Intergovernmental Oceanographic Commission

2024 Capacity Assessment of Tsunami Preparedness in the Indian Ocean

Executive Summary

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English only

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BACKGROUND

The devastating Indian Ocean Tsunami (IOT) of 26 December 2004 resulted in over 230,000 people losing their lives and more than a million people displaced from their homes (Figures 1 and 2). At that time there was no regional tsunami warning system in the India Ocean. Only a few countries had a capability to provide very basic alerts to their communities.

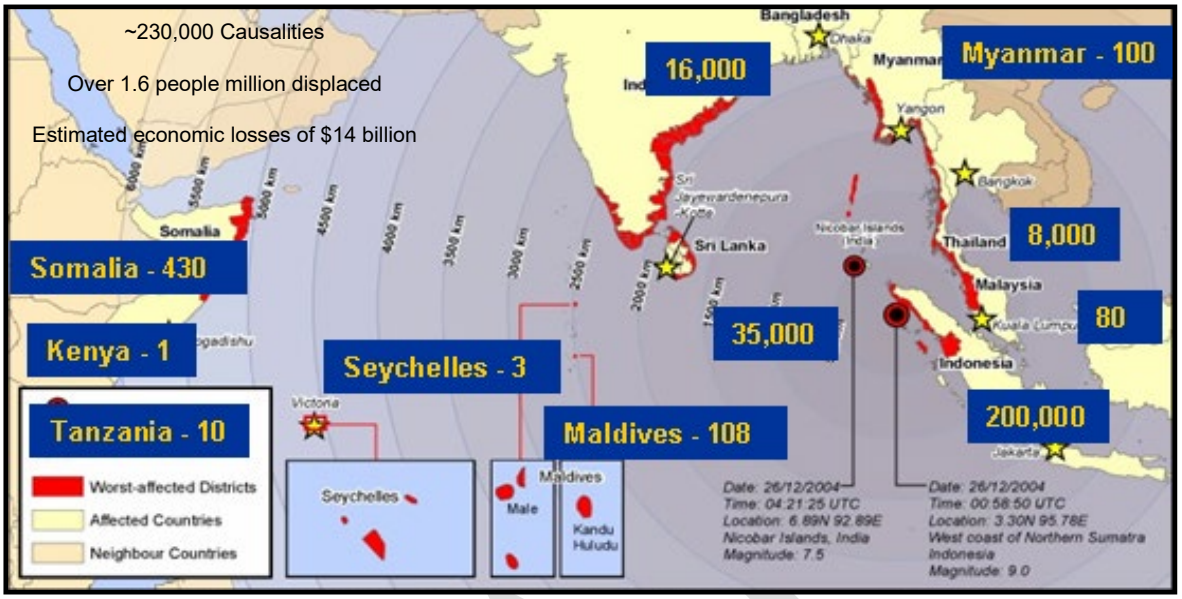


Figure 1: Approximate deaths and damage caused by Indian Ocean Tsunami on 26 December 2004.

Figure 2: Some of the devastation in 2004 in Banda Aceh, Indonesia, close to tsunami source.

In early 2005, the UNESCO Intergovernmental Oceanographic Commission (IOC) was given the mandate by the United Nations General Assembly (UNGA) to coordinate the establishment of the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) to alert countries all around the Indian Ocean of any future threats. It was to initially be based on the Pacific Tsunami Warning & Mitigation System (PTWS), which had been established by UNESCO-IOC in 1965 following the tsunami generated by the 1960 earthquake in Chile that devastated many countries around the Pacific Ocean. An Interim Alert Systems (IAS) was quickly established with the help of the Government of United States of America and the Government of Japan, utilising their expertise in the PTWS.

As one of the initial steps, UNESCO-IOC in 2005 facilitated an assessment of capacity development requirements[1] to build an effective and durable tsunami warning and mitigation system in the Indian Ocean. This was facilitated by Expert Missions to 16 of the 25 Member States identified as in particular requiring capacity development.

In August 2005, UNESCO-IOC established the Intergovernmental Coordination Group (ICG) for the IOTWMS. Its primary role was to coordinate the efforts of Member States around the Indian Ocean to build the IOTWMS and support its ongoing implementation[2]. The UNESCO-IOC ICG/IOTWMS meets at least every two years and is supported by the UNESCO-IOC ICG/IOTWMS Secretariat (funded by the Government of Australia). It is organised according to three strategic pillars: 1) Risk; 2) Detection, Warning, and Dissemination; and 3) Community Awareness and Preparedness.

By 2011 the IOTWMS was fully established. The IAS accordingly ceased operation in 2013 after a period of parallel operation and cross-evaluation of the new system. The IOTWMS is now extensively exercised every two years in IOWave Exercises (2009, 2011,2014, 2016, 2018, 2020, 2023) coordinated by the UNESCO-IOC ICG/IOTWMS and supported by the UNESCO-IOC Secretariat. Member States are also encouraged to conduct national exercises during the in-between years.

There are two main sources of tsunami threat (Figure 3). While the 2004 IOT and most tsunamis are generated by the Sumatra earthquake subduction zone in the eastern Indian Ocean, there is a similar threat from the Makran Source Zone (MSZ) in the NW Indian Ocean. The Indian Ocean has experienced 33 more tsunami events across the Indian Ocean since 2004, of which seven have taken lives (Table 1). While most of the tsunami events across the Indian Ocean have been due to subduction earthquakes, the two events in 2018 in Sulawesi and Anak Krakatau in Indonesia were due to submarine landslides and a volcano flank collapse respectively. In 1945[3] over 4000 people lost their lives due to a tsunami generated in the MSZ. Accordingly, and with support of the Trust Fund for Tsunami, Disaster and Climate Preparedness managed by the UN Economic and Social Commission for Asia and the Pacific (ESCAP), much effort has also gone into developing the national capabilities in tsunami warning and mitigation of countries in this sub-region, where a major tsunami may also arrive in minutes from the nearby source.

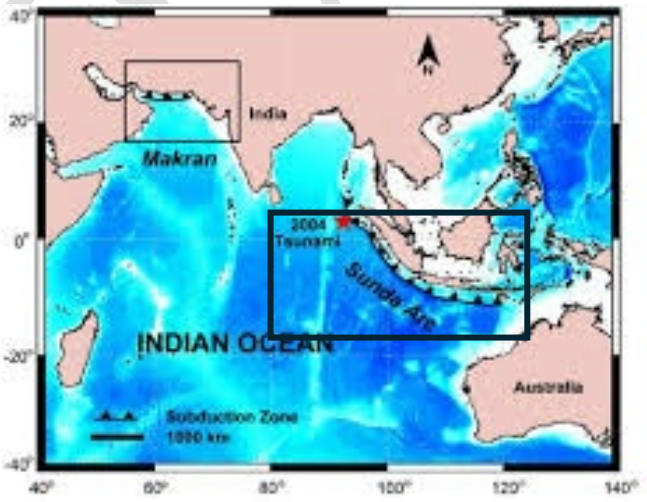


Figure 3: Two main subduction earthquake zones for generating tsunamis in the Indian Ocean[4].

[1] UNESCO-IOC; UN-ISDR/PPEW; WMO. Assessment of Capacity Building Requirements for an Effective and Durable Tsunami Warning and Mitigation System in the Indian Ocean: Consolidated Report for 16 Countries Affected by the 26 December 2004 Tsunami. Paris, UNESCO 2005. IOC Information Document No. 1219

[2] Indian Ocean Tsunami Warning and Mitigation System IOTWS. Implementation Plan, Sixth Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS-V), Hyderabad, India, 7-9 April 2009, IOC Technical Series No. 71. (Revision 2), UNESCO 2009

[3] UNESCO-IOC. 2015. Remembering the 1945 Makran Tsunami – Interviews with Survivors Beside the Arabian Sea. 2015. Paris, UNESCO. (IOC Brochure 2015-1)

[4] Heidarzadeh, M., M. D. Pirooz, N. H. Zaker, A. C. Yalçiner (2009): Preliminary estimation of the tsunami hazards associated with the Makran subduction zones at the northwestern Indian Ocean. Journal Nat. Hazards 48:229-243

At its 10th Session (Muscat, August 2015), the ICG/IOTWMS identified the need to conduct a reassessment of the state of tsunami preparedness of the Indian Ocean Member States. This was to help evaluate progress since the 2004 IOT, as well as identify remaining gaps and prioritise capacity development requirements at both the regional and national level for strengthening the end-to-end tsunami warning and mitigation system.

At its 11th Session (Putrajaya, April 2017) the ICG/IOTWMS established the inter-sessional "Task Team on Capacity Assessment of Tsunami Preparedness" (TT-CATP) to oversee the capacity assessment of tsunami preparedness of the IOTWMS. The TT-CATP designed an extensive online survey covering all aspects of the end-to-end tsunami warning and mitigation system. A total of 20 ICG/IOTWMS Member States responded to the reassessment survey. The 2018 assessment[5] [6] provided a new baseline of the status of tsunami preparedness capacity in the region, including capacity development requirements at both regional and national levels. The recommendations from the 2018 assessment provided core input into the subsequent development of the work programmes of the ICG Working Groups and Task Teams.

As 2024 marks the 20th anniversary of the 2004 IOT, the UNESCO-IOC ICG/IOTWMS at its 13th Session (Bali, 2022) (Figure 4) decided it was timely to conduct the next reassessment of the state of tsunami preparedness in ICG/IOTWMS Member States. An *Ad Hoc* Task Team 2024 IOTWMS CATP was established under Working Group 3 Tsunami Ready Implementation.

Table 1: Tsunami events claiming lives in Indian Ocean since 2004 (*Source NOAA NCEI, USA*)

Date	**Location**	**Cause**	**Countries impacted**	**Deaths** (estimate)
26/12/2004	Off W. Coast of Sumatra	Mag. 9.1 earthquake	Indian Ocean	227,899
28/03/2005	W. Coast N. Sumatra, Indonesia	Mag. 8.6 earthquake	Indonesia	16
14/03/2006	Seram Island, Indonesia	Mag. 6.7 earthquake	Indonesia	4
17/07/2006	South of Java, Indonesia	Mag. 7.7 earthquake	Indonesia,	802
25/10/2010	Mentawai, Sumatra, Indonesia	Mag. 7.8 earthquake	Indonesia	431
28/09/2018	Sulawesi, Indonesia	Mag. 7.5 earthquake/ submarine landslide	Indonesia	4340 tsunami + earthquake
22/12/2018	Anak Krakatau Volcano, Indonesia	Volcanic eruption	Indonesia	437

Figure 4: 13th Session ICG/IOTWMS, Bali, Indonesia. November 2022

[5] UNESCO-IOC. 2020. Capacity Assessment of Tsunami Preparedness in the Indian Ocean – Status Report 2018: Executive Summary. Paris, UNESC (IOC Brochure 2020-2)

[6] UNESCO-IOC. 2020.Capacity Assessment of Tsunami Preparedness in the Indian Ocean – Status Report, 2018. Paris, UNESC (IOC Technical Series No. 143)

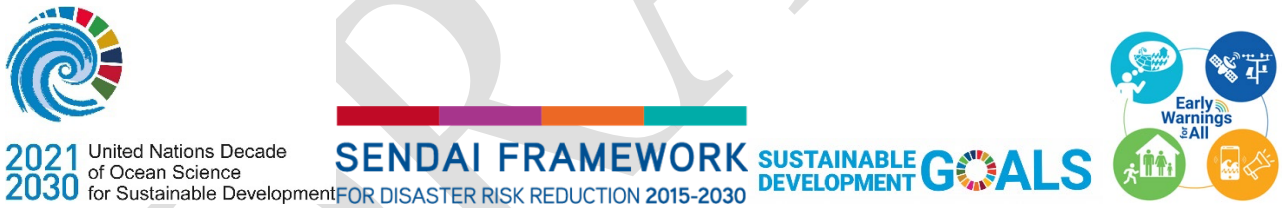
CAPACITY ASSESSMENT AND GLOBAL CONTEXT

The overall UNESCO-IOC Tsunami Programme (see tsunami.ioc.unesco.org) includes tsunami warning and mitigation systems in the Indian Ocean, Pacific Ocean, Caribbean and adjacent regions, NE Atlantic and Mediterranean and connected seas. It contributes to several global frameworks within a Multi-Hazard Early Warning System (MHEWS) context. Of particular relevance is also the UN initiative launched in 2022 by the UN Secretary-General, Antonio Guterres, “Early Warnings for All” (EW4ALL), which aims to ensure that everyone on Earth is protected from hazardous weather, water, or climate events through life-saving early warning systems by the end of 202. While tsunami warning and mitigation systems relate to a geophysical hazard, the core warning and mitigation elements within countries are similar and often the responsibility of the same agencies. Improvements to tsunami warning and mitigation systems will therefore contribute to the EW4ALL initiative.

