

## Reference Stations for the International Indian Ocean Expedition (IIOE)

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Reference stations, specific locations in the ocean where measurements are made repeatedly, to monitor changes in ocean parameters, have been established for decades (Cronin et al., 2012). Long-term data series from these sites are crucial for understanding effects of climate change and other human-induced environmental changes.

A less-frequent use of reference stations is to measure parameters at these locations for the purpose of comparisons of measurements made by different ships, different analysts, and different equipment. This type of reference station is located where the parameters are not expected to change significantly over seasons to a few years. A current example of this type of reference station are the cross-over stations used by the GEOTRACES project to compare measurements of trace elements and isotopes measured by the ships of different nations (see <https://www.geotraces.org/crossover-stations-2/>). GEOTRACES cross-over stations are locations where the transects of two nations intersect, where the ships measure the same parameters. The data from these stations are compared by the GEOTRACES Standards and Intercalibration Committee to ensure that the data can be added to the global dataset of GEOTRACES parameters.

At the 10<sup>th</sup> Pacific Science Congress in Honolulu on 21 August-6 September 1961, the idea of establishing reference stations in the Indian Ocean for the International Indian Ocean Expedition (IIOE) was raised ([15 Sept 1961 Circular Letter to National SCOR Committees](#)). This idea was based on a reference station that had been occupied by the Australian ship HMAS *Diamantina* since 1959. (This station was to become SCOR-UNESCO Reference Station #1). The 15 Sept. 1961 circular letter proposed that nations that had major IIOE programs (France, Japan, South Africa, UK, USA, USSR were specifically identified) should suggest suitable locations for reference stations, but comments were welcomed from all national SCOR committees.

The eventual set of Reference Stations accreted gradually over a period of about one year, through written inputs from national SCOR committees and several regional meetings. These stations are variously referred to as “SCOR-UNESCO Reference Stations” and “SCOR-IOC Reference Stations”. The idea for reference stations eventually became that deep stations would be relatively unchanging from cruise to cruise, so could be used for intercalibration of chemical measurements. (This assumed low variability of the chemistry of deep water masses.) Surface measurements of biology would change, but variations measured in different seasons could provide a better idea about surface ocean processes in the Indian Ocean.

In response to Humphrey’s 15 Sept. 1961 circular letter, The Indian National Committee on Oceanic Research submitted to SCOR a list of [five desired reference stations in the Arabian Sea](#). George Humphrey transmitted these suggestions to the UK, USA, and USSR national SCOR Committees on [8 January 1962](#). Humphrey sent a letter to the Secretary of the U.S. SCOR Committee on [18 January 1962](#) asking if the U.S. Committee had any reaction to his circular letter. U.S. scientists [Robert Fisher](#) and [John Knauss](#) had written to Columbus Iselin, Director of the Woods Hole Oceanographic Institution, with suggestions in September and October 1961,

respectively. (Iselin was apparently coordinating the U.S. response.) Knauss did not suggest any specific coordinates, but did think that the cruise of the R/V *Argo* from the Scripps Institution of Oceanography would be the “South of Cochin” station. Fisher suggested stations on the equator at 70 and 83°E, and a station in the Java Trench at 8°54’S, 105°33’E, which is close to what became Reference Station #2. Fisher’s letter noted that the stations proposed by India might fit transects planned by Knauss, but that four of the stations had water depths of “100 fathoms or less”, which would have made them inappropriate for intercalibrations.

Stations 1 and 2 were selected at the SCOR Executive Committee meeting in London (UK) on 16-18 April 1962. They were transmitted from George Humphrey to Warren Wooster (IOC Executive Secretary) in a [letter of 11 May 1962](#), with the suggestion that [the measurements done by Australian scientists](#) at the proposed Reference Station #1 could provide a model for other reference stations. (Station #3 in this letter eventually became Station #2, and Station #2 in this letter was not included in the final station list.)

Stations 13-15 were selected at a southwest Indian Ocean coordination meeting held in Laurenc Marqes (Maputo, Mozambique) on 30 April-2 May 1962.<sup>1</sup> A draft circular memo from IOC Acting Secretary, K.N. Federov, to national IIOE Committees was sent to George Humphrey on 7 June 1962. This letter lists the stations that eventually became Reference Stations 1, 2, 13, 14, and 15 (plus a 5°N, 69°E station that was not adopted). The final circular letter was sent from Warren Wooster to national IIOE committees on [22 June 1962](#).

