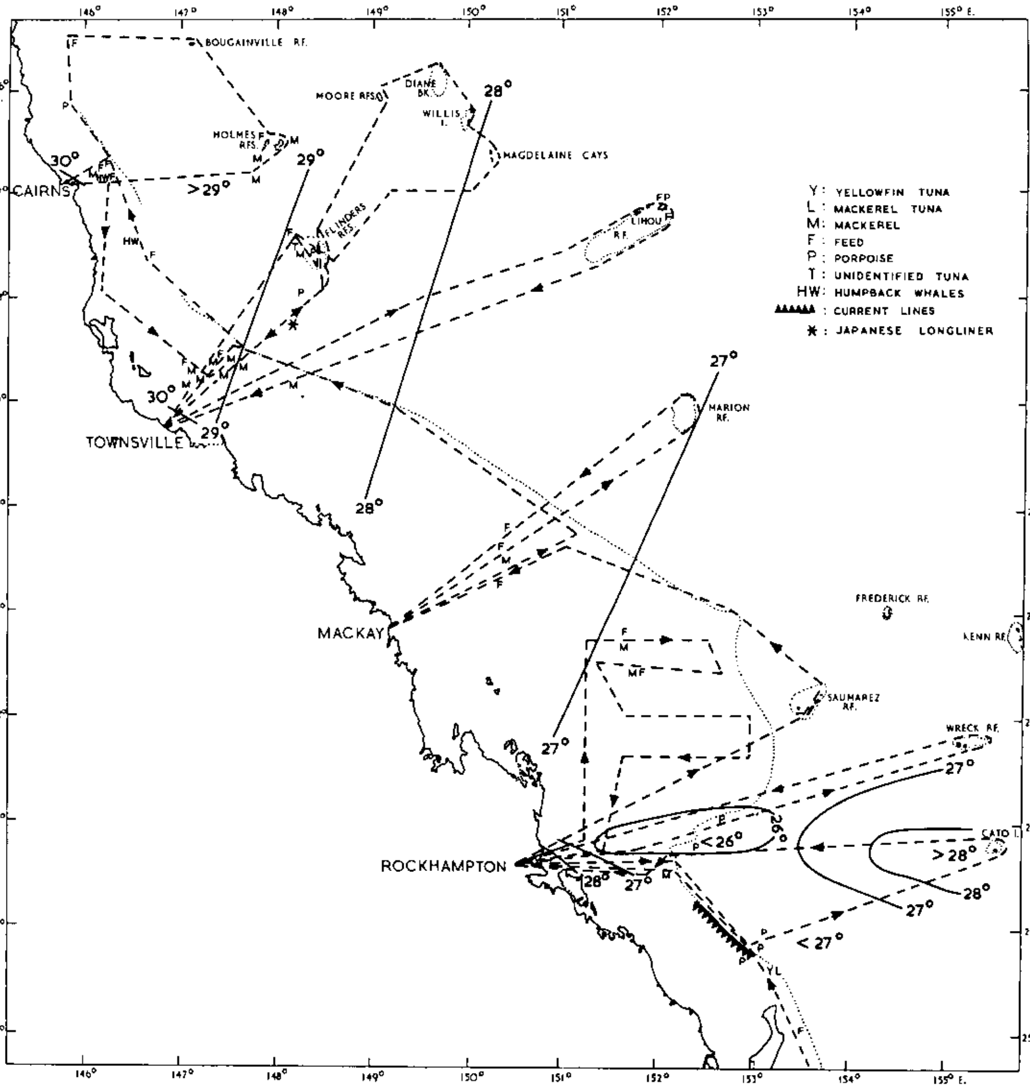

Fig. 27.—Aircraft flight paths, sightings, and surface isotherms (°C) 4–15.i.67.