In June 2021, UNESCO-IOC also launched the Ocean Decade Tsunami Programme (ODTP)[7] [8] as part of the Decade of Ocean Science for Sustainable Development (2021–2030)(https://oceandecade.org/) – an effort to further bolster the global tsunami warning system by greatly enhancing response times and community readiness. The ODTP main objectives are to:

- Enhance systems’ capacity to issue actionable and timely warnings for tsunamis from all identified sources to 100% of coasts at-risk.
- Guarantee that 100% of communities at risk are prepared and resilient to tsunamis by 2030 through efforts like the UNESCO-IOC Tsunami Ready Recognition Programme (TRRP)[9].

The UNESCO-IOC Tsunami Programme, including the IOTWMS, makes significant contributions to the implementation of all the Sustainable Development Goals (SDGs) of the UN 2030 Agenda for Sustainable Development, in particular SDG #11 (Sustainable Cities and Communities) and SDG #14 (Life Below Water). Within the overarching Sendai Framework for Disaster Risk Reduction providing globally agreed guidance, the UNESCO-IOC Tsunami Programme supports all of the framework targets.



METHODOLOGY

As part of the capacity assessment process, a survey was disseminated by the UNESCO-IOC Secretariat to all ICG/IOMTWS Member States in May 2024. Formally designated Tsunami Nationally Contacts (TNCs) of the ICG/IOTWMS for each Member State coordinated national responses to the survey. A total of 22 of the current 24 active Member States responded.

The 2024 survey was based on the survey undertaken for the 2018 Capacity Assessment of Tsunami Preparedness of Member States of the ICG/IOTWMS, thereby also facilitating a comparison of results between 2018 and 2024. The survey consisted of six main parts. The University of Huddersfield of the United Kingdom again assisted with the preliminary analysis of the survey data. The overall assessment was also

[7] UNESCO-IOC. 2023. Research, Development and Implementation Plan for the Ocean Decade Tsunami Programme – Executive Summary, UNESCO, Paris. (IOC Brochure 2023-4)
[8] UNESCO-IOC. 2023. Research, Development and Implementation Plan for the Ocean Decade Tsunami Programme. Paris, UNESCO (IOC Technical Series No180)
[9] UNESCO-/IOC. 2022. Standard Guidelines for the Tsunami Ready Recognition Programme. Paris, UNESCO (IOC Manuals and Guides No. 74)

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based on further information on capacity and gaps identified by the work of the ICG/IOTWMS Working Groups and Task Team, and an ongoing assessment of national tsunami warning chains and associated Standard Operating Procedures (SOPs). The *Ad Hoc* Team 2024 IOTWMS CATP met at a workshop hosted by UNESCAP to review and validate the assessment findings and develop recommendations for capacity development.

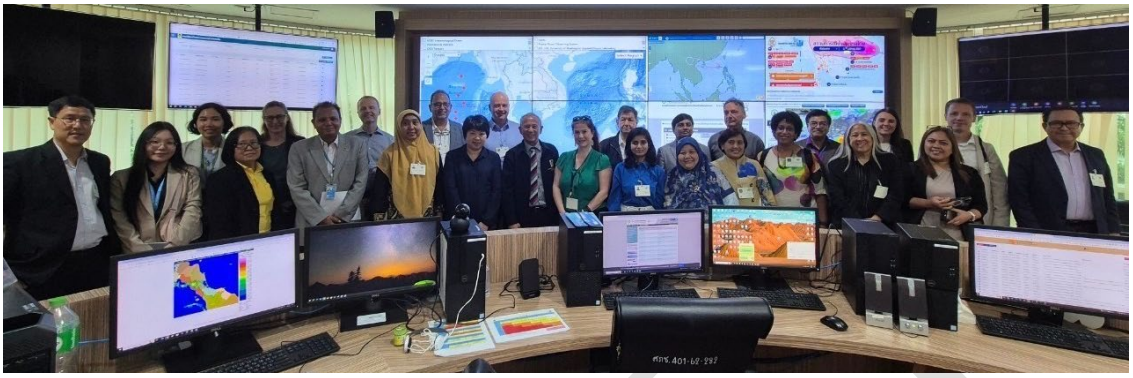

Figure 5: Participants 2024 IOTWMS CATP Validation Workshop, 4-6 September 2024, Bangkok, Thailand.

CAPACITY ASSESSMENT RESULTS

Policies and Plans

The survey indicates that 20 (91%) of the 22 countries have some form of a national tsunami policy. A majority address tsunami as a part of a multi-hazard policy. Over 80% of countries have a national policy that includes an emergency response component, over 75% include the preparedness component, and 68% include prevention and mitigation component. However, less than 60% of countries have a policy that addresses the rehabilitation and reconstruction component. 14 (64%) countries have some form of local tsunami policy. A majority of those address tsunami as also part of a multi-hazard policy. Over 60% of countries have a local policy with emergency response and preparedness components, and over 50% have a policy that includes prevention and mitigation & rehabilitation and reconstruction components.

All 22 (100%) countries have some form of tsunami disaster risk reduction plan. A significant majority of countries address tsunami risk reduction as a part of a multi-hazard plan, rather than as standalone plans. 19 (86%) countries reported that their tsunami disaster risk reduction plans are based on hazard and/or risk assessments. Across all four components of disaster management, availability of plans is significantly higher at the national level, followed by the local level. There is least availability at the community level.

All 22 (100%) countries have some form of national tsunami guidelines. A majority of countries (>60%) have national tsunami guidelines that address all disaster management components. However, there is least availability in the rehabilitation and reconstruction component. 17 (77%) countries have some form of local tsunami guidelines. Across the disaster management components, the majority of local guidelines address tsunami as a part of multi-hazard guidelines.

After major improvements in 2018 since 2005, progress has mainly plateaued since 2018, except for a major increase in national guidelines (Figure 6). While capacity remains in general high at the national level, capacity development is still required at the local level for policies, plans and guidelines for around 40% of countries. Policies and plans should continue to be included as part of a multi-hazard approach.

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Figure 6: Country activity and capacity status for policies and plans.

Hazard and Risk Assessment

Awareness is the first step in the development of any warning and mitigation system. All countries around the Indian Ocean are at some level of risk of being impacted by tsunamis. Even relatively small tsunamis of 1m in amplitude can create dangerous currents, leading to loss of life and impacts on livelihoods, such as ports, fishing and tourist industries. Awareness facilitates the development of appropriate preparedness.

Hazard and risk assessments for tsunamis generated by subduction earthquakes continue to be updated and over 75% integrated within multi-hazard frameworks to provide awareness to governments, response authorities, and the community on any possible threat. The UNESCAP funded project "Strengthening Early Tsunami Warning in the NW Indian Ocean through Regional Collaboration" has produced a Probabilistic Tsunami Hazard Assessment (PTHA) for the region. The PTHA now needs to be extended to the rest of the Indian Ocean.

21 (96%) countries conduct hazard assessments of some kind to understand the hazard threat to their territories of tsunamis generated by subduction zone earthquakes (Figure 5). 13 (59%) countries carry out the tsunami hazard assessment at a national level, 10 (45%) countries at the regional level, 10 (45%) at the city level, and six (27%) at the village level. 11 (50%) countries carry out hazard assessments at multiple levels

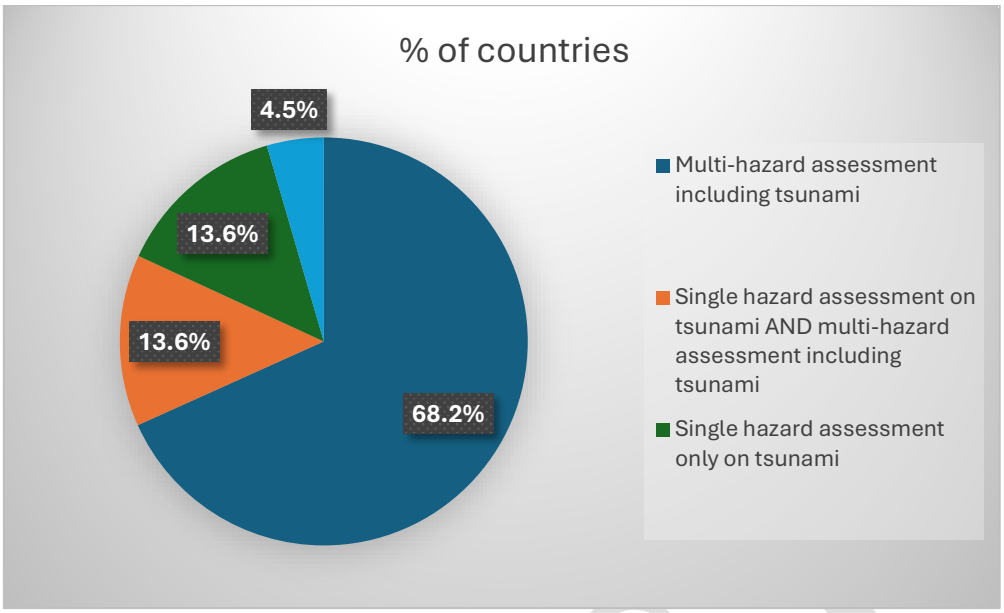

Figure 7: Type of hazard assessment.

19 (86%) countries participating in this survey conduct tsunami risk assessments (Figure 7). Of the countries that carry out tsunami risk assessments, 11 (50%) conduct them at the national level, and eight (36%) at a regional and or city level (Figure 8). Seven (32%) at village level and four (18%) at community level are less common, but there is a significant increase in reporting of them when compared with the 2018 results. Nine (41%) countries carry out risk assessment at multiple levels. A risk map is produced by 17 (77%) countries.

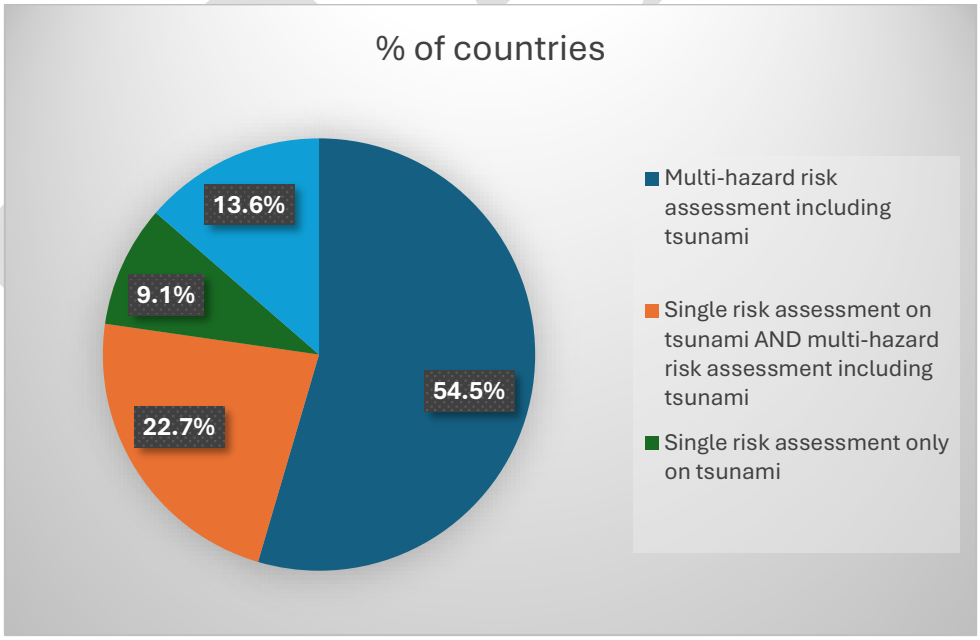

Figure 8: Types of risk assessment.