A Working Group on Coordination of Operating Plans for the Northwestern Indian Ocean met at the UK National Institute of Oceanography in Wormley on 9-11 July 1962 and recommended to SCOR a set of 9 stations in the northwestern Indian Ocean, transmitted to G. Bohnecke from the Executive Secretary of the UK Royal Society in a [26 July 1962 letter](#). All 9 stations were adopted in the final list of stations, as Reference Stations #5-13 (see Table 1).

There was an extended correspondence between George Humphrey and Warren Wooster about the adequacy and accuracy of IOC promotion of the Reference Stations. On [29 April 1963](#), Humphrey stated in relation to IIOE Information Paper 2 that there was “some confusion and lack of knowledge on reference stations.” Humphrey suggested that this be clarified in the next IIOE Information Paper. Wooster responded on 21 May 1963 that the Reference Station list in IIOE Information Paper 1 “is quite clear, and I know of no new information to be reported. The list given there is as authoritative as any I know.” George Humphrey responded on [29 May 1963](#) that the stations should be referred to as “SCOR-UNESCO Reference Stations”, expressed his impression that “the list in IIOE Information Paper 1 is not clear or up to date”, and suggested that national IIOE committees be requested to provide information about their sampling at these stations when the national coordinators met.

To summarize, 15 SCOR-UNESCO Reference Stations were established about half-way through the IIOE, as shown in Table 1 and Figure 1.

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<sup>1</sup> I have not been able to find a record of this meeting or the meeting noted in the next paragraph detailing how the positions of Reference Stations were decided.

Table 1. Final locations of SCOR-UNESCO Reference Stations and where these stations were selected. All except Reference Station #16 were mentioned in [IIOE Information Paper No. 1](#).

Station #	Latitude, Longitude	How stations were decided
Station 1	32°S, 111°50'E	Agreed at April 1962 SCOR Executive Committee meeting in London
Station 2	9°S, 105°E	Agreed at April 1962 SCOR Executive Committee meeting in London
Station 3	15°N, 90°E	Agreed at July 1962 Wormley Meeting
Station 4	0°, 90°E	Agreed at July 1962 Wormley Meeting
Station 5	0°, 80°E	Agreed at July 1962 Wormley Meeting
Station 6	10°N, 74.5°E	Agreed at July 1962 Wormley Meeting
Station 7	20°N, 65°E	Agreed at July 1962 Wormley Meeting
Station 8	12°N, 63°E	Agreed at July 1962 Wormley Meeting
Station 9	24°N, 60°E	Agreed at July 1962 Wormley Meeting
Station 10	0°, 55°E	Agreed at July 1962 Wormley Meeting
Station 11	7°N, 52°E	Agreed at July 1962 Wormley Meeting
Station 12	13°N, 50°E	Agreed at July 1962 Wormley Meeting
Station 13	8°S, 44°E	Agreed at May 1962 Laureco Marques meeting
Station 14	18°S, 41°E	Agreed at May 1962 Laureco Marques meeting
Station 15	32°S, 35°20'E	Agreed at May 1962 Laureco Marques meeting
Station 16	10°N, 90°E	Agreed on 22-24 January 1964 at IIOE Coordinators meeting in Paris, France. IIOE Information Paper No. 6

Station 1 had been sampled by Australian scientists since 1959 and the sampling procedure at this station was reported in [IIOE Information Paper No. 1](#) (1962). Stations 11 and 13-15 were near stations occupied by the UK ship *Discovery II* before the reference stations were set. A station at 5°N, 69°E proposed at the London meeting was not approved at later meetings. A Station 16 at 10°N, 90°E, was added in 1964, according to [UNESCO/NS/IOC/INF-49](#). According to [IOC Information Paper No. 2](#), the South African Council for Scientific and Industrial Research recommended moving station No. 15 to 31.5°S, 34.5°E because they had more pre-existing sampling at this location and “this position was likely to yield more useful information.” The report from the R/V *Argo* cruise in May 1963 notes that this revision was accepted, but that the *Argo* scientists were not notified until after they had occupied the original Station 15.