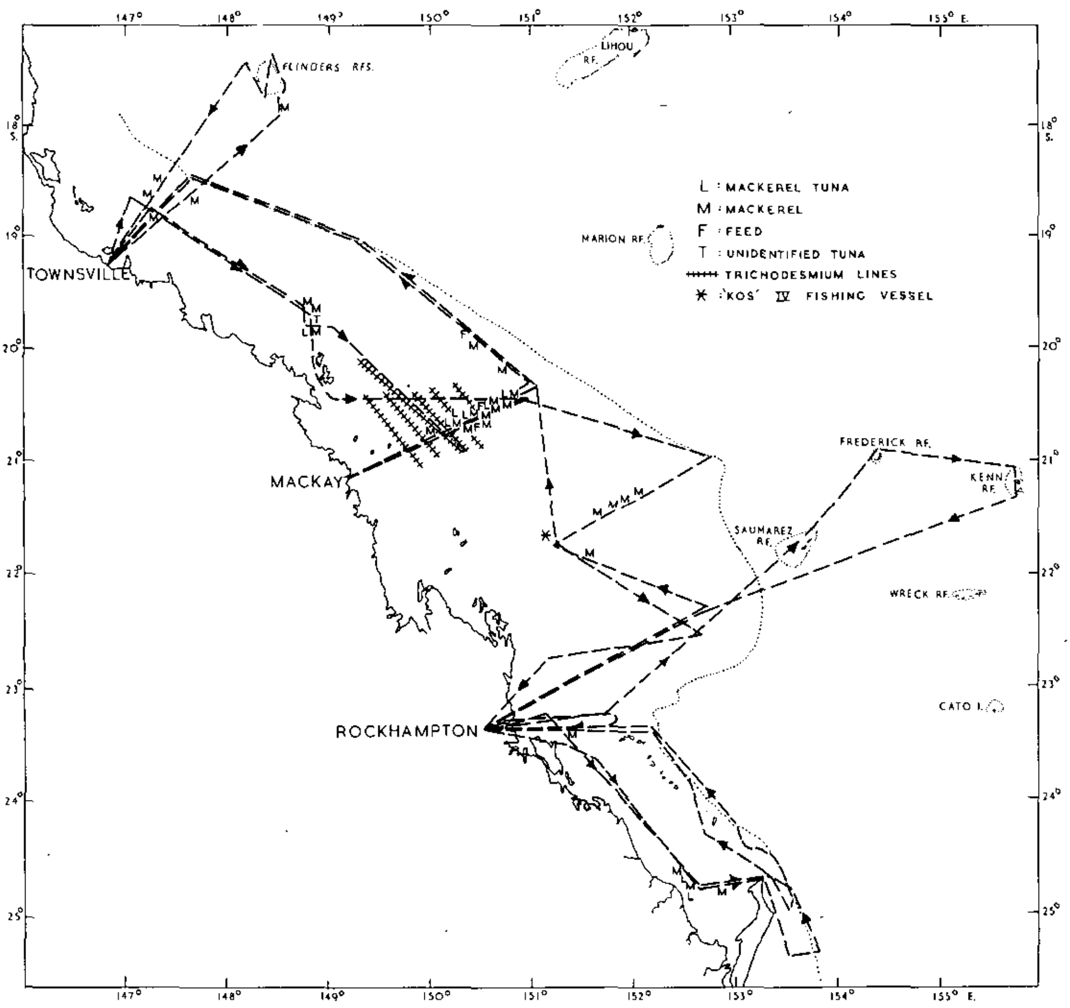

Fig. 28.—Aircraft flight paths and sightings 16–31.i.67.