11 (50%) or more countries produce guidelines from the risk assessments. Action plans remain a less common output, with just seven (32%) countries producing them.

Once again it can be seen that after significant improvements between 2005 and 2018, progress has mainly plateaued since 2018 (Figure 9). There currently remains a wide-ranging capacity to undertake detailed tsunami hazard assessments, with 13 (59%) countries rating themselves as having very good or good, while six (27%) countries rate themselves as having fair capacity. Three (14%) countries rated themselves as having low or very low capacity. The highest priorities for capacity improvement requested by the countries were hazard mapping and inundation mapping, followed by deterministic tsunami hazard analysis and then PTHA.

There is also a wide-ranging capacity to undertake detailed risk assessments (Figure 9). Over 85% of countries rates their capacity as fair or better, with nine (40%) countries rating their capacity as very good or good. This is a significant improvement when compared to the 2018 survey results. However, three countries (14%) still rate themselves as having low or very low capacity and require capacity development.

More effort is required to make the data more publicly available, to provide hazard and risk assessments at the village/community level and for tsunamis generated by non-seismic and complex sources. More measures of uncertainty associated with all assessments will better inform risk-based decisions

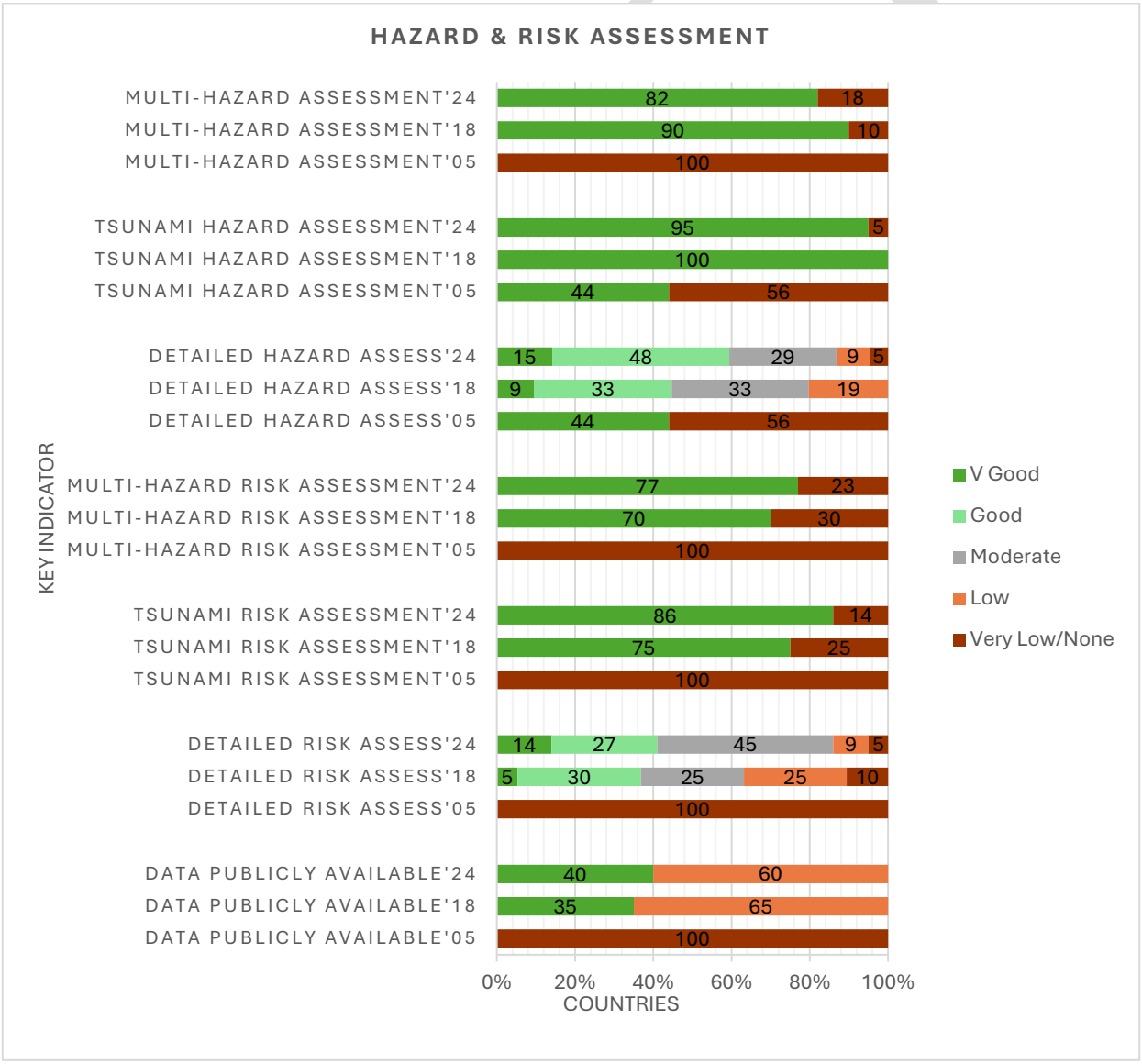

Figure 9: Country activity and capacity status for hazard and risk assessment.

Detection, Warning, and Dissemination

Coordinated networks of seismometers and sea-level monitoring systems (tide gauges and deep ocean tsunameters) across the Indian Ocean continue to provide real-time information for the detection of potentially tsunami generating earthquakes and confirmation whether a tsunami has been generated. Tsunami Service Providers (TSPs: operated by Australia, India, Indonesia) designated by the ICG for the IOTWMS provide the National Tsunami Warning Centres (NTWCs) in each country with interoperable (same format) tsunami threat information for tsunamis generated by earthquakes for the entire Indian Ocean (Figure 10). The tsunami warning process at each TSP is ISO accredited. The performance of the TSPs is measured against Key Performance Indicators agreed by the ICG. Training on the TSP products and their use are provided to countries every two years. Countries select which TSP (or a number of TSPs) they use the tsunami threat information from. One TSP (Australia) is now also providing regional threat information products for tsunamis generated by non-seismic and complex sources, such as volcanoes. Two countries (Indonesia and France) have developed national warning systems for local tsunamis generated by volcanoes.

Figure 10: UNESCO-IOC Tsunami Services Providers (Australia, India, Indonesia) utilise seismic and sea level observations and modelled forecasts to provide detailed tsunami threat information to all countries around the Indian Ocean.

All 22 (100%) countries reported that they have a national capability to assess and/or receive potential tsunami threat information and advise / warn their coastal communities (Figure 11). This capacity has successfully remained constant since 2018, and of course a major improvement since 2005 (Figure 12). 17 (77%) countries reported that the organisation responsible for identifying a potential tsunami threat also issues national tsunami watches, advisories, alerts and/or warnings. 20 (91%) countries reported that the organisation responsible for assessing and/or receiving potential tsunami threat information operates 24x7. Two countries reported operating weekdays and daytime only due to a lack of resources, which is a major concern, especially as one country is at higher-risk with a near-field threat.

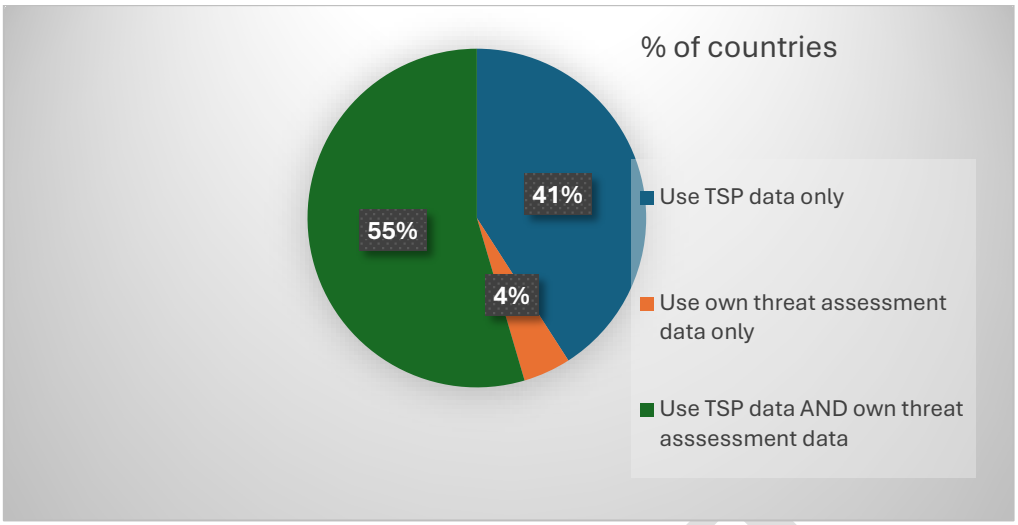

Figure 11: Sources of tsunami threat assessment used to generate national tsunami warnings.

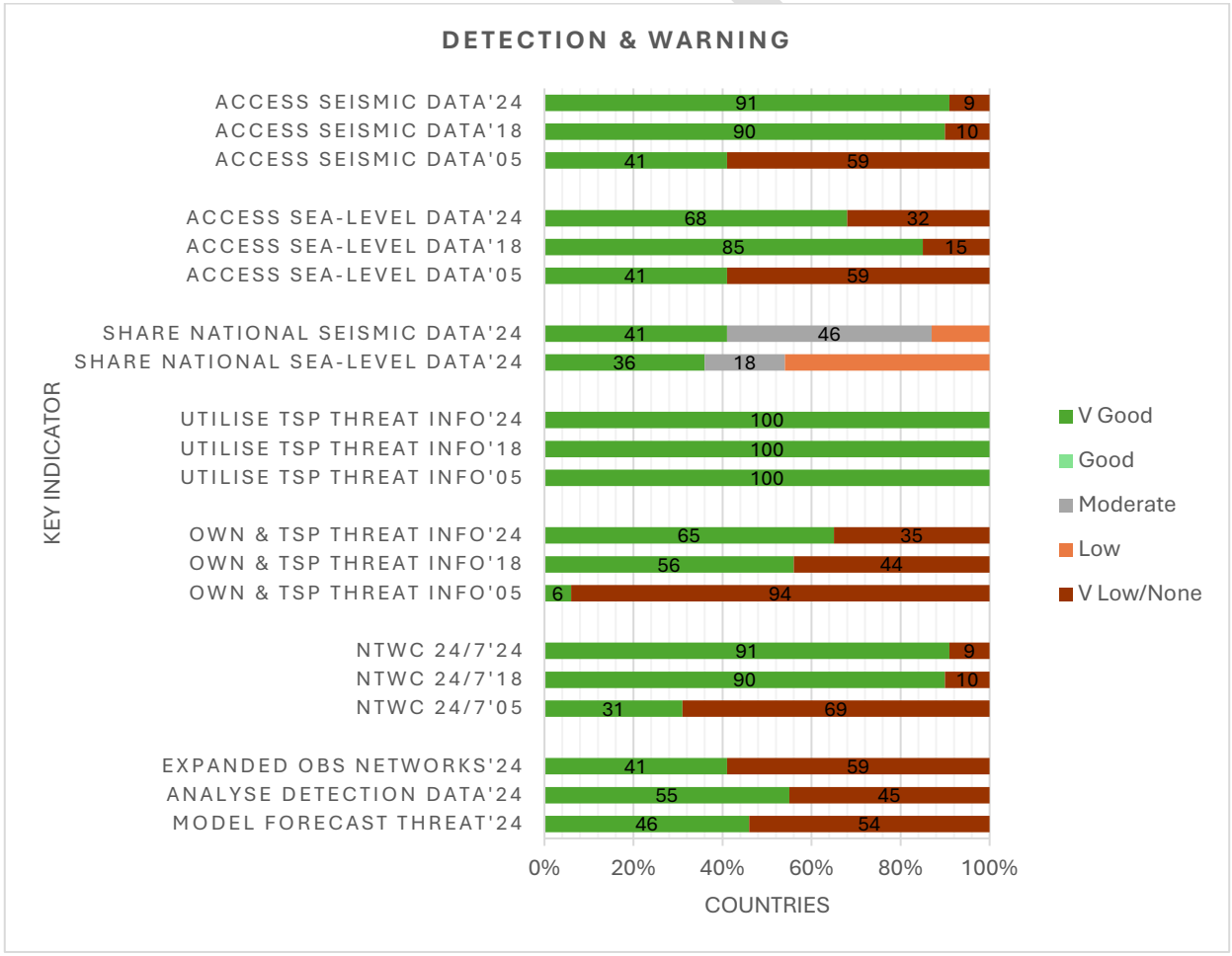

Figure 12: Country activity and capacity status for detection and warning.