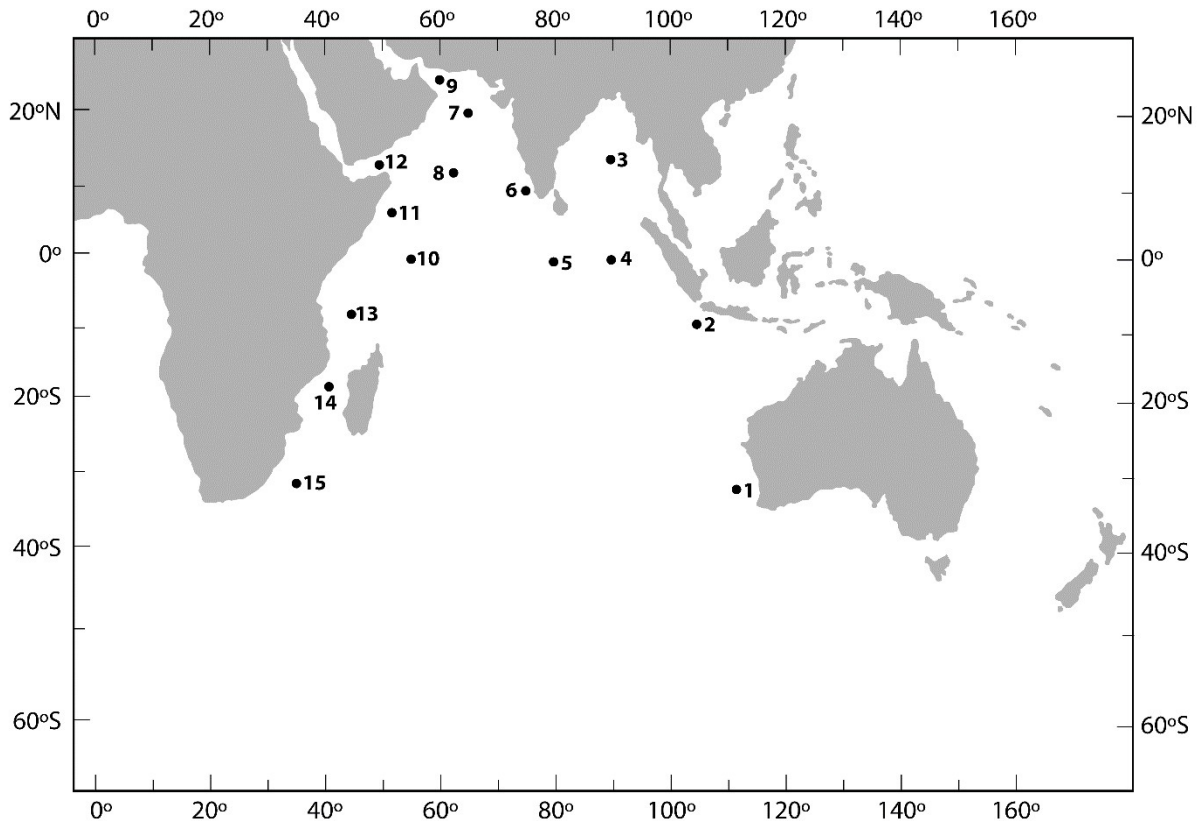


Figure 1. Position of first 15 SCOR-UNESCO Reference Stations (adapted from Rochford, 1965). Reference Station #16 (10°N, 90°E) was established in January 1964, but is not shown on the map. It is not clear than any nations besides India occupied it.

At least two nations, South Africa (<https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-8.pdf>) and India (<https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-9.pdf>, Annex IV; <https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-11.pdf>, Annex I), established national reference stations. It is not clear whether these were just for the duration of IIOE, or had been established before and/or were intended to extend after IIOE.

Sampling at the reference stations was not accomplished often. IOC IIOE Information Paper No. 10 (<https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-10.pdf>) noted that, although a request for lists of observations of occupations of Reference Stations had been made in January 1964, only Australia had sent such lists (see Annex 4, page 1-2 of [Information Paper No. 10](#) for data).