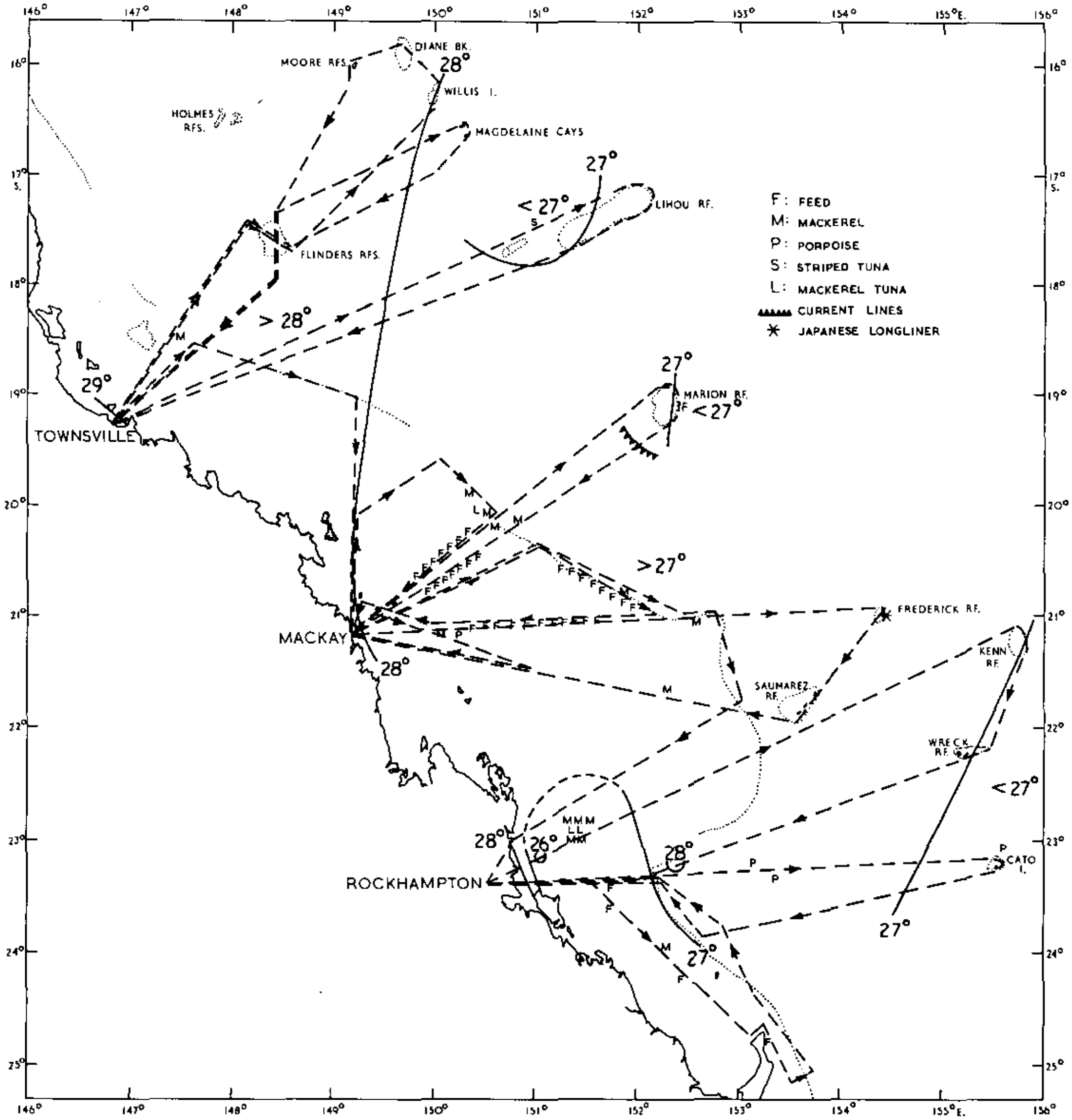

Fig. 29.—Aircraft flight paths, sightings, and surface isotherms (°C) 8–23.ii.67.