20 (91%) countries reported that the responsible organisation has access to national or international seismic networks, with 19 having access to both national and international data networks. Only nine (41%) countries reported that all national seismic data is shared in real-time, while ten (46%) countries reported that only some national seismic data is shared in real-time. 15 (68%) countries reported that they have access to national or international sea-level data networks, with most having access to both national and international networks. Only eight (36%) countries share all their national sea-level data in real-time, while four (18%) countries share some sea-level data in real-time. This may compromise detection and warning capabilities and is a concern. Furthermore, and as recommended by the UN Ocean Decade Tsunami Programme, to greatly enhance the timeliness and accuracy of warnings to save more lives, for tsunamis generated by not only subduction earthquakes, but also by non-seismic and complex sources, requires more observations. Not only accessibility to all existing observations in real-time, but also implementation of an expanded network of observations, including the use of new technologies. Only 9 (41%) countries currently building that capacity and much more is required.

Only 12 (55%) countries reported having the capability of analysing real-time seismic and sea-level data for potential tsunami threat. Software tools used for this purpose vary greatly across the countries. 10 (46%) of countries reported having the capability for tsunami modelling to support generation of threat forecasts. A range of software tools are used across the countries. Capacity development is required, although not essential as the threat information is available from the TSPs

Email, SMS, Radio and Television remain in widespread use (>90% of countries) for disseminating tsunami information (warning, public safety action, etc (Figure 13). Since 2018 there is a significant reduction in the number of countries using Fax (85% to 50%) and an increased use of Social Media (65% to 96%). These are positive developments in helping reduce TSP communication costs and wider reach to the community respectively.

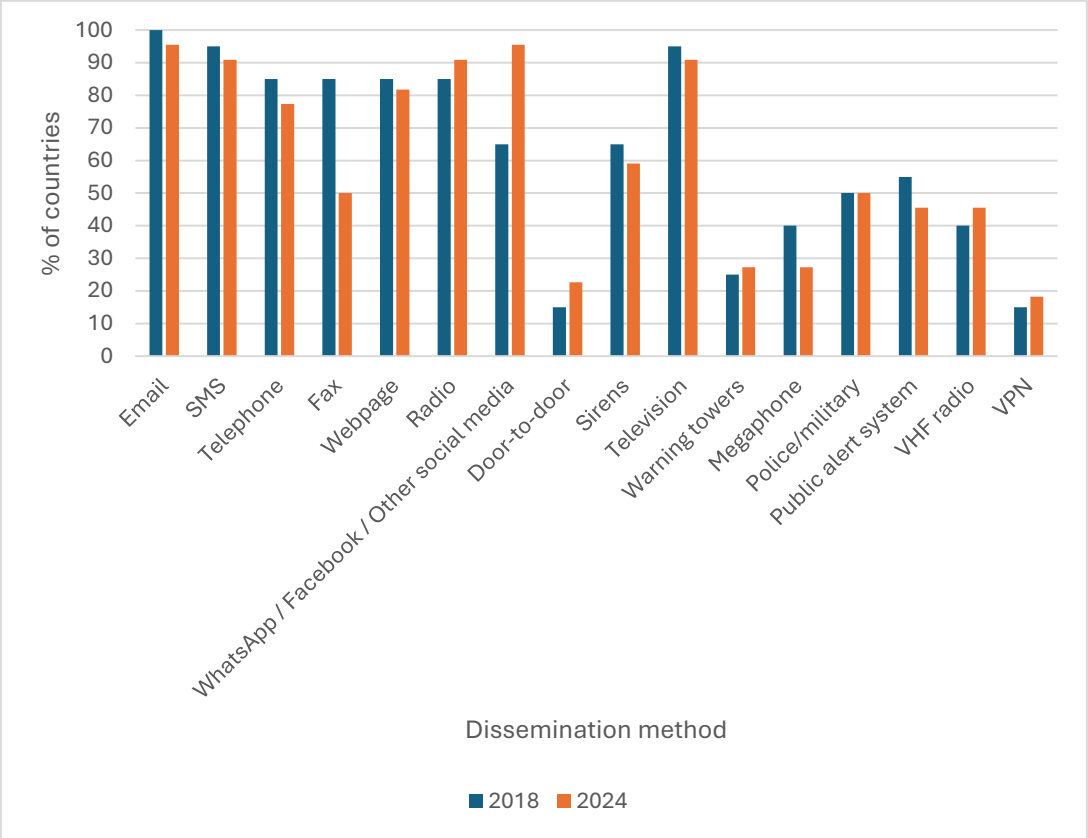

Figure 13: How tsunami information is disseminated

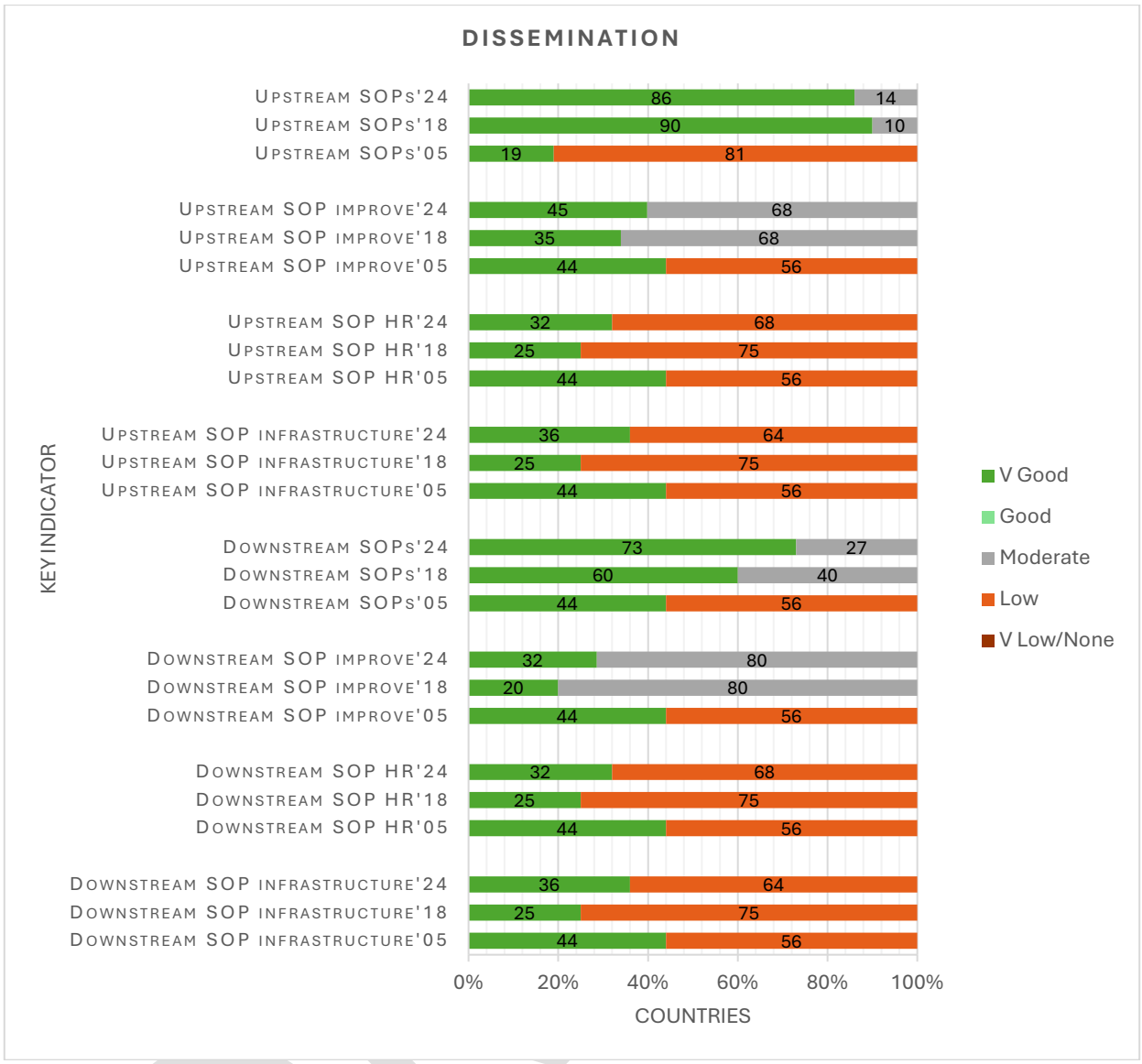

Figure 14: Country activity and capacity status for warning dissemination.

With regards to warning dissemination, the survey results (Figure 14) plus a forensic analysis of national tsunami warning chains of all countries (Figure 15), undertaken during SOP workshops held in 2023 organised by the ICG/IOTWMS Secretariat and the UNSECO-IOC Indian Ocean Tsunami Information Centre (IOTIC: funded by the Government of the Republic of Indonesia), indicate further effort is required nationally by some countries to ensure Standard Operating Procedures (SOPs)[10] underpin every link in the warning chain, especially in the downstream components, to ensure early warnings reach all in the community. 17 (77%) countries reported enhancements to their national warning Standard Operating Procedures (SOPs) since 2018 and since the SOP workshops. The UNESCAP funded project in the NW Indian Ocean has already developed more robust national tsunami warning chains underpinned by SOPs for that sub-region. The SOP training provided by the ICG/IOTWMS Secretariat and IOTIC in 2023 now needs to be followed up in the remaining identified countries with support. As well as further developing the SOPs themselves, capacity development is also required in associated human resources and infrastructure by many countries. Efforts by the ICG/IOTWMS to enhance national tsunami warning chains will also help underpin efforts by the UN EW4ALL initiative, as there are many common elements for other hazards. More countries need to implement national tsunami exercises, within a multi-hazard framework and down to the community level, to ensure their warning systems remain fit-for-purpose and ready to engage for any tsunami threat.