In [IIOE Information Paper No. 14](#), the recommendation of the Second Meeting of the International Coordination Group for the International Indian Ocean is given that “observations on reference stations should be continued on a voluntary basis for as long a period of time as possible. The Group also recommended that in any presentation of the IIOE results those coming

from the reference stations should be singled out. For example, a volume of station-diagrams for reference stations might be envisaged as a part of the Cruise and Data Reports series or the IIOE Atlases.” The *Diamantina* (Australia) reported observations at Reference Stations #1 and #2 in 1966 (<https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-17.pdf>), but I could find not other records of post-IIOE occupation of Reference Stations by ships of other nations.

References to sampling at or near the Reference Stations are given in Appendix A. Toward the end of the IIOE, Rochford (1965) wrote that any Reference Stations that fall within the north Indian Ocean deep water mass would be unsuitable for chemical intercomparisons, but could be very useful for observing changes in deep circulation over time. Further study of data at Reference Stations could be accomplished by looking in the World Data Center system for data at or near the geographic coordinates of the Reference Stations for data from the IIOE period and beyond.

Reference Stations were probably a good idea for the IIOE, but were developed half-way through the program and there was not enough buy-in for nations to agree to sample in the locations selected. By the time the Reference Stations were agreed, many cruises were already completed and/or cruise tracks were set and could not be altered to occupy the Reference Stations. The GEOTRACES project currently underway shows the utility of selected locations for intercalibration purposes.

### References

- Barnes, H., and D.J. Tranter. 1965. A statistical examination of the catches, numbers, and biomass taken by three commonly used plankton nets. *Australian Journal of Marine and Freshwater Research* 16(3):293-306.
- Cronin, M.F., R.A. Weller, R.S. Lampitt, and U. Send. 2012. Ocean Reference Stations. Pp. 203-228 in Rustam B. Rustamov (ed.), *Earth Observations*. IntechOpen.
- Hamon, B.V. 1965. Geostrophic currents in the south-eastern Indian Ocean. *Australian Journal of Marine and Freshwater Research* 16(3):255-272.
- IIOE Information Paper No. 1. 1962. Intergovernmental Oceanographic Commission. UNESCO/NS/IOC/INF-22.
- IIOE Information Paper No. 2. 1963. Intergovernmental Oceanographic Commission. UNESCO/NS/IOC/INF-42.
- IIOE Information Paper No. 6. 1964. Intergovernmental Oceanographic Commission. UNESCO/NS/IOC/INF-49.
- Rochford, D.J. 1965. Rapid changes in the characteristics of the deep salinity maximum of the south-east Indian Ocean. *Australian Journal of Marine and Freshwater Research* 16(2):129-150.
- Rochford, D.J. 1969. Seasonal variations in the Indian Ocean along 110°E. I. Hydrological structure of the upper 500 m. *Australian Journal of Marine and Freshwater Research* 20(1):1-50.

## Appendix A

### Sampling at SCOR-UNESCO Reference Stations

The following table lists actually sampling at the SCOR-UNESCO Research Stations, based on information from national cruise reports. For some Reference Stations (3, 7, 9) there is no evidence of sampling. The cruise reports for many nations that participated in IIOE have not yet been found (see list of available reports at <https://scor-int.org/project/iioe-1/#reports>). Cruises 31 and 31 of the Russian ship *Vityaz* were conducted too early to have sampled at the Reference Stations.

Station #	Ship	Dates	Reference
1	HMAS <i>Diamantina</i> (Australia)	25 Sept. 1962	<a href="#">Oceanographical Cruise Report No. 18</a>
		16 Oct. 1962 12 Nov. 1962	<a href="#">Oceanographical Cruise Report No. 20</a>
		7 May 1963	<a href="#">Oceanographical Cruise Report No. 24</a>
		10 July 1963	<a href="#">Oceanographical Cruise Report No. 25</a>
		25 March 1964	<a href="#">Oceanographical Cruise Report No. 36</a>
		11 August 1964	<a href="#">Oceanographical Cruise Report No. 40</a>
		19 July 1965	<a href="#">Oceanographical Cruise Report No. 49</a>
		27 October 1965	<a href="#">Oceanographical Cruise Report No. 51</a>
	HMAS <i>Gascoyne</i> (Australia)	19 August 1962	<a href="#">Oceanographical Cruise Report No. 17</a>
		18 Jan. 1963 16 Feb. 1963	<a href="#">Oceanographical Cruise Report No. 21</a>
	<i>Vityaz</i> (USSR)	2-9 August 1962	<a href="#">Tranter (1963)</a>
	<i>Koyo-Marui</i> (Japan)	February 1963	<a href="#">Record of Oceanographic Works in Japan</a>
2	HMAS <i>Diamantina</i> (Australia)	26 Oct. 1962 3 Nov. 1962	<a href="#">Oceanographical Cruise Report No. 20</a>
		7 and 18 April 1963	<a href="#">Oceanographical Cruise Report No. 23</a>
		27 April 1963	<a href="#">Oceanographical Cruise Report No. 23</a>
		16 and 25 May 1963	<a href="#">Oceanographical Cruise Report No. 24</a>
		19 and 20 July 1963	<a href="#">Oceanographical Cruise Report No. 25</a>
		18 and 31	<a href="#">Oceanographical Cruise Report</a>