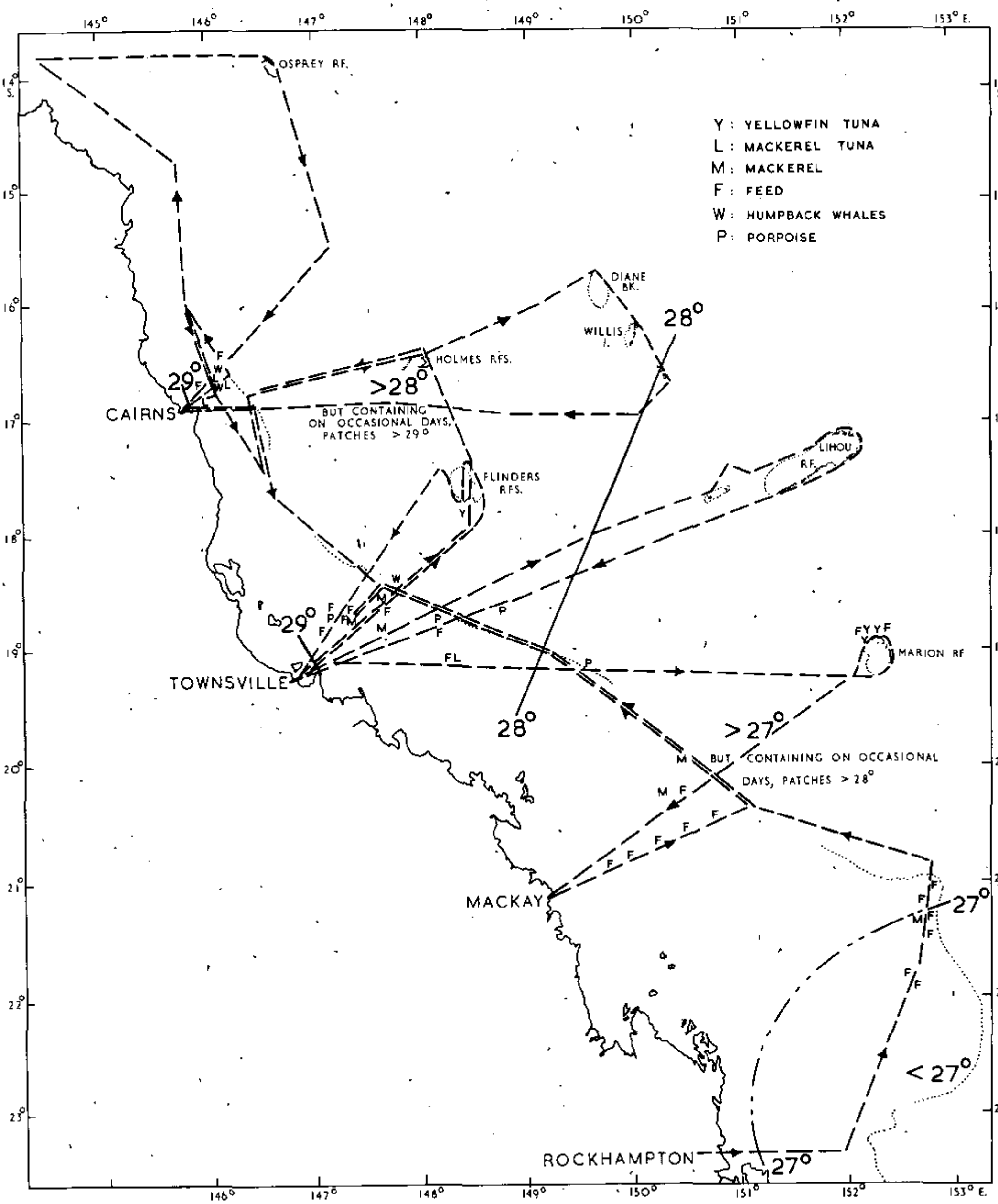

Fig. 30.—Aircraft flight paths, sightings, and surface isotherms (°C) 27.ii–4.iii.67.