[10] UNESCO-IOC. 2017. Plans and Procedures for Tsunami Warning and Emergency Management. Paris, Intergovernmental Oceanographic Commission of UNESCO 2017. 72 pp. (IOC Manuals and Guides No.76)

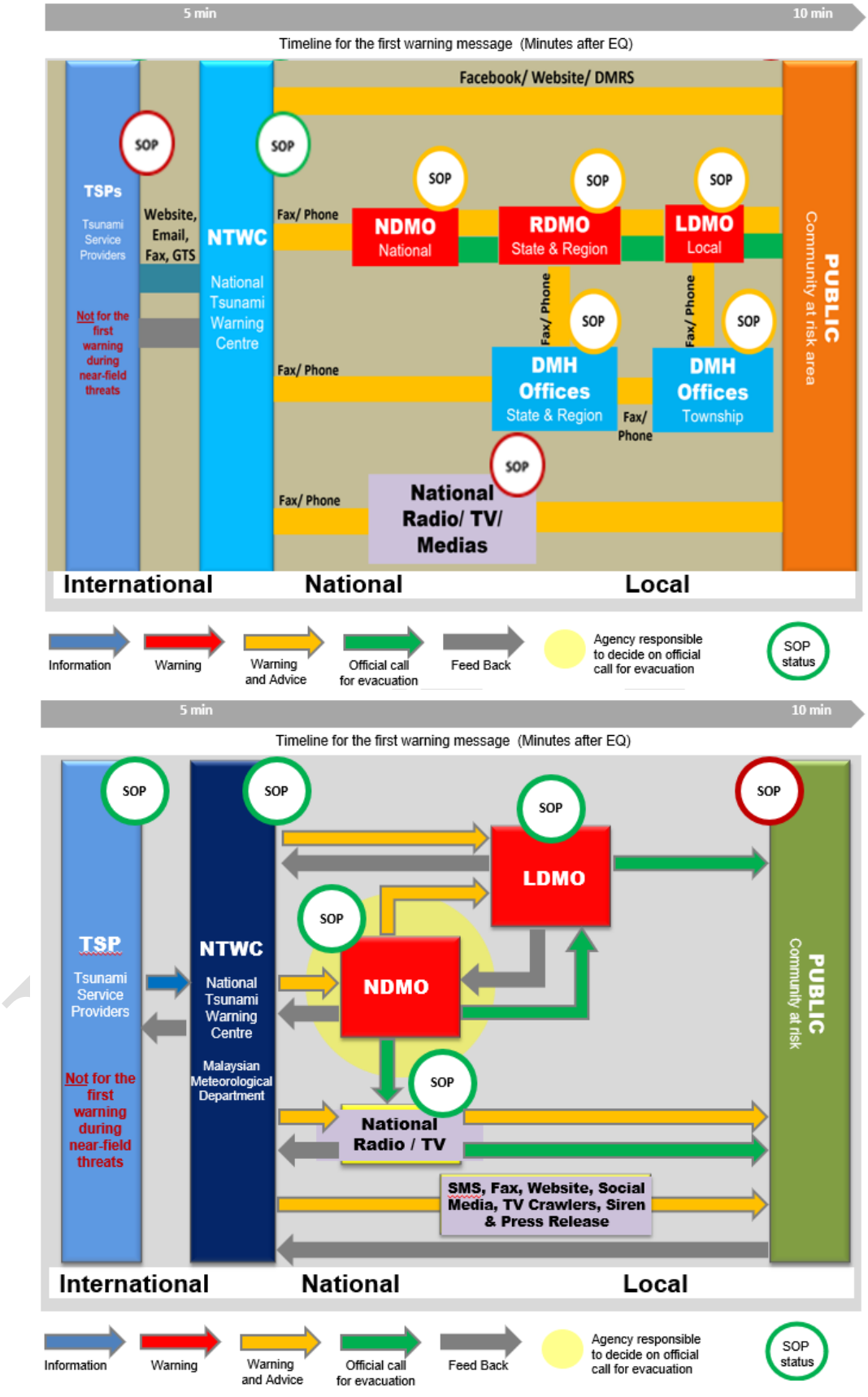

Figure 15: Examples of national tsunami warning chains and SOP status, showing differences from country to country due to different national arrangements, plus different status of required SOPs.

Public Awareness, Preparedness, and Response

Figure 16 shows which type of organisation takes responsibility for tsunami public awareness programmes. Several countries reported that is the responsibility of multiple organisations, including the NDMO, LDMO, NTWC and international organisations.

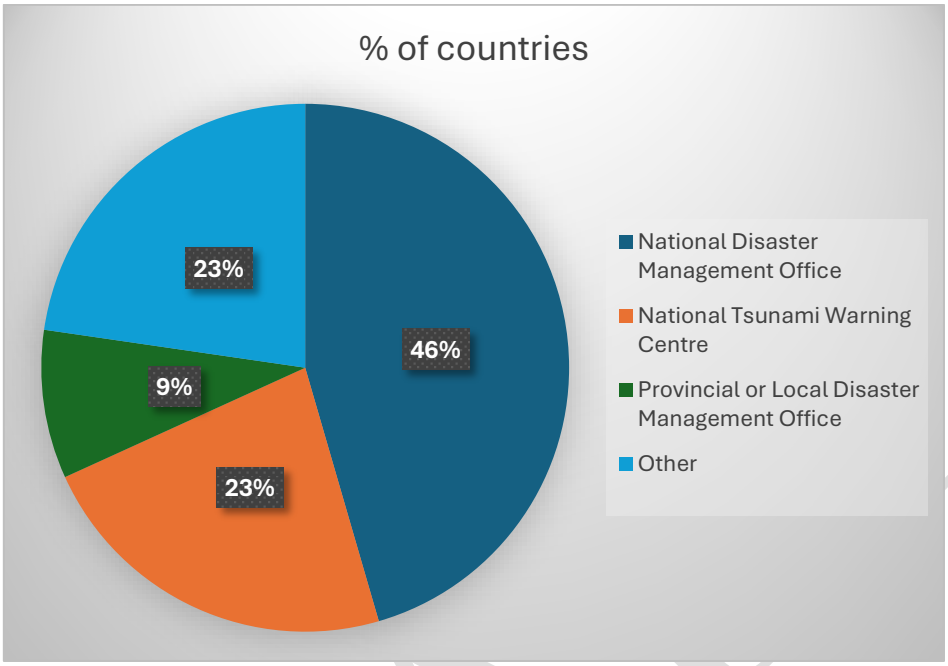

Figure 16: Organisation responsible for tsunami public awareness programmes

The UNESCO-IOC IOTIC continues to be the major source of training and developer of education materials IOTIC remains a significant asset to the ICG/IOTWMS. In a similar outcome to 2018, posters, leaflets and flyers, booklets and video/oral media were identified as being used by the majority of countries (Figure 17). Education materials such as information boards and school curricular were also used in nine (41%) countries. Less common were the use of teaching kits, indigenous knowledge, signage and public evacuation maps. Among other responses, were a tailored-to-Australia conditions online tsunami education resource called "Tsunami: The Ultimate Guide" and a sensitisation campaign.

School and child related awareness activities and tsunami exercises, as well as global awareness raising days, were the most widely carried out across respondent countries (Figure 18). There is a significant increase in the reporting of activities linked to the Tsunami World Awareness Day (WTAD) and International Day for Disaster Risk Reduction (IDDRR) when compared to the 2018 survey results (45% to 73%).

With regards to communication methods used in communicating between organisations/agencies when responding to emergency situations, for National DMOs, telephones, email and SMS are all widely used in many countries (90% or more). The situation is similar for Local DMOs (80% or more). Use of Fax has diminished significantly since the 2018 survey results for both National DMOs (90% to 55%) and Local DMOs (75% to 45%). For communicating with the media, the telephone and email remain the most widely used methods, but again, use of the Fax has diminished (75% to 45%). Unsurprisingly, the pattern of responses for the general public and coastal communities is similar, and more than 50% of countries use to some extent SMS and sirens to reach these groups. Other communication methods mentioned by countries included websites, social media, radio, dedicated applications, broadcast alert systems, and television.

While there has been significant support provided by the UNESCO-IOC IOTIC since 2005 and 2018, even more support in the development of tsunami awareness programmes, activities or campaigns, participation by international agencies or experts, or provision of general tsunami awareness materials is widely requested by countries (more than 60%) (Figure 19).

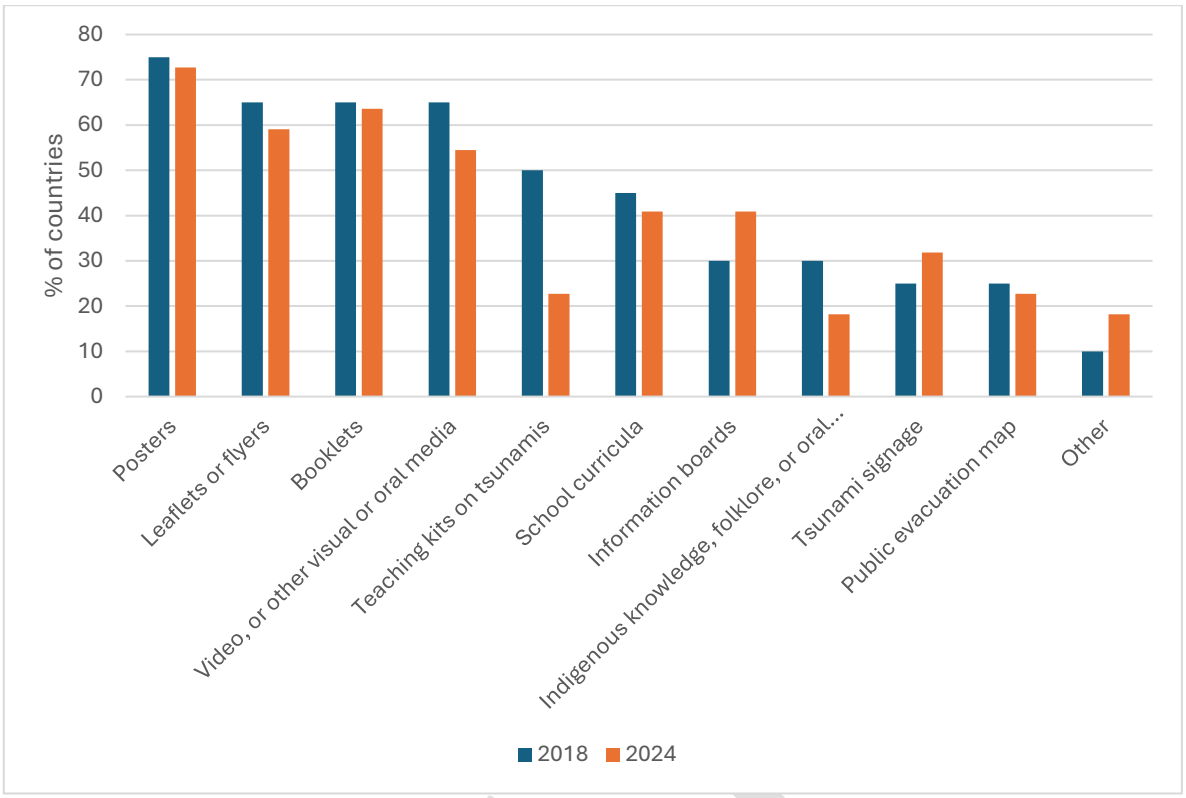

Figure 17: Public awareness materials

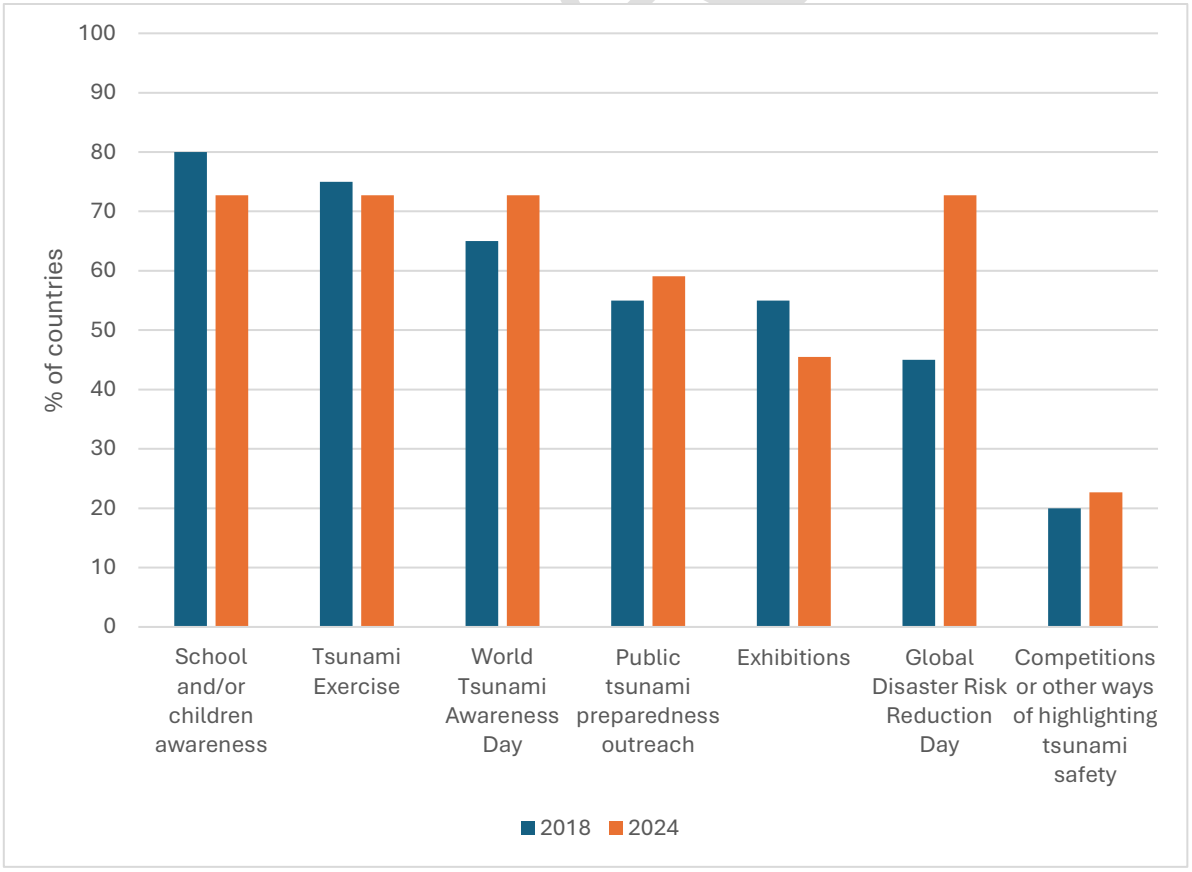

Figure 18: Public awareness activities

Just over 50% countries utilise evacuation infrastructure in some form. Evacuation signage is only used in nine (41%) countries and vertical evacuation structures are utilised in seven (32%) countries. Training in the development of evacuation maps remains a priority for 11 (50%) countries. While SOPs for community evacuation exist in 16 (73%) countries, 15 (68%) countries are requesting support to further develop them, including associated human resources (59%) and infrastructure (64%). The UNESCAP funded project has provided training in evacuation planning (including evacuation mapping) for the NW Indian Ocean countries. Similar training now needs to be extended across the Indian Ocean region to other countries.