		August 1964	<a href="#">No. 40</a>
	HMAS <i>Gascoyne</i> (Australia)	29 August 1962 7 Sept. 1962	<a href="#">Oceanographical Cruise Report No. 17</a>
		28 Jan. 1963 and 7 Feb. 1963	<a href="#">Oceanographical Cruise Report No. 21</a>
	<i>Koyo-Marui</i> (Japan)	Winter 1962- 1963 Winter 1963- 1964	<a href="#">Record of Oceanographic Works in Japan</a>
Station 3			
Station 4	R/V <i>Argo</i> (USA)	3-4 July 1962 (64 miles from station) 8,27 April 1963 (30 miles from station)	<a href="#">Reports of Lusiad and Monsoon Expeditions</a> <a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf</a>
	USC&GS <i>Pioneer</i>	May have been sampled	<a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-6.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-6.pdf</a>
Station 5	R/V <i>Argo</i> (USA)	8 July 1962 2 Sept. 1962 5 April 1963	<a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf</a>
	R/V <i>Anton Bruun</i> (USA)	15 July 1963	Sampling near Reference Station not mentioned in cruise report.
Station 6	RRS <i>Discovery</i>	19-20 May 1964	<a href="#">Cruise 3 Report, https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-14.pdf</a>
Station 7			
Station 8	RRS <i>Discovery</i>	23 May 1964	<a href="#">Cruise 3 Report, https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-14.pdf</a>
Station 9			
Station 10	R/V <i>Argo</i> (USA)	18 July 1962 (21 miles from station) 27 March 1963 (6.5 miles from station) 31 August 1964	<a href="#">Reports of Lusiad and Monsoon Expeditions</a> <a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf</a>
Station 11	RV <i>Argo</i> (USA)	24 August 1964	<a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf</a>
Station 12	R/V <i>Argo</i> (USA)	21 Sept. 1962 (21 miles from	<a href="#">Reports of Lusiad and Monsoon Expeditions</a>

		station)	<a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf</a>
	RRS <i>Discovery</i> (UK)	10 Aug. 1963 8 March 1964 27-28 Aug. 1964	<a href="#">Cruise 1 Report</a> <a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-14.pdf">Cruise 3 Report, https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-14.pdf</a>
	R/V <i>Anton Bruun</i> (USA)	25 Feb. 1963	Sampling near Reference Station not mentioned in cruise report.
Station 13	R/V <i>Argo</i> (USA)	19 May 1963 (4.5 miles from the station)	<a href="#">Reports of Lusiad and Monsoon Expeditions</a> <a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf</a>
Station 14	R/V <i>Argo</i> (USA)	22 May 1963 (8.5 miles from the station)	<a href="#">Reports of Lusiad and Monsoon Expeditions</a>
	Commandant Rober Giraud		<a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-4.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-4.pdf</a>
Station 15	R/V <i>Argo</i> (USA)	26 May 1963	<a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-12.pdf</a>
	R/V <i>Anton Bruun</i> (USA)	5 Sept. 1964	Sampling near Reference Station not mentioned in cruise report.
Station 16	<i>Kistna</i> (India)	June-July 1964	<a href="https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-11.pdf">https://scor-int.org/wp-content/uploads/2020/04/IIOE-Information-Paper-No.-11.pdf</a>