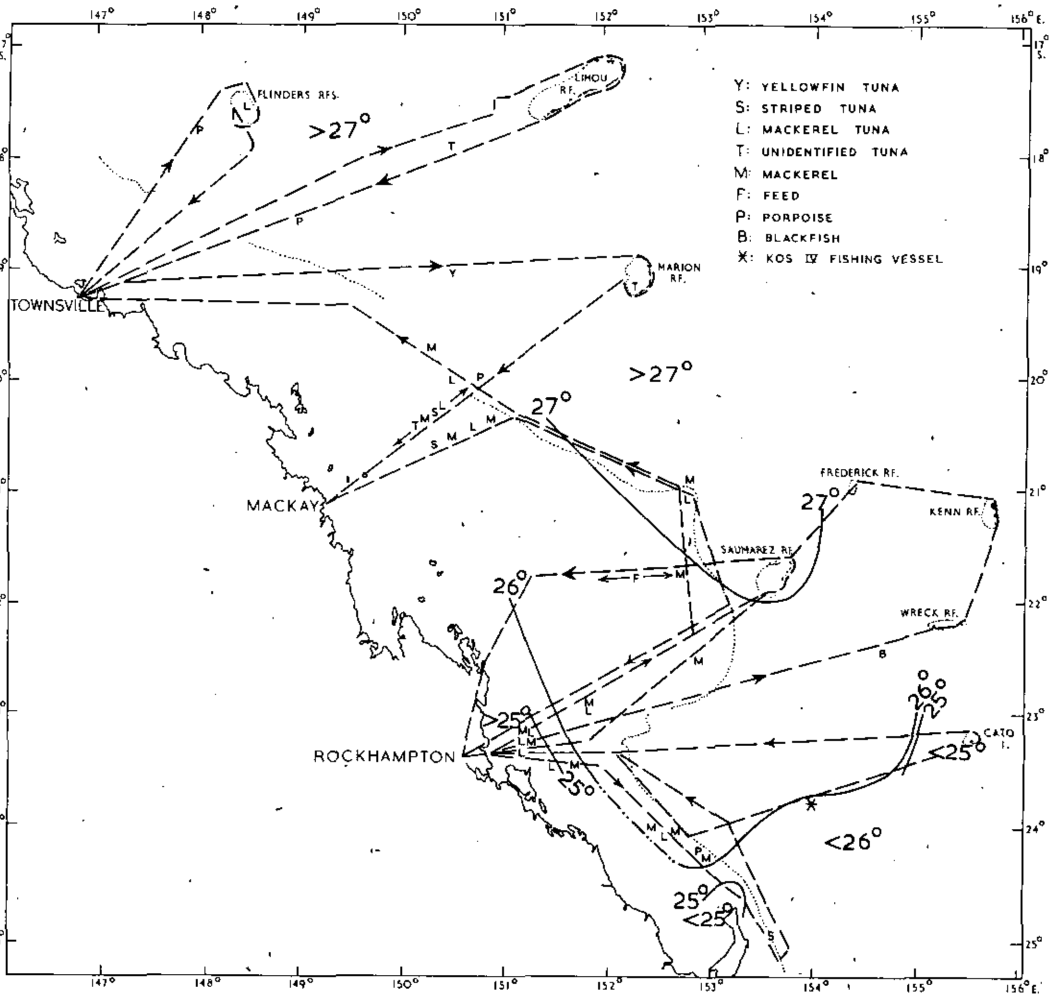

Fig. 31.—Aircraft flight paths, sightings, and surface isotherms (°C) 18–24.iii.67.

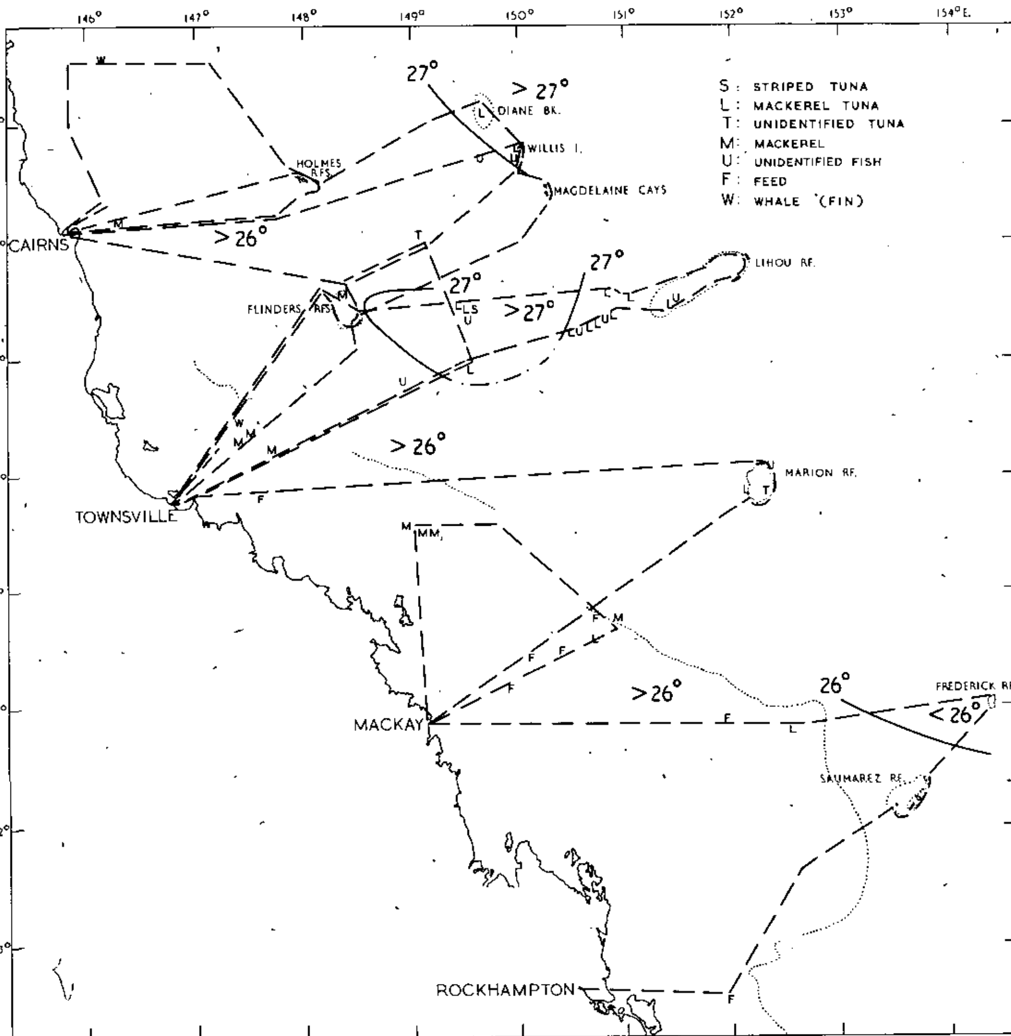

Fig. 32.—Aircraft flight paths, sightings, and surface isotherms (°C) 2–8.iv.67.