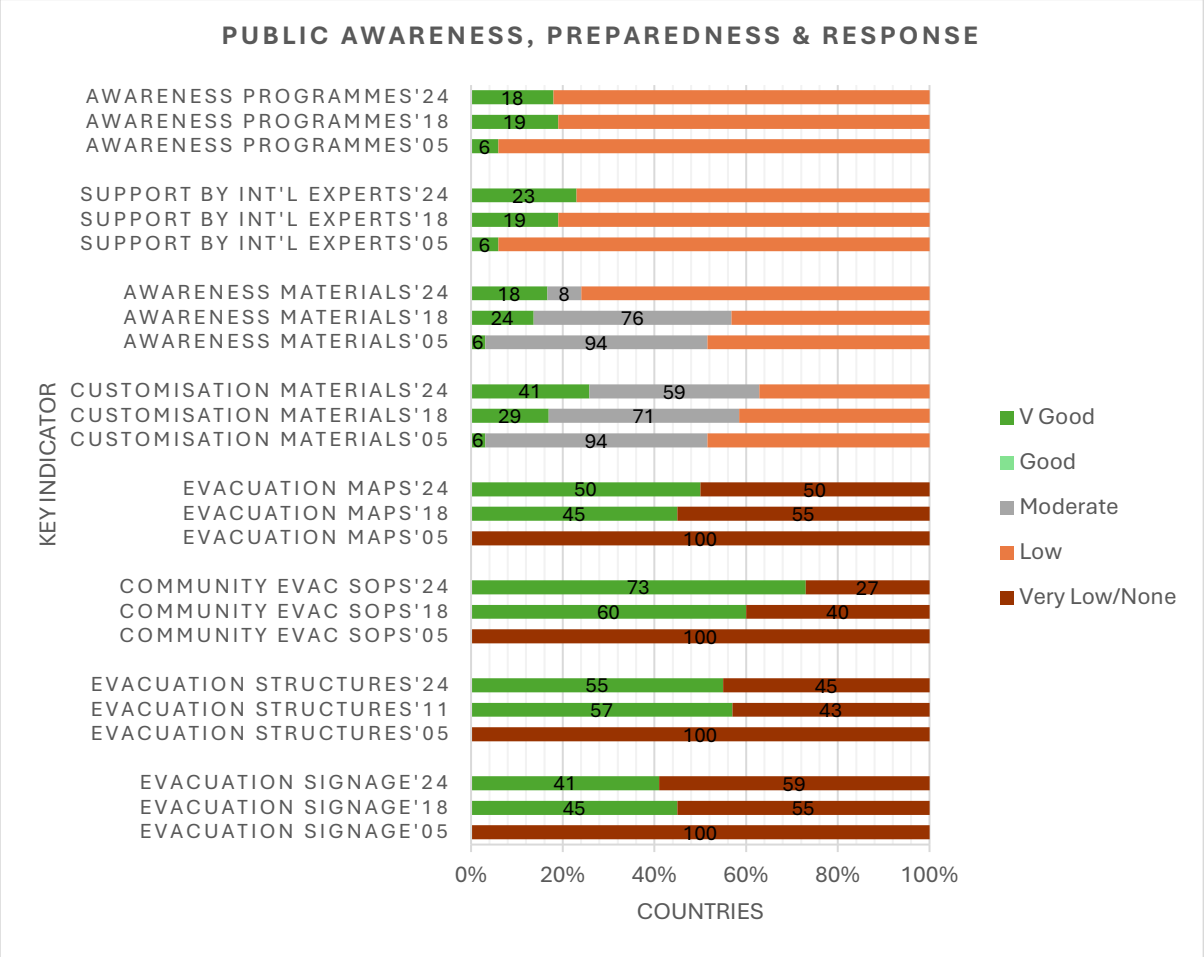

Figure 19: Country activity and capacity status for public awareness, preparedness, and response.

Tsunami Ready Recognition

Countries were asked a series of questions about their involvement in the UNESCO-IOC Tsunami Ready Recognition Programme (TRRP) [11] or other similar national tsunami resilience and preparedness related initiatives. The UNESCO-IOC TRRP is implemented as a voluntary, performance-based, community recognition programme that promotes an understanding of the concept of readiness as an active collaboration among national and local warning and emergency management agencies and government authorities, scientists, community leaders, and the public. UNESCO-IOC TRRP was only in pilot mode in a couple of

[11] UNESCO-/IOC. 2022. Standard Guidelines for the Tsunami Ready Recognition Programme. Paris, UNESCO (IOC Manuals and Guides No. 74)

countries at the time of the 2018 assessment. Therefore, the survey questions in 2024 differed significantly from 2018 and comparable data is often not available.

13 (59%) countries confirmed that they are participating in UNESCO-IOC TRRP in some form (two fully and 11 beginning to implement) and have preparedness capacity, while eight (36%) responded that they are not currently doing so (Figure 20) and therefore less prepared. Of those not currently participating, six (27%) responded that they have plans to do so in the near future, while two (9%) do not and least prepared.

Six (27%) countries responded that they are currently implementing other initiatives and programmes. Examples included the village disaster resilient programme (DESTANA) in Indonesia, as well as a range of national level campaigns and exercises, such as tabletop exercises, training of trainers, awareness raising workshops, and as part of multi-hazard workshops. Indonesia has also extended their programme to include tsunami ready recognition for critical infrastructure (such as airports). 14 (63%) countries responded they are not currently implementing any other programmes or initiatives. Two (10%) have no plans for any programmes, presumably based on a relatively lower risk of tsunamis impacting those countries.

Five (23%) countries reported having a National Tsunami Ready Board (NTRB), which is responsible for initiating and guiding the community on the steps for Tsunami Ready recognition and for the review and approval of the community's Tsunami Ready application. Of the countries that reported not having a NTRB, nine (41%) reported an existing coordination mechanism that can fulfil this role. These included a range of National Councils, Committees and Advisory Groups.

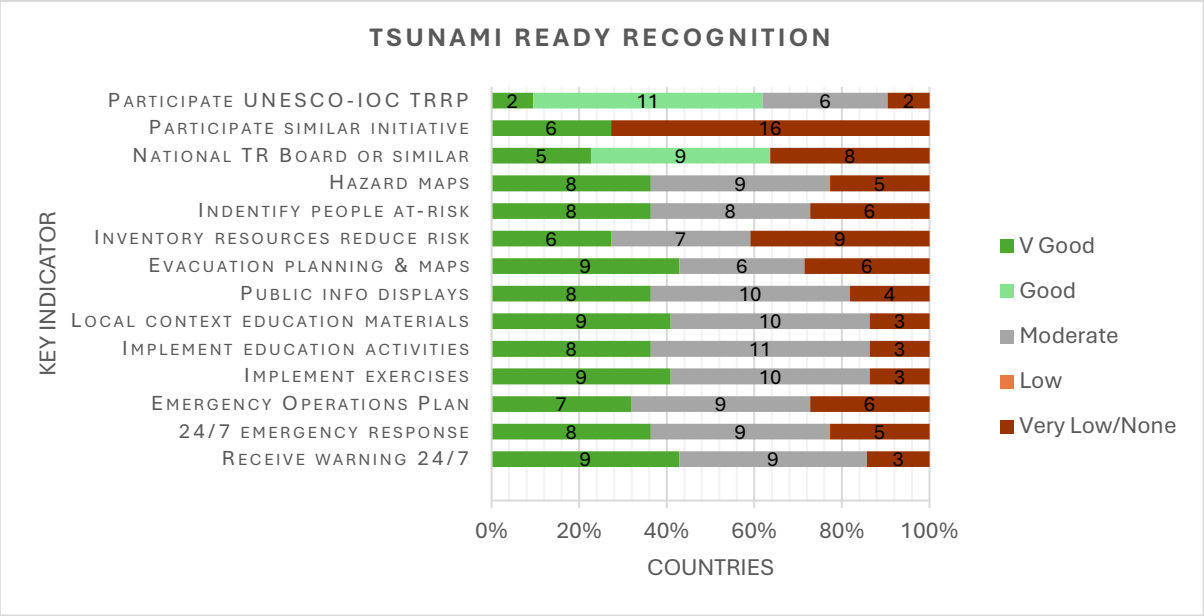

Figure 20: Country activity and capacity status for Tsunami Ready Recognition.

12 (55%) countries reported that some communities (for example, villages, cities, districts, provinces or states) are currently working towards implementing or are interested in implementing the UNESCO-IOC TRRP or similar national initiative. However, only two countries (India and Indonesia) reported having achieved recognition through UNESCO-IOC TRRP or a similar national initiative (Figure 21).

Countries identified the most significant challenges to implement the UNESCO-IOC TRRP or similar national initiatives (Figure 22). Only three (14%) countries reported that none of the identified challenges inhibited implementation. The other challenges identified by at least one country included the infrequent nature of tsunami hazard events and the lack of perceived tangible benefits demonstrated for the UNESCO-IOC TRRP.

Figure 21: Tsunami Ready recognition of communities in Indonesia and India.