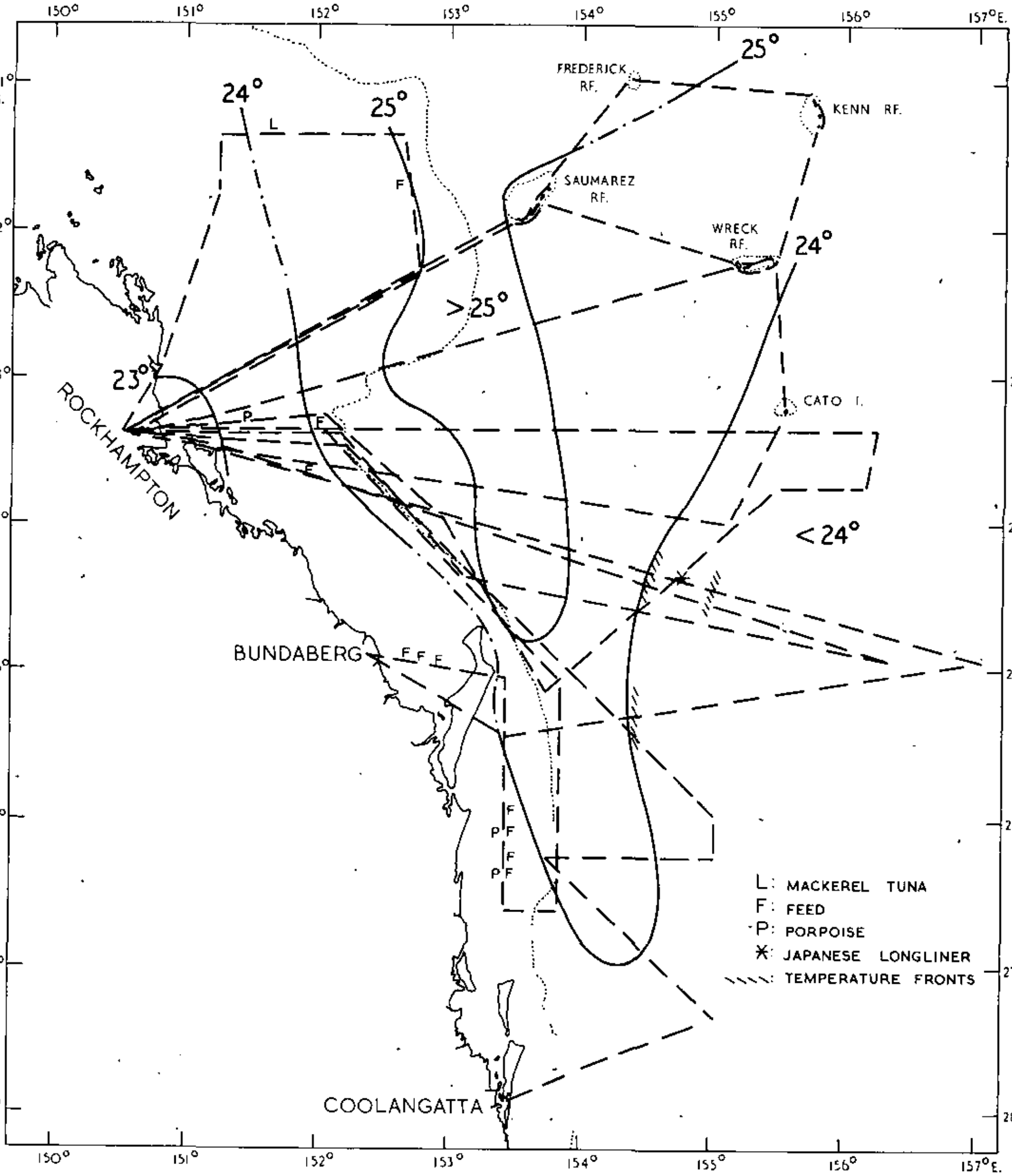

Fig. 33.—Aircraft flight paths, sightings, and surface isotherms (°C) 22.iv–1.v.67.

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15. Hamon, B. V. (1963).—Australian tide recorders.
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17. Wood, E. J. F. (1963).—Dinoflagellates in the Australian region. III. Further collections.
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