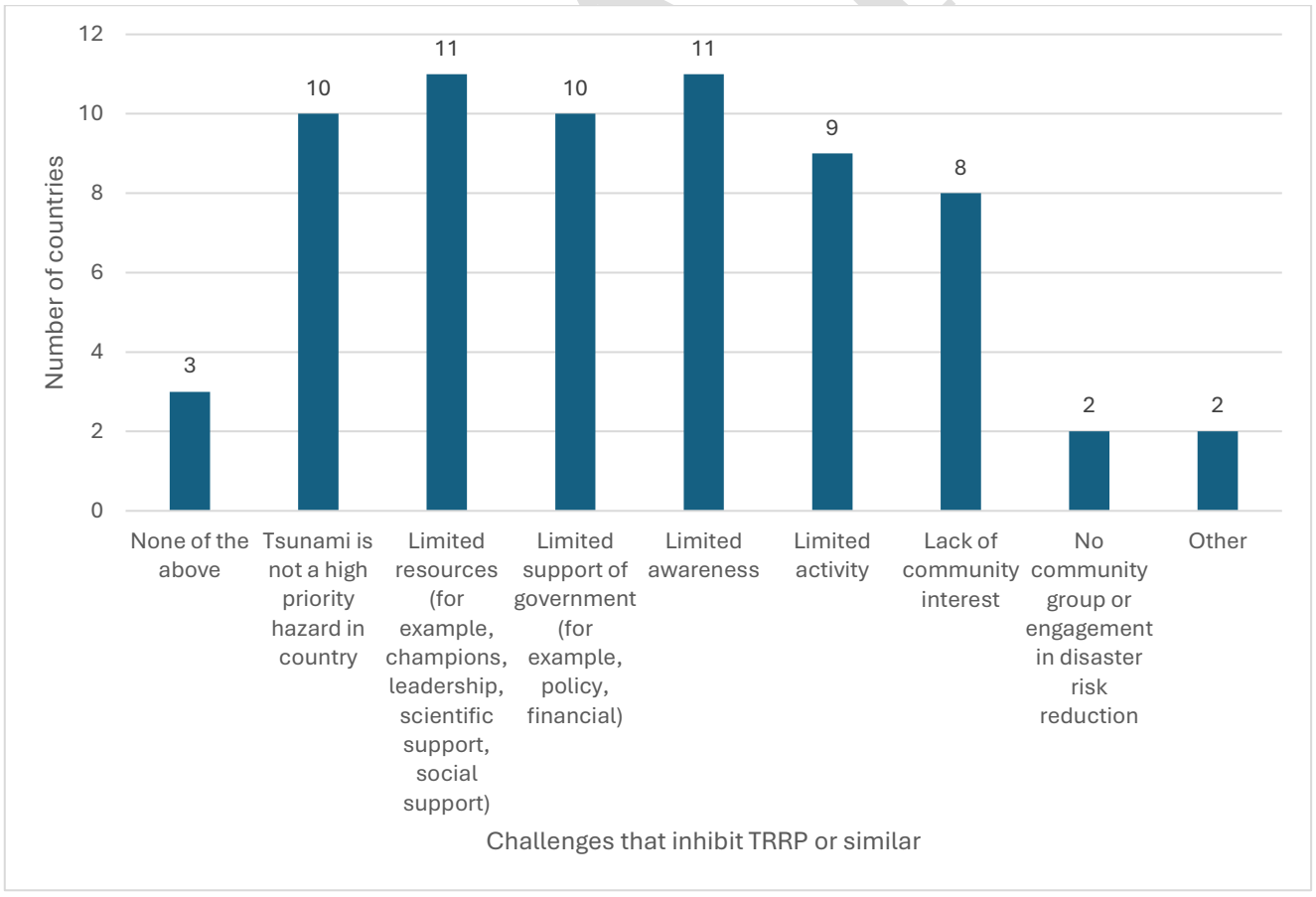

Figure 22: Challenges that inhibit the implementation of UNESCO-IOC Tsunami Ready Recognition Programme (TRRP) or similar national initiatives

Exercises

The interoperable system developed by the UNESCO-IOC ICG/IOTWMS is routinely tested and exercised though six-monthly communication tests and biennial IOWAVE Exercises organised by the ICG/IOTWMS and supported by the Secretariat (Figure 23).

Figure 23: Indian Ocean exercises (IOWave) coordinated by the UNESCO-IOC ICG/IOTWMS are held across the Indian Ocean every two years

20 (91%) countries reported that their country's National Tsunami Warning Centre (NTWC) participated in the six-monthly communications tests conducted by the IOTWMS TSPs.

21 (96%) countries reported conducting tsunami exercises at one or more levels during the inter-sessional period (Figure 24). The results show a significant improvement since 2005, but also a small reduction in the conduct of all exercise types when compared to 2018. It is higher for schools and cities in 2024. 20 (91%) countries reported that they took part in the Indian Ocean Wave exercise. Tabletop exercises (intra- and inter-organisational), as well as national and local tsunami exercises were undertaken by 11 (50%) countries or more in 2024. More exercises at the community, village, city, levels are required to meet UNESCO-IOC TRRP requirements for preparedness.

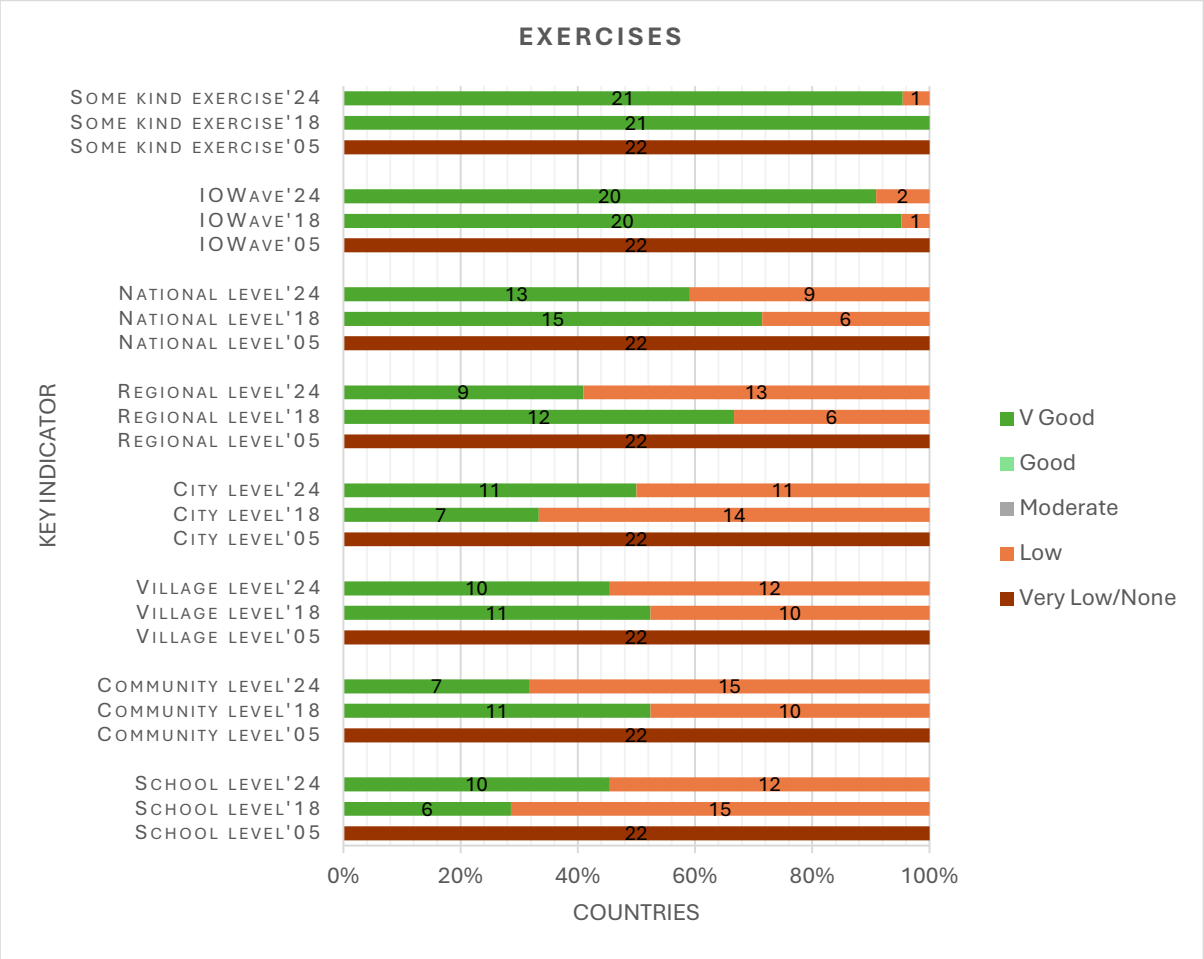

Figure 24: Country activity and capacity status for tsunami exercises.

CONCLUSIONS AND RECOMMENDATIONS

Significant progress was made between 2005 and 2018 to develop a robust and then state-of-the-art regional tsunami threat information system and associated national tsunami warning systems. However, between 2018 and 2024 progress has somewhat plateaued with regards to preparedness at the community level. Much more work needs to be done. The potential impacts of tsunamis are very challenging to prepare for, as they are a relatively low risk, but with major consequences and impacts should they occur. They may best be managed and supported through expansion of a multi-hazard approach, whereby observations, warning systems, community education and preparedness activities are integrated and contribute to multi-hazard national initiatives, noting the economies of scale and to ensure the tsunami threat remains centre of mind in well prepared at-risk communities, especially where the tsunami may arrive in minutes. It's also important to note that while some countries may have the capability, they don't necessarily have the capacity/resources to fully implement.

Since 2011 an interoperable IOTWMS has been successfully established, continues to operate, and is routinely exercised. TSPs operated by Australia, India, and Indonesia provide threat information to enable NTWCs to develop and disseminate warnings for their communities for tsunamis generated by earthquakes. However, only around 50% of available seismic and sea-level detection data is shared in real-time. Work needs to continue to ensure all links in the national tsunami warning chains are underpinned by SOPs to ensure warnings reach all in the community in line with the UN EW4ALL initiative. To meet the goal of the UN Ocean Decade Tsunami Programme of more timely and accurate warnings for tsunamis generated by

all sources (i.e. including non-seismic and complex sources) by 2030, capacity development through significant expansion of existing and implementation of new observing networks is required.

For a tsunami warning to be effective once it reaches all in the community, the community must be prepared and know what to do. To meet the goal of the UN Ocean Decade Tsunami Programme of 100% at-risk communities being prepared and resilient to the tsunami threat by 2030, further support is required to nationally develop awareness of the risk and educate communities. The UNESCO-IOC IOTIC continues to provide training and development of community education and awareness materials. Further capacity development is required at the national level to implement the UNESCO-IOC TRRP or similar national initiatives across the region for the at-risk communities. The challenges in implementing the UNESCO-IOC TRRP or similar national initiatives have been identified and countries need training and support to help address these.

The UNESCO-IOC IOTIC (funded by Indonesia) continues to be a great asset in providing provide training and development of community education and awareness materials. The UNESCO-IOC ICG/IOTWMS Secretariat (funded by Australia) continues to support the governance requirements of the ICG and provide great value in coordinating all the efforts and contributions to the IOTWMS of the Member States.

The *Ad Hoc* Team 2024 IOTWMS CATP has developed recommendations and key actions for capacity development to address the identified gaps and to help guide the work programmes of the ICG/IOTWMS and contributions by donors (Annex 1). Also included are some general recommendations with regards to the assessment.

ACKNOWLEDGMENTS

The 2024 Capacity Assessment of Tsunami Preparedness in the Indian Ocean was an activity undertaken in 2024 by the UNESCO-IOC Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS), chaired by Prof Dwikorita Karnawati from Indonesia. An *Ad Hoc* Task Team2024 IOTWMS CATP was established under Working Group 3 Tsunami Ready Implementation to carry out the required work. Members of the Ad Hoc Task Team included: Ms Suci Anugrah (Chair, ICG/IOTWMS WG-3 Tsunami Ready Implementation) (Indonesia); Mr Ardito M. Kodijat (Head UNESCO-IOC Indian Ocean Tsunami Information Centre) (Indonesia); Ms Sunanda Manneela (Vice-Chair, ICG/IOTWMS RWG NW Indian Ocean) (India); Dr Yuelong Miao (Vice-Chair ICG/IOTWMS) (Australia); Dr Mohammad Mokhtari (Chair, ICG/IOTWMS RWG North-West Indian Ocean) (Norway); Mr Jijjavarapu Padmanabham (Chair, ICG/IOTWMS WG-2 Tsunami Detection, Warning and Dissemination) (India); Dr Harkunti Rahayu (Chair, ICG/IOTWMS WG-1 Tsunami Risk, Community Awareness and Preparedness) (Indonesia); and Ms Weniza (Chair ICG/IOTWMS Task Team Exercise IOWave23) (Indonesia). It included the contributions of invited experts: Prof Richard Haigh (University of Huddersfield) (UK); Prof Dilanthi Amaratunga (University of Huddersfield) (UK); and Mr Harald Spahn (Tsunami warning chain and evacuation planning expert) (Germany). Dr Laura Kong (UNESCO-IOC/NOAA International Tsunami Information Centre and ICG/PTWS representative) (USA) and Ms Lara Bland (ICG/PTWS representative) (New Zealand) provided perspectives from another ocean basin TWS.

Survey responses were received from 22 countries: Australia; Bangladesh; Comoros; France Indian Ocean Territories; India; Indonesia; Iran; Kenya; Madagascar; Malaysia; Maldives; Mauritius; Mozambique; Myanmar; Oman; Pakistan; Seychelles; Singapore; South Africa; Sri Lanka; Thailand; and United Arab Emirates. Prof Richard Haigh and Prof Dilanthi Amaratunga (University of Huddersfield) (UK) provided the initial analysis of the survey data in consultation with the *Ad Hoc* Task Team.

Mr Rick Bailey (Tsunami expert consultant, former Chair ICG/IOTWMS, and former Head ICG/IOTWMS Secretariat) helped coordinate the work of the *Ad Hoc* Task Team 2024 IOTWMS CATP and compiled this Technical Summary Report and its Executive Summary. Ms Nora Gale (ICG/IOTWMS Secretariat) assisted

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ANNEX 1: Capacity Development Recommendations

#	Warning & Mitigation System Attribute
	Policies and Plans
TPP.1	Provide training in development of integrated national MHEWS and stand-alone tsunami policies and plans for authorities and stakeholders (such as DMOs, local governments, research institutions, communities, etc) across following levels: 1. National 2. Provincial 3. Local 4. Community
TPP.2	Provide training in development of specific tsunami guidelines in a multi-hazard framework with respect to: 1. Disaster Risk Reduction (DRR) based urban and spatial planning incorporating city/district level (scale 1:25,000) and detailed spatial plan for sub-district level (scale 1:5,000). 2. Contingency Plan for tsunami generated by multi-sources (seismic, non-seismic, and complex sources) 3. Operation Plan for tsunami generated by multi-sources (seismic, non-seismic, and complex sources) 4. Prevention and Mitigation: Tsunami Building Code, Critical Facilities Tsunami Ready Guide, Hotel Ready for Tsunami 5. Integration of tsunami DRR strategies into planning processes for mitigation and preparedness, e.g. zoning laws that prevent construction in tsunami high-risk areas and the development of tsunami-resistant infrastructure 6. Mainstreaming of inclusivity in all aspects of tsunami-related activities, policies, and plans, including scientific research, community education and preparedness, evacuation planning, and post-disaster management. 7. Sustainable grey and green coastal protection management practices that reduce vulnerability to tsunamis, such as nature-based solutions for the restoration of mangroves and coral reefs. 8. Rehabilitation and Reconstruction planning and Sustainable Recovery through lessons learnt to Build Back Better
TPP.3	Optimise national resources in tsunami preparedness and response planning, in areas such as tsunami hazard assessments, harmonisation of early warning systems, and joint exercises by: 1. Utilising cross-border tsunami warning and response coordination and planning for countries sharing coastlines (e.g. North-West Indian Ocean (NWIO)). 2. Exchange of best-practice policies, plans and guidelines for tsunami preparedness and response planning between Member States
	Tsunami Hazard and Risk Assessment
THRA.1	Help further raise awareness of Member States and at-risk communities of the Indian Ocean tsunami hazard by: 1. Utilising international expertise and collaboration to provide an updated best-practice Probabilistic Tsunami Hazard Assessment (PTHA) across the entire Indian Ocean, including tsunamis generated by non-seismic and complex sources 2. Develop tsunami hazard assessments for the Indian Ocean in a multi-hazard framework.
HRA.2	Enhance the national capacity to undertake tsunami hazard and risk assessments in a multi-hazard framework down to local level where required by: 1. Identification of national authorities responsible for undertaking tsunami hazard and risk assessments. 2. Identification of authorities to provide local level tsunami inundation maps to facilitate community preparedness initiatives. 3. Increasing the essential data available to undertake tsunami hazard assessments (e.g. bathymetry, topography) 4. Provision of training in national tsunami hazard assessment. 5. Provision of training in national inundation mapping for pilot areas to help identify communities at-risk 6. Collection of detailed tsunami risk data at village and community levels, especially information on vulnerable and inclusive groups, to better inform tsunami risk assessments 7. Provision of training in tsunami risk assessment

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	Tsunami Detection, Warning, and Dissemination
TDWD.1	Enhance the timeliness and accuracy of tsunami threat information and warnings by: 1. Designing the optimal seismic & sea level observing systems to guide implementation of observational networks to quantifiably improve the timeliness and accuracy of tsunami warnings 2. Sustaining, fully utilising, and expanding existing seismic and sea level observational networks to implement optimal observing systems to quantifiably improve the timeliness and accuracy of tsunami warnings 3. Trial and adopt new technologies (such as SMART cables, GNSS network) to implement optimal seismic and sea level observing systems to quantifiably improve the timeliness and accuracy of tsunami warnings 4. Demonstrating the impact of gaps in real-time exchange of seismic and sea level data on the timeliness and accuracy of tsunami detection and warning 5. Exchanging all data in real-time required for tsunami detection, warning, and monitoring by all National Tsunami Warning Centres (NTWCs) and regional Tsunami Service Providers (TSPs) to improve the timeliness and accuracy of tsunami detection and warning. 6. Establishing collaboration channels and training activities for sea level network operators to create awareness on needs for tsunami detection and warning to encourage expansion and sustainability of existing networks 7. Developing guidelines and delivering training on adoption and implementation of advanced analytical platforms that utilise artificial intelligence and machine learning to integrate and analyse data from multiple sources to enhance the accuracy of tsunami models and improve warning decision-making processes
TDWD.2	Enhance the capacity and effectiveness of National Tsunami Warning Centres (NTWCs) by: 1. Ensuring all NTWCs operate 24/7 2. Provision of human and infrastructure resources to support NTWC operation 3. Training for NTWCs in analysing and utilising real-time seismic and sea-level data and models to develop capacity to undertake own tsunami threat analysis 4. Develop capabilities & Standard Operating Procedures (SOPs) for detection, warning, and monitoring of tsunamis generated by non-seismic and complex sources (e.g. IOC M&G 183) 5. Developing tsunami warnings in a multi-hazard framework to optimise available resources
TDWD.3	Ensure People Centred national tsunami warnings reach all in the community by: 1. Ongoing forensic analysis and regular review of national tsunami warnings chains and underpinning SOPs to identify weak links and gaps 2. Providing ongoing training in national tsunami warning chain and SOP development to address weak links and gaps, facilitated by training Member States from geographical regions with similar tsunami threat and warning requirements (e.g. NWIO project funded by ESCAP), with particular focus on N/P/LDMO and Media SOPs. 3. Training in delivery of tsunami warnings using common terminologies and formats (e.g. Common Alerting Protocol (CAP)) to ensure more effective use and all-inclusive community responses. 4. Continuous reviewing of existing (internet, GTS, SMS, satellite, radio, fax, etc) and implementation of new (social media, cell broadcast, etc) tsunami warning dissemination and communication technologies to ensure robust and timely dissemination of tsunami warnings to all-inclusive groups in the community and communications between warning and response operational staff.
	Community Tsunami Awareness and Preparedness
TPAPR.1	Raise community awareness of tsunami threat by: 1. Sharing and utilising national and Indian Ocean Tsunami Information Centre (IOTIC) Information Education & Communication (IEC) tsunami awareness materials, materials used in other oceans and developed by other Tsunami Information Centres (TICs), nationally tailored materials for individual stakeholders, translated as needed at local level and all inclusive 2. Disseminating IEC tsunami awareness materials using a wide range of formats and platforms for dissemination (e.g. brochures/fliers, e-posters, booklets, e-books, YouTube, TikTok, Instagram, Facebook) 3. Participation/support by international agencies or experts in national activities 4. Utilising internationally coordinated activities, such as International Day for Disaster Risk Reduction (IDDRR) (13 October) and World Tsunami Awareness Day (WTAD) (5 November)

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TPAPR.2	Enhance national capacities in tsunami evacuation planning by: 1. Expanding training on tsunami evacuation planning provided in NWIO to other regions and Member States, including sharing of best practices through a hands-on and collaborative learning approach. 2. Providing regional training on best practices in utilising vertical infrastructure for tsunami evacuations. 3. Engaging professional societies and experts in national activities to advise best practices and certified national criteria for evaluating shelter options in the context of tsunami vertical evacuation strategies 4. Share examples of best practice in national tsunami signage, taking into consideration recommendations from the UNESCO-IOC TOWS-WG TTDMP.
TPAPR.3	Enhance tsunami awareness and preparedness in schools by: 1. Continuing the work of UNDP, in consultation with IOTIC, in the development of tsunami school community awareness IEC materials and training 2. Implementing tsunami awareness and preparedness training in school national curricula.
	Tsunami Ready Recognition
TRRP.1	Train, both regionally and nationally (with priority for Small Island Developing States (SIDS), Least Developed Countries (LDCs), and African State), the implementation of UNESCO-UNESCO-IOC Tsunami Ready Recognition Programme (TRRP) or similar national or international initiatives (e.g. Weather Ready) to build resilience and make at-risk communities prepared and resilient against the tsunami threat, by: 1. Supporting National Tsunami Ready Focal Points (TRFPs) and Tsunami National Contacts (TNCs) through training, advocacy and provision of IEC materials (e.g. UNESCO-IOC M&G 74 and IOTIC education and awareness materials), including translation to national and/or local languages where needed 2. Exchanging Member State best practices and experiences on initiating, implementing, and demonstrated value of TRRP to assist other Member States to initiate. 3. Assisting Member States review national tsunami preparedness programs & 12 Tsunami Ready Indicators.
TRRP.2	Implement and expand national Tsunami Ready Recognition Programmes (TRRP) or similar national initiatives to make at-risk communities prepared and resilient against the tsunami threat by: 1. Identifying tsunami risk and educate communities and key stakeholders of the risk and value of TRRP 2. Investigating if TRRP can be integrated within a similar national initiative or obtain seed funding to start the TRRP nationally (or an equivalence) to demonstrate value in a multi-hazard context. 3. Establishing a National Tsunami Ready Board (NTRB) as per IOC M&G 74 or utilise similar national body 4. Identifying and providing data on communities/villages in tsunami-prone areas (as described in M&G 74) to develop a prioritised plan for implementing TRRP nationally 5. National authority with responsibility for TRRP or similar national initiative collaborating with at-risk communities to create education materials tailored to their local context 6. Assuring local communities' ownership of TRRP or similar national initiatives by strengthening local capacities, engagement to develop local preparedness plans, activities in line with the TRRP indicators, and commitment to sustain it. 7. Engage the private sector to implement and help resource implementation 8. Engage Non-Government Organisations (NGOs) & other agencies supporting national implementation 9. Integrating other ocean and multi-hazard approaches with the TRRP approach
	Tsunami Exercises
TE.1	Continue to organise and enhance biennial IOWave Exercises for the Indian Ocean region to routinely test regional and national tsunami preparedness by: 1. Including scenarios of nighttime and/or weekend tsunami events to test 24/7 procedures and performance. 2. Including an objective testing and validating of SOPs along national tsunami warning chains. 3. Avoiding times when DMOs, etc, are busy responding to other seasonal hazards, by scheduling two different times/seasons for biennial IOWave Exercises within scheduled year. 4. Nationally extending involvement at at-risk local and community levels. 5. Involving international expert observers to help review and evaluate future IOWave Exercises
TE.2	Increase national tsunami exercises to more frequently test national tsunami preparedness by: 1. Establishing regular programme of tsunami exercises into cities, villages, communities and schools as a key to community preparedness, through conduct of national exercises between Indian Ocean-wide exercise (IOWave exercises) 2. In addition to IOC MG58 and MG86, developing further guidance on how to the conduct tabletop or similar tsunami warning exercises to routinely review and test SOPs, helping to maintain preparedness and reduce the potential for complacency among countries that have not experienced a recent tsunami event.

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	General Recommendations
GR.1	In some cases, more information may be required to be supplied with answers to help better understand and learn from the responses. For example: - What is the reason for the slight reduction in countries doing hazard assessments in 2024? - Why do fewer countries have access to sea level data in 2024? - Why aren't some countries sharing all their seismic and sea level data? - What are the barriers to some countries not being able to expand their observing networks? - Do countries need even more support from IOTIC, or can they further develop awareness nationally themselves? - Are more countries considering utilising evacuation structures and signage? - When reporting a capability to implement elements, how much can be implemented/is being implemented and the time trajectory for possible full implementation?